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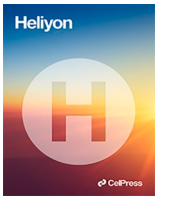

Research article

Glucose management in critically ill adults: A qualitative study from the experiences of health care providers

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ABSTRACT

Aims and objective: To explain the components and elements of glucose management in critically ill adult patients from the healthcare providers' experiences.
Background: Critically ill adults are highly susceptible to stress-induced hyperglycaemia due to glucose metabolic disorders. Healthcare workers play a key role in the glycaemic management of critically ill patients. However, there is a lack of qualitative studies on the content and elements of glycaemic management and healthcare workers' perceptions about glycaemic management in China.
Design: Qualitative study that followed the Consolidated Criteria for Reporting Qualitative Research (COREQ) guidelines.
Methods: Individual semi-structured interviews were conducted from January to April 2022. Fifteen physicians and nurses were recruited from ten hospitals in mainland China. Data were analysed using inductive thematic analysis.
Results: Glucose management in critically ill adult patients from their experiences included two parts: the inner ring (practice behaviours) and the external space (methods and drivers). The practice behaviours of glucose management include five elements, while the methods and drivers of glucose management focus on three elements. The content covered under each element was identified.
Conclusion: This study developed a glycaemic management model for critically ill adult patients, clarified its elements based on the perceptions of healthcare providers and elaborated on the methods and drivers covered under each element to provide a reference for physicians and nurses to develop a comprehensive glycaemic management guideline for critically ill adult patients.
Relevance to clinical practice: Our study proposed a glucose management practice model for critically ill adult patients, and the elements and components included in this model can provide a reference for physicians and nurses when performing glucose management in critically ill patients.

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What does this paper contribute to the wider global community?

- ●From the experience of healthcare professionals, the components of a glucose management model in critically ill adult patients can be divided into two spaces: the inner ring of practice behaviours, and the external space of methods and drivers.
- ●In the management of critically ill hyperglycaemic patients, health care professionals rely more on their own clinical experience than on the content of insulin infusion protocols.
- ●There is still lack of a comprehensive and standardized strategies for glucose management in critically ill patients to provide a more scientific approach to their care.

1. Introduction

Stress hyperglycaemia (SHG) is very common in critically ill patients [1]. Although many studies have concluded that SHG is seen as an adaptive response [2], it still causes high mortality and morbidity of patients in intensive care unit (ICU) [3]. Numerous studies have demonstrated the bad impact of uncontrolled blood glucose elevation in ICU patients with different diseases. In patients with acute stroke, SHG is strongly associated with mortality within 30 days, the need for mechanical ventilation, the use of vasopressors, and the occurrence of haemorrhagic transformation, and it is an important predictor of poor prognosis [4]. In critically ill patients in the perioperative period, SHG is associated with several postoperative complications, including sepsis, myocardial infarction, surgical site infection (SSI), and death [5]. In addition, hyperglycaemia after severe traumatic brain injury (TBI) is a significant predictor of patient mortality, ICU length of stay, ventilation-associated pneumonia (VAP), acute respiratory distress syndrome (ARDS), and injury severity score [6]. Previous studies have also demonstrated that hyperglycaemia in critically ill patients without a history of diabetes is associated with worse complications and prognosis than in patients with a history of diabetes [7].

The current treatment of glucose control in critically ill patients is continuous insulin therapy based on the insulin infusion protocol (IIP) [8]. The frequent blood glucose measurements and careful adjustment of intravenous insulin dosages during insulin infusion require much exposure to healthcare professionals, especially during the implementation of IIPs [9]. In the process of blood glucose management for patients, ICU physicians are the primary managers of glycaemic control, with responsibility for treatment decision making, clinical examination, etc [10]. While ICU nurses are important drivers in the monitoring of blood glucose, insulin infusion and adjustment, provide physical care, and attend to the concerns of the patient's family during protocol implementation [11,12]. Therefore, the perceptions of healthcare professionals in the ICU about glucose management have a direct impact on the effectiveness of glucose management in critically ill patients. However, more studies have tended to explore the development of IIPs and the effectiveness of glycaemic control [13,14], few studies have focused on this.

This is a continuation of a previous study in which we investigated the knowledge, attitude, and practice (KAP) of glucose management among ICU healthcare workers. We found that the KAP of glucose management among ICU professionals was acceptable [15], but the perceptions of strategies for glucose control, doubt or contradiction, implementation and innovations of glucose management protocols, and individualized glucose management need further study, which is one of the reasons for conducting this study. Therefore, the qualitative method was adopted in this study, and semi-structured interviews were conducted with ICU physicians and nurses involved in the glucose management of ICU patients. We sought to understand the content and elements of glucose management in critically ill patients, clarify the perceptions and feelings about glucose management and provide a roadmap for further strategizing best care practices in this field.

2. Methods

2.1. Design

Given that qualitative research can capture the real experiences and feelings of ICU professionals during glycaemic management, it can better help researchers and clinical practitioners to understand the complexity of glycaemic management in critically ill adult patients. A qualitative, descriptive design was adopted using semi-structured, individual interviews [16,17]. An a priori theoretical framework was not chosen for this study because we wanted to obtain the unbiased perceptions and experiences of healthcare professionals. The Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist was followed in this study [18] (Appendix S1).

2.2. Study setting and recruitment

Purposive sampling was used in this study, ensuring the maximum sample size and determining which potential participants would be most informative [19]. This research was conducted in ten tertiary-level hospitals in mainland China, all of which had general and specialty ICUs. A poster with all study recruitment information was sent to the ICU nurse managers of all accessible hospitals via WeChat (Tencent, Shenzhen). ICU nurse managers informed all physicians or nurses in their ICUs of the study recruitment information and registered interested health care workers for the study. The nurse manager then gave their contact information to the researchers for confirmation of their eligibility. The eligible participants signed an informed consent form before the formal interview.

2.3. Participant eligibility

Eligible criteria were as follows: (i) being a registered nurse or physician, (ii) working in an ICU >1 year, (iii) having responsibility for the management of critically ill patients with glucose disorder, and (iv) willing to participate in this study and sign informed consent.

2.4. Data collection

A semi-structured interview guide was developed by researchers, and it included a total of 10 questions. We selected a physician and a nurse in the ICU for a pre-interview. After the pilot interview, minor edits were made, and no questions were excluded from the study (Appendix S2). Formal in-depth interviews were conducted from January to April 2022 by the first author, a female Ph.D. candidate, who was trained in qualitative interview techniques and had experience with qualitative research. She also had an ICU nursing background and no prior relationship with any of the participants. Because the study took place during the COVID-19 pandemic, face-to-face interviews were conducted for participants in nearby hospitals, but participants in other cities were interviewed via the Tencent Meeting platform. All face-to-face interviews were conducted in a quiet, private room with only the researcher and the interviewee in the room. After providing consent, demographic and professional data about the physicians and nurses were collected before the interview, including their age, sex, education, ICU type, current role in the ICU, and ICU experience. Each interview lasted 30–60 min, and all interviews were audio-recorded and field notes were made. Data are collected and analysed synchronously [20], data collection was suspended when no new information emerged to describe the research topic (i.e. i.e. no more new primary codes) [21,22]. Saturation was achieved by the 14th interview, but to ensure saturation, we added that interviewee. After data saturation was achieved, recruitment ended.

2.5. Data analysis

The demographic data were entered in SPSS (version 25.0, IBM Corp.). Descriptive statistics were used to describe numerical data. The audio recordings were listened to several times, transcribed verbatim into a Microsoft Word document by researchers within 24 h after the interview was completed, and the first author added field notes to the text. All transcripts were returned to the interviewees to verify the authenticity and accuracy. After completing the verification of the interviewees, the data were managed in NVivo 12 (version 12, QSR International).

To preserve the original meaning of the interviews, the data were analysed using the original transcribed text in Chinese [23]. A linear, bottom-up, inductive thematic analysis [24] was used, in which researchers #1 studied the data to determine preliminary codes and check emerging codes, categories, and preliminary themes, which were subsequently translated into English. To ensure the objectivity and consistency of each code, category, and topic summarized, multiple meetings were conducted to discuss and involve all researchers on the team in the discussion and resolution of discrepancies. The final Chinese and English versions of the codes, categories, and themes were validated by the researchers.

2.6. Ethical considerations

Ethical approval was granted by the Ethics Committee of The Second Affiliated Hospital of Chongqing Medical University(Approval Number: 2021–84, Date: September 17, 2021). Participants were informed that participating in the study was voluntary and that they

Table 1
Participant demographics.

Interview #	Gender	Age	City	High EDU nurse	High EDU Physician	ICU type	Working YRS	YRS current unit	Interview
1	F	34	Chongqing	BD		GICU	11	11	Face to face
2	F	35	Chongqing	MSN		GICU	13	13	Face to face
3	F	35	Chongqing	BD		GICU	12	12	Face to face
4	M	32	Shanghai	MSN		CSICU	6	6	Video conference
5	F	31	Shanghai	MSN		CSICU	8	7	Video conference
6	F	31	Yangzhou	BD		GICU	8	8	Video conference
7	F	31	Nanjing	MSN		GICU	5	5	Video conference
8	F	30	Hangzhou	MSN		GICU	4	4	Video conference
9	M	32	Chongqing	MSN		GICU	6	6	Face to face
10	M	40	Chongqing		MSM	GICU	16	11	Face to face
11	M	50	Chongqing		MSM	GICU	26	16	Face to face
12	F	39	Chongqing	BD		GICU	18	18	Face to face
13	M	33	Nanjing		MSM	SICU	4	2	Video conference
14	M	35	Mianyang		BD	GICU	8	5	Video conference
15	M	41	Nanjing		PhD	EICU	18	16	Video conference

F = female; M = male; BD = baccalaureate degree; MSN = master of science in nursing; MSM = master of science in medicine; PhD = doctor of philosophy; GICU = general intensive care unit; CSICU = cardiosurgery intensive care unit; SICU = surgical intensive care unit; EICU = emergency intensive care unit; YRS = years.

had the option to stop the interview at any time if they changed their mind about participating. There were no conflict of interest between the interviewees and the researchers. All information provided by interviewees was and is kept in a safe place.

3. Findings

3.1. Characteristics of participants

In total, 15 face-to-face (N = 7) or video conference (N = 8) interviews from 10 tertiary hospitals were conducted with ICU nurses (N = 10) and physicians (N = 5). Participants were on average 35.37 ± 5.14 years old, had an average work experience of 10.87 ± 6.13 years, and their ICU work experience was 9.33 ± 4.76 years. The median length of each interview was 38.13 min and ranged from 30 to 59 min. The interviews were held at a location preferred by the participants. Further details of the participants' characteristics are presented in Table 1.

3.2. Themes identified during the interviews

The participants described in great detail the many elements that were of great concern to them in performing glycaemic management of critically ill patients. Several interconnected themes and subthemes were identified for each element, and the study created a model to explain the interconnectedness of the elements of glucose management in critically ill patients (Fig. 1. A model of glycaemic management in critically ill adult patients). The model can be divided into two parts: the inner ring focuses on the behaviours in practice, while the outer space focuses on the methods of glucose management and the drivers of the practice process.

3.2.1. Inner ring: Practice behaviour

(a) Blood glucose (BG) assessment

As the most basic part of glycaemic management of patients, many interviewees mentioned that the content of the assessment should consider all factors affecting the patient's glycemia, such as the presence of a history of diabetes, disease type, underlying disease, and individual sensitivity to insulin, surgery, and medication, whenever possible. Most interviewees expressed more concern about patients with a history of diabetes, and they noted that this may be because in most ICUs, physicians usually recommend discontinuing home blood glucose control methods in favour of insulin infusions when a diabetic patient is admitted. In addition to

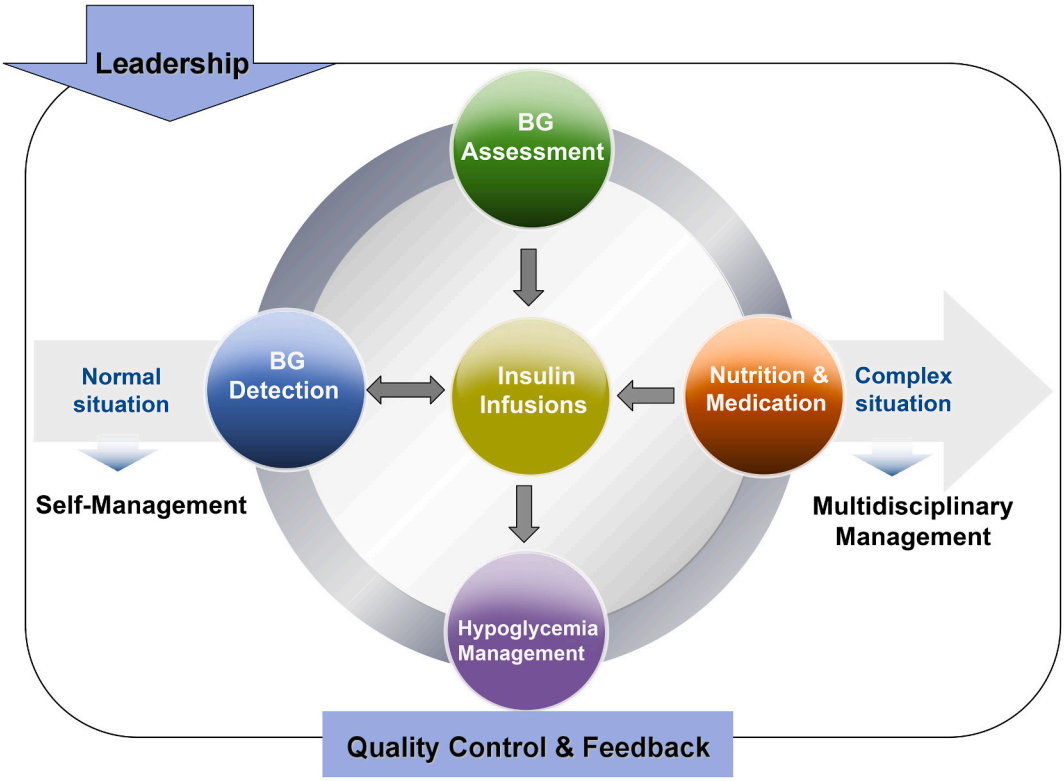

Fig. 1. A model of glycaemic management in critically ill adult patients

ensuring that the assessment is comprehensive and complete, study participants also said the health care staff needed to have extensive clinical experience and specific blood glucose assessment tools, and the assessment should be done in stages so that the patient's blood glucose could be measured at the time of admission to the ICU, then before, during, and after the insulin infusion.

> *"Some patients do not have diabetes before surgery, but after surgery, they will have a rise in blood sugar. One may be caused by our medication, and another may be caused by the disease itself. These are factors you must take into account."* (Interview #5)

> *"There are differences between patients without a history of diabetes and those with a history of diabetes. For example, some patients may have hypoglycaemia with the same blood glucose value and the same dose of insulin, while others may remain in a hyperglycaemic state."* (Interview #14)

> *"Our current assessment is very simple. Even our nursing record sheet reflects very little, mainly whether the doctor has ordered nutritional support. The nurses feel that they have done relatively little of the assessment work. We are mainly monitoring the blood glucose and adjusting the insulin."* (Interview #7)

> *"A novice nurse is significantly weaker than an experienced clinical nurse, and I believe that a healthcare provider with at least 5 years of clinical experience is likely to be better equipped for the job(BG assessment)."* (Interview #12)

(b) Insulin Infusions

Most of the interviewees pointed out that the main elements of insulin infusion for critically ill hyperglycaemic patients are the selection of insulin type, insulin configuration, delivery method, the timing of insulin use, performers of insulin infusion, adjustment of insulin infusion, and insulin administration in special situations. The current insulin infusion in ICU patients is more dependent on the Insulin Infusion Protocol (IIP), so in addition to the discussion of what is included under this dimension, some respondents also suggested that the existing protocol needs to be updated and that "protocol violations" are common in clinical practice. The influence of instruments and devices on insulin infusion was also mentioned by some respondents, but this is usually not reflected in the IIP.

> *"The dose of insulin is usually adjusted by us (nurses) because the doctor will advise us to determine the insulin use according to the target blood sugar range. Then, we follow the doctor's prescription, and do the next assessment."* (Interview #8)

> *"This protocol (IIP) I remember when I came to work. I came to work in the ICU in 2017 and have always used this protocol."* (Interview #8).

> *"I worked in 2013. I've been working for 9 years. Anyway, this protocol has been the management method since I started working in the ICU until now."*(Interview #5)

> *"This protocol (IIP) is only a reference. That is, in the actual blood glucose management process nurses cannot be very rigid. They cannot follow the IIP exactly."* (Interview #3).

> *"In our ICU, especially when glucose testing of patients is more frequent, nurses may be more inclined to proceed based on their own experience, and this can also keep blood glucose in an appropriate range."* (Interview #6)

> *"I find that the 50 ml syringe seems to adsorb insulin, while the 20 ml syringe has a slightly weaker adsorption effect on insulin. Currently, the 50 ml syringe is used more often in the clinic to reduce the number of times the drug is deployed."* (Interview #11)

(c) BG detection

BG monitoring mainly includes the methods of BG detection, blood collection site, and frequency. Although it would be more convenient to adopt continuous glucose monitoring (CGM) for critically ill patients, many interviewees expressed that it would be difficult to conduct CGM in clinical practice, so BG monitoring is still recommended based on bedside BG testing, and nursing staff can make flexible adjustments. The interviewees also mentioned that, in addition to the accuracy of glucose value, it is necessary to pay attention to the emotions of patients during invasive operations, the impact of night-time BG testing on patients' sleep, the replacement of blood collection sites in long-term ICU patients, and the consistency of the regulation of insulin infusion and the adjustment of the frequency of BG monitoring.

> *"We also have patients in the ICU using CGM, but relatively few because of the cost. We will provide CGM equipment for rent, which is much cheaper for patients. Mainly because the subcutaneous implantation of BG detectors is invasive, many patients and their families find it difficult to accept the services."* (Interview #14)

> *"In many cases, when patients need to be monitored for BG is based on the judgment of the nurses."* (Interview #7)

> *"Once my patient had hypoglycaemia because the patient's insulin infusion dose was raised at that time, and it was during a shift change. I reminded the next nurse, but at that time there was another patient who needed CPR resuscitation, and everyone went to help resuscitate the patient. So, my patient's blood sugar was not paid attention to in time, and hypoglycaemia occurred."* (Interview #9)

"Sometimes it is painful for us to watch the patient keep getting stuck with the needle (multiple capillary glucose measurements). So, sometimes we refer to the BG value in the blood gases analysis, or if the patient needs to have venous blood collection, we will keep the collected venous blood for glucose measurement." (Interview #5)

(d) Nutrition & Medication

ICU providers need to be aware of the nutritional and medication management related to blood glucose, and attention needs to be paid to the nutritional methods, type, rate, amount, duration of nutrition, medications, and administration methods that may cause fluctuations in patients' blood glucose. If necessary, the involvement of a nutritionist and pharmacist is needed. In addition, the patient's nutrition and medication need to be considered when adjusting the frequency of BG detection and insulin dosage. However, there are still some controversial issues, such as whether enteral or parenteral nutrition in SHG patients needs to be accompanied by insulin infusion or insulin should be added directly to intravenous nutrition solution, the large variability of nutrition and medication recommended by different specialties and for disease types, and whether it is necessary to categorize glucose management for critically ill patients by different disease types.

"Sometimes the patient's BG value will be high during the glucose infusion. Then, we will generally increase the frequency of this monitoring instead of directly delivering insulin. To see the dynamic changes in BG and blood glucose, you cannot simply look at one value, but the value needs to be seen in the context of the patient's current treatment or nutrition." (Interview #3)

"For diabetic patients, we generally choose TPF-D (produced by Fresenius Kabi Deutschland GmbH) for enteral nutrition, which is a slow-release starch, so there is no possibility of a rapid rise in blood sugar after use. But if we choose other types of nutrition solutions, they may involve the use of insulin." (Interview #11)

"In our Cardiac Intensive Care Unit, we usually do not infuse parenteral fat emulsion, and we infuse relatively little enteral nutrition. So without parenteral nutrition, the nutrition actually has very little effect on blood sugar. Part of the enteral nutrition is still retained in the gastric tube, and the stored gastric contents will be pumped out again the next day." (Interview #4)

(e) Hypoglycaemia management

The main causes of hypoglycaemia in the ICU are the patient's disease and medical errors. Recurrent and severe hypoglycaemia caused by the disease is most common. In terms of treatment, hypoglycaemia in the ICU is treated by oral administration, intravenous infusion, and intravenous push of glucose. The interviewees thought that compared with hyperglycaemia, the danger, complexity, urgency and importance of hypoglycaemia were much higher. Thus, the treatment of hypoglycaemia patients is more personalized than that of hyperglycaemia patients. In addition, the majority of respondents agreed that hypoglycaemia caused by insulin infusion is easier to correct than that caused by patients' diseases.

"For example, after the nutrient infusion is completed, the nurse does not notice or stop the insulin infusion, which I think is a very common cause of hypoglycaemia." (Interview #12)

"Most of the hypoglycaemic patients in our ICU have liver failure; in addition, some terminal patients are prone to persistent hypoglycaemia." (Interview #7)

"Stubborn hypoglycaemia may not be very easy to correct anyway, but if the patient is not treated, he may die from hypoglycaemia." (Interview #8)

"The management of hypoglycaemia seems to lack a complete specification or process and is treated more as an emergency, and doctors treat it more like a complication of a disease." (Interview #8)

3.2.2. External space: Methods and drivers

(f) Methods

Generally, the conventional glucose management of ICU patients is undertaken by the medical and nursing staff in the unit. If patients have poor results with conventional glucose control methods, such as recurrent severe hypoglycaemia, large variability in blood glucose, persistently high blood glucose values, a multidisciplinary consultation mode can be adopted (i.e., incorporating endocrinologists, dieticians, pharmacists) to participate in the glucose management of patients.

However, in the current process of blood glucose management, study participants said there is still controversy about the need to implement grouped blood glucose management for different ICUs, different diseases, and different hospitals separately. The point of controversy is that some study participants indicated that there is a large, individualized difference in the occurrence of stress hyperglycaemia except for patients with a history of diabetes and diseases with liver or islet damage. They said the differential management of blood glucose should not be based on the type of ICU or disease but on the patient's blood glucose value and his or her

situation, including the need for nutritional support and whether complications are present.

> *"If the patient's blood sugar is not too high and there are no serious complications, there is no need to consult the endocrinology department. But if the patient is a "tricky one", with high blood glucose and severe infection, we will call in the endocrinology department."* (Interview #11)

> *"We once had poor blood glucose control, which was caused by the patient's poor nutritional support, because many times the ICU doctors prescribed nutrition for the patient's nutritional management, with little involvement of the dietitian."* (Interview #12)

> *"I do not recommend subgroup glucose management for patients. It is still based on blood glucose values and body consumption due to disease, patient nutritional support, and infection, and if the patient's infection is relatively mild, the blood glucose target range can be relaxed appropriately."* (Interview #1)

(g) Quality control & feedback

The core of supervision and feedback in glucose management of ICU patients lies in the establishment of a supervisory team of hierarchical management. The hospital-wide glucose management team led by the endocrinology department supervises the ICU patient glucose management team. The ICU patient glucose management team is usually recommended to be composed of senior ICU physicians and nurse leaders, advanced practice nurses, nursing team leaders, and senior nurses. The ICU glucose management team needs to undertake the development and updating of glucose management protocols for ICU patients, supervision of protocol implementation, conduct training related to glucose management, and organize regular discussion and improvement seminars for health workers on glucose management.

> *"It would certainly be better if the management process of blood glucose in all ICUs could be unified on a large hospital level, but it may be difficult."* (Interview #10)

> *"I don't recommend that the glucose management team in the ICU unit include doctors or nurses from other departments; the supervision and feedback within the department should be more like a self-reflection process."* (Interview #6)

(h) Leadership

The sources of leadership involved in the process of glucose management in ICU patients are at the hospital level, the nursing department level, and the department level, which is a top-down process, and managers at each level need to reach a consistent view on glucose management. In addition, leadership, as an important facilitating factor, needs to be integrated into the entire glucose management process, especially when the current glucose management protocol needs to be improved and innovated. An enlightened leader needs to understand the clinical practice of the ICU, know the methods of glucose management for critically ill patients, make changes to the practice, have good communication skills, and know how to empower and give certain authority to the glucose management team members in their department.

> *"Our nurse manager was very supportive of our patient glucose management improvement project, but our department head thought it was unnecessary and that it would be better to maintain the current protocol, and then it was dropped."* (Interview #4)

> *"Whenever there is a replacement or update to the current glycaemic protocol, you need to get this approval from the ICU director before you can implement it, or you need to consider adding to your research team administrative job holders such as the director of nursing, the ICU director, the ICU nurse manager, etc., but they don't necessarily assume the role of researcher."* (Interview #7)

> *"Like most leaders, she needs to have some vision in blood glucose management and communicate well with the physicians and nurses in the unit and her leadership, and she may also need to understand the knowledge and methods of research."* (Interview #11)

4. Discussion

This study provides visual and vivid evidence for the glucose management of critically ill adult patients in China. The five major elements involved in the practice of glucose management in critically ill patients are glucose assessment, insulin infusion, glucose monitoring, nutrition and management of medication and hypoglycaemia, which interact and are interlinked and are together in the inner ring of the model. The methods, quality control and feedback of glucose management in the external space and leadership as a driving factor permeate the entire glucose management process and all aspects of it. Many studies have confirmed that glycaemic management of critically ill patients is a complex process involving multiple elements and that history of diabetes [25], surgery [26], insulin sensitivity [27], disease [28], and nutrition [29] are all important factors influencing glycaemic fluctuations in critically ill patients. This is consistent with the glycaemic assessment section of this study, which also found that ICU healthcare providers showed a more sensitive attitude toward patients with a history of diabetes. In addition to the change in glycaemic control methods before and after admission to the ICU, patients with a history of diabetes are more prone to glycaemic-related complications [30]. Some

researchers have pointed out that the severity of hypoglycaemia in patients with a history of diabetes is greater than that in patients without a history of diabetes [31].

It is common for critically hyperglycaemic adult patients to adopt continuous insulin infusion based on paper-based or electronic IIPs for glycaemic control [32]. The exploration of the contents of IIPs has also been the focus of research in the past 20 years, and many IIPs have very comprehensively encompassed many elements of the insulin infusion process and have proven their effectiveness in the glycaemic control treatment of critically ill patients [33]. Therefore, insulin infusion should be located at the core of the entire glycaemic management model.

In the model, BG detection and insulin infusion are interactive, and as the dose of insulin is adjusted, the frequency of BG detection is also adjusted. Our study also confirms that it is still difficult to implement CGM for critically ill patients in mainland China. In addition to cost considerations, the invasive operation and accuracy of monitoring are still points of concern for healthcare professionals, which is also consistent with the concerns expressed in the guidelines for inpatient glucose management issued by the American Diabetes Association (ADA) [34]. In addition, frequent capillary blood glucose monitoring can cause pain, and nursing staff choose to collect blood from arterial or venous cannula connectors for blood glucose testing from a humanistic perspective, although this may cause inconsistency and inaccuracy of blood glucose measurement, an operation that is affirmed by the latest expert consensus on glucose management in critically ill patients [35].

In the context of early enteral nutrition for critically ill patients, hyperglycaemia caused by nutrition is common [36]. Many studies have confirmed that the use of drugs such as glucocorticoids and salicylates can cause fluctuations in patients' blood glucose [37], so nutrition and medication can be regarded as important determinants of insulin infusion adjustment, but contradictory to reality, nutrition and medication are rarely included in the IIP [38][. In addition, this study also found that in the clinical practice of glucose management, nursing staff would combine their own experience and implement enteral nutrition along with insulin infusion to maintain the patient's glucose stability in the event of hyperglycaemia. Although studies currently suggest that insulin should be given according to the patient's glucose value during nutrition implementation, further quantitative studies are needed to confirm.

This study found that ICU healthcare professionals have an individualized approach to the management of hypoglycaemia, which has led to an attitude of managing hypoglycaemia more like a complication of insulin therapy. As the goal of glycaemic control for critically ill patients has changed from "strict" to "loose" in recent years [39] and more scientific and standardized IIPs are used, hypoglycaemia in patients caused by insulin infusion is declining. Therefore, it is recommended that the management of hypoglycaemia should be more prevention-oriented, with early identification of risk factors for the occurrence of hypoglycaemia, such as malnutrition, immunodeficiency, sepsis, blood purification, and organ failure [40]. It is also possible to prevent the occurrence of hypoglycaemia with the help of some hypoglycaemic risk prediction tools [41].

In our model of this study, it is recommended that the managers of blood glucose also switch from ICU professionals to a multidisciplinary glucose management team including ICU professionals according to the complexity of the patient's glucose control; the interviews also revealed the disagreement on standardized glucose control or individualized glucose control, but given that evidence has not confirmed the absolute advantages or benefits of individualized glucose management for critically ill patients [14] and the relative shortage of human resources in critical care in China [42], standardized glucose management protocols are still recommended; under special circumstances, ICU medical and nursing staff can also apply their glucose management experience under the guidance of the protocols.

Previous studies have confirmed that team-based management plays an important role in clinical decision-making and protocol development in ICUs [43]. This interview showed that different levels of glucose management need to be established for quality control and feedback in the "outer space" of the model and throughout the whole process of glucose control. The study also clarified the structure, members, and responsibilities of the blood glucose management team. However, further research is needed on the development, innovation, and cooperation of members of the glucose management team [44]. The leader belongs to the "outer space" in the model and is an important facilitator in determining the success of blood glucose control for critically ill patients. Many studies have confirmed the facilitating role of leadership in the process of ICU program implementation and quality improvement [45]. However, in the process of IIP implementation, researchers seem to pay more attention to the achievement of target blood glucose and the occurrence of complications [13,33]. Few studies have mentioned the role of leadership. In our study, almost all of the interviewees mentioned the role of leadership, which may also be related to the fact that most of the participants in this study indicated that their ICUs did not pay enough attention to blood glucose management.

5. Limitations

Our study has several limitations. First, we did not analyse ICU physicians and nurses separately due to time and sample size limitations. Thus, future studies can explore the differences in the perception of glycaemic management in ICU patients from the experience of physicians and nurses. Second, because the interviews were conducted during the COVID-19 pandemic, some respondents were interviewed by video conference, and the information obtained may be less rich than that obtained via face-to-face interviews. Finally, to ensure the accuracy of the data analysis, we coded and analysed the data in the Chinese version and translated the interviewees' text into English. Although our bilingual team with rich qualitative experience reviewed the translated version several times to ensure the accuracy of the meanings expressed, reverse translation could not be carried out due to time and energy constraints.

6. Conclusion

This study describes the model of glucose management in critically ill adult patients. The practice of glucose management in the "inner ring" includes glucose assessment, insulin infusion, glucose detection, nutrition, medication, and hypoglycaemia management. The methods, quality control, feedback, and leadership in the process of glucose management are in the "outer space" of the model, which explains many elements and dynamic management processes in the glucose management of critically ill patients in China. All ICU healthcare workers involved in patient glucose management need to recognize and understand this model and clarify what is covered within each element. It is necessary to develop a comprehensive and standardized strategy for glucose management in critically ill patients to provide a more scientific approach to their care.

Recommendations for future research

This study provides a valuable experience on the management of glycaemia in critically ill adults, which can help health care providers gain a comprehensive understanding of what is involved in the management of these critically ill patients at a theoretical level. Future studies could build on this foundation to explore guidelines for the management of glucose in critically ill adults, and more interventional studies still need to be conducted to test the feasibility of this model.

Implications for policy and practice

Physicians and nurses in adult critical care units should incorporate relevant elements at the level of practice behaviours and at the level of methods and facilitators as fully as possible when performing glycaemic management for patients. Managers of clinical practice units should take an active role in the process of glucose management and promote practice activities around insulin infusion as the core glucose management practice.

CRediT authorship contribution statement

Miao Huang: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Validation, Writing – original draft. **Li Yang:** Formal analysis, Data curation, Investigation, Software. **Chuanlai Zhang:** Supervision, Writing – review & editing. **Xiuni Gan:** Supervision, Resources, Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e24545.

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