

Research on Technological Innovation and Clinical Application of Intelligent Non-Invasive Blood Glucose Monitoring System: A Case Study of “Hengtang Zhihang”

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Abstract: With the global prevalence of diabetes escalating, traditional blood glucose monitoring technologies are constrained by inadequate precision, discontinuous monitoring, and inefficient clinical collaboration. This paper focuses on the “Hengtang Zhihang” intelligent non-invasive blood glucose management system, which is developed based on China’s pioneering third-generation glucose sensing technology. It systematically analyzes the system’s integrated solution covering hardware, software, and clinical services, and comprehensively compares its advantages over traditional methods such as capillary blood glucose monitoring and conventional continuous glucose monitoring. Clinical application data from a tertiary hospital in Shanghai verifies that the system significantly reduces diabetes-related complications and improves the operational efficiency of medical institutions. Additionally, this paper explores the system’s market-oriented operation path and technological iteration direction. The research findings provide valuable references for promoting the innovation and development of diabetes monitoring technology and advancing the localization of high-end medical devices in China.

Keywords: Diabetes; Blood glucose monitoring; Third-generation glucose sensing technology; Intelligent medical system; Non-invasive monitoring

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1. Introduction

1.1. Diabetes epidemic situation

Data from the International Diabetes Federation (IDF) and Huajing Industry Research Institute show that in 2019, there were 463 million adult diabetic patients worldwide, expected to reach 700 million by 2045 ^[1]. In China, the diabetes incidence rate is 12.9% ^[2], with 834,000 annual deaths from diabetes-related complications, accounting for 19.2% of chronic disease deaths. In hospitals, 38.7% of inpatients have hyperglycemia (over 50% in ICUs),

increasing complication risks by 2–3 times.

1.2. Limitations of traditional technologies

Capillary blood glucose monitoring (BGM): Only provides real-time static data, requires repeated blood sampling, and misses occult hyperglycemia/hypoglycemia.

Glycated hemoglobin (HbA1c): Reflects 2–3 months of average glucose but fails to capture short-term fluctuations.

Traditional continuous glucose monitoring (CGM): Needs daily fingerstick calibration, has semi-disposable designs (high cross-infection risk), and lacks real-time data transmission^[3].

2. Technical architecture and innovations of “Hengtang Zhihang”

2.1. Overall architecture

The system adopts a “trinity” design: Hardware layer: Integrates BGM intelligent glucose meters (5-second testing, 0.5 μ L blood sample), CGM devices (7–14 days monitoring), and CSII patch insulin pumps (simulating artificial pancreas). Software layer: Connects to hospital HIS/EMR systems, with modules for data integration (20-second real-time transmission), intelligent analysis (AI-based abnormal warnings), and clinical collaboration (cross-department consultations).

2.2. Working principle

The core of the “Hengtang Zhihang” system relies on the third-generation glucose sensing technology, which uses high-precision optical sensing combined with electrochemical detection. It captures glucose molecule signals in the interstitial fluid without piercing the skin, converts the biological signal into a digital signal through a built-in chip, and then uses an AI algorithm to correct interference factors such as body temperature and humidity to output accurate blood glucose values. The hardware and software layers achieve real-time interconnection through Bluetooth routers: the hardware collects physiological data, the software processes and analyzes the data, and synchronizes it to the hospital’s HIS/EMR system in real time, while the clinical service layer provides professional diagnosis and treatment suggestions based on the analyzed data to form a closed-loop management of blood glucose monitoring and intervention.

2.3. Usage method

Hardware activation: Unpack the BGM intelligent glucose meter, CGM device, or CSII patch insulin pump, power it on, and complete Bluetooth pairing with the supporting mobile APP or hospital terminal.

Device wearing/operation: For the CGM device, attach the disposable sensor to the abdomen or upper arm following the 4-step implantation process (clean the skin → tear off the sensor adhesive film → fix the sensor → activate the device); the BGM intelligent glucose meter can complete testing with a 0.5 μ L blood sample by touching the blood sampling area; the CSII patch insulin pump is attached to the skin and the insulin dosage is set through the app.

Data viewing and management: Medical staff can check real-time blood glucose data, historical trends, and abnormal alerts through the hospital system, while patients can view their own blood glucose status through the mobile app. For abnormal blood glucose values, the system will automatically alert, and medical staff can initiate cross-department consultations through the software module.

Device replacement and maintenance: The CGM sensor is replaced every 7–14 days as a disposable product; the BGM intelligent glucose meter only needs regular charging, and the CSII patch insulin pump is replaced

according to the insulin residual capacity and wearing time, generally once every 3–7 days.

2.4. Application scenarios

Hospital clinical scenarios: It is widely used in the endocrinology department, ICU, general ward, and other departments of tertiary hospitals, especially suitable for inpatients with hyperglycemia, postoperative patients who need blood glucose monitoring, and critically ill patients in ICUs who are at high risk of blood glucose fluctuations.

Community medical scenarios: Applied in community health service centers to provide long-term blood glucose monitoring services for elderly diabetic patients, helping community doctors grasp the patient's condition in a timely manner and adjust treatment plans.

Home monitoring scenarios: Suitable for type 1 and type 2 diabetic patients who need daily blood glucose management. Patients can complete blood glucose testing and data recording at home without frequent hospital visits, and doctors can remotely monitor the patient's condition through the system.

Special population scenarios: Used in obstetrics and gynecology departments for blood glucose monitoring of pregnant women with gestational diabetes; applied in sports medicine institutions for real-time monitoring of athletes' blood glucose during exercise; and used in physical examination centers for early screening of abnormal blood glucose in obese people ^[4].

2.5. Core innovations

Third-generation glucose sensing technology: Achieves non-invasive monitoring without calibration. Its mean absolute relative difference (MARD) is 7.45%, lower than the international standard (<10%), with strong anti-interference. Single-use design: CGM sensors are fully disposable, eliminating cross-infection risks and simplifying operation (4-step implantation). Full-link data interconnection: Bluetooth routers enable real-time data sharing between devices, platforms, and hospital systems, breaking data silos ^[5].

3. Clinical application and effects

3.1. Clinical cases

In a tertiary hospital in Shanghai (1,500 beds), after 6 months of application (July to December 2023): Efficiency improvement: Cross-department consultation time shortened from 4.5 hours to 30 minutes; BGM testing time reduced by 50%. Patient prognosis: Diabetes-related complication rate dropped from 12.3% to 5.8%; average hospital stay for diabetic patients decreased from 8.2 days to 6.5 days. Hospital management: Bed turnover rate of the endocrinology department increased by 27.8%; patient satisfaction with monitoring rose from 65% to 92%.

3.2. Adaptability to different populations

Diabetic patients: Type 1 patients benefit from CGM-CSII linkage; Type 2 patients (mostly middle-aged and elderly) enjoy easy operation (one-click BGM testing). Special groups: Pregnant women get low-intensity monitoring (30-minute updates); athletes receive real-time pre-during-post exercise monitoring; obese people get early abnormal glucose detection.

3.3. Comparative advantages

Technology type monitoring cycle MARD convenience clinical value, Capillary BGM: Real-time, blood sampling needed, misses abnormal glucose. Traditional CGM: 7–14 days 8–12%, calibration required, high infection risk,

no real-time alerts “Hengtang Zhihang”: Real-time + 7–14 days 7.45%, non-invasive, auto-upload, real-time alerts, cross-department collaboration.

4. Business model and future outlook

4.1. Business model

Hardware sales: 20–30% cheaper than imported products (e.g., BGM: ~1,500 yuan; CGM set: ~800 yuan). Software services: Annual hospital fee (~50,000 yuan); paid patient premium version (1,200 yuan/year). Consumables supply: Disposable CGM sensors (14-day service life) as the long-term profit core.

4.2. Future iteration

Expand indicators: Add blood pressure, lipid, and heart rate monitoring for integrated “three highs” (hypertension, hyperglycemia, hyperlipidemia) management. Upgrade AI: Build a “three highs” risk prediction model based on big data. Wearable devices: Develop lightweight smart patches (0.5 mm thick) for 24-hour non-invasive monitoring.

5. Conclusion

The “Hengtang Zhihang” system, leveraging third-generation glucose sensing technology, solves the pain points of traditional monitoring. Its clinical application proves its ability to improve patient outcomes and hospital efficiency. With market expansion and technological iteration, it is expected to become a benchmark in global diabetes monitoring, promoting the localization of China’s high-end medical devices.

Disclosure statement

The authors declare no conflict of interest.

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