Journal of Clinical and Nursing Research, 2026, Volume 10, Issue 4
http://ojs.bbwpublisher.com/index.php/JCNR
Online ISSN: 2208-3693
Print ISSN: 2208-3685

Application and Effect Evaluation of Smart Blood Collection System in Outpatient Blood Collection in Oncology Specialty Hospitals

Yufeng Pan†, Fan Yang†, Manli Liu, Min Li, Fengjie Li, Huahui Guan, Le Xia, Xuefang Huang*, Aihua Zhuang*

State Key Laboratory of Oncology in South China, Guangdong Provincial Clinical Research Center for Cancer, Sun Yat-sen University Cancer Center, Guangzhou 510060, Guangdong, China
† These authors contributed equally to this work and share the first authorship.

***Corresponding authors:** Xuefang Huang, Huangxf1@sysucc.org.cn; Aihua Zhuang, zhuangah@sysucc.org.cn

Abstract: *Objective*: To explore the application effect of the intelligent blood collection system in the outpatient blood collection of cancer specialized hospitals, and to provide a basis for improving the quality of outpatient blood collection nursing and the medical experience of patients. *Methods*: 136,274 blood specimens collected using the traditional manual blood collection mode from January to June 2020 were selected as the control group, and 176,989 blood specimens collected using the intelligent blood collection system from January to June 2021 were selected as the observation group. The blood collection process time, blood specimen quality, incidence of adverse events and patient satisfaction of the two groups were compared. Measurement data were expressed as $\overline{x} \pm s$ and analyzed by *t*-test. Counting data were expressed as cases (%), and the χ^2 test was used. A p value < 0.05 was considered statistically significant. *Results*: The registration and number collection time, specimen submission time and total process time of the observation group were significantly shorter than those of the control group ($p < 0.001$). The total error rate of blood samples decreased from 0.374% to 0.050%, and the error rate of blood collection tube usage decreased from 3.8% to 0.7%. The patient satisfaction rate increased from 88% to 96%, and the differences were statistically significant ($p < 0.05$). *Conclusion*: The intelligent blood collection system can optimize the outpatient blood collection process, shorten the service duration, reduce the error rate of specimens, improve the efficiency of nursing and patient satisfaction, and has good application value in the outpatient blood collection management of tumor specialized hospitals.

Keywords: Smart healthcare; Intelligent blood collection; Outpatient nursing; Tumor hospital; Nursing quality; Specimen management

Online publication: Apr 30, 2026

1. Introduction

Outpatient venous blood collection is an indispensable part of the tumor diagnosis and treatment process. It is characterized by concentrated patient flow, diverse specimen types, strict quality requirements, and sensitive service experience. The process efficiency and nursing quality directly affect the overall service level of the hospital and patient satisfaction [1–3]. The traditional manual blood collection mode relies on nurses to complete the entire process of information verification, barcode printing, blood collection tube selection, labeling, classification, and submission for testing. It has problems such as many manual steps, high error risk, long process time, and difficulty in specimen traceability, which can easily lead to unqualified specimens, long waiting times, and poor patient experience [4].

With the construction of smart hospitals and the rapid development of medical information technology, automated and intelligent blood collection equipment has been gradually applied to the clinic, and through process reengineering and information technology fusion, the standardization, automation and traceability management of the whole blood collection process have been realized, which has provided a new path to improve the quality of nursing care [5–10]. In this study, the oncology outpatient blood collection center of the hospital is taken as a practical object, and the key indicators before and after the application of the smart blood collection system are compared and systematically evaluated. This study takes the oncology outpatient blood collection center of our hospital as the practice object, compares the key indexes of the intelligent blood collection system before and after its application, and systematically evaluates its role in optimizing the process, guaranteeing the quality of specimens, and enhancing the efficiency of the service, so as to provide a practical reference for the construction of outpatient blood collection intelligence of oncology hospitals [11].

2. Information and methodology

2.1. General information

The outpatient blood collection center of our hospital was selected as the study site, with 10 standard blood collection windows, 10 fixed blood collection nurses, and the working hours of 7:30–16:30. control group: traditional artificial vein blood collection was used from January to June 2020, with a total of 21,300 cases of blood collection and 136,274 blood specimens. Observation group: January–June 2021 using fully automatic intelligent blood collection system, a total of 23958 cases of blood collection, blood specimens 176989. The age, gender, tumor type, blood collection items, outpatient flow and nurse operation level of the two groups were balanced and comparable, and the difference was not statistically significant ($p > 0.05$).

2.2 Methodology

2.2.1. Control group blood collection procedure

Adopt traditional manual blood collection mode: manual call number → identity information verification → manual printing bar code → manual selection of blood collection tube → manual paste bar code → venous blood collection operation → manual classification of specimens → manual transfer to the laboratory.

2.2.2. Blood collection process in the observation group

Adopting i-pres with-C full-automatic intelligent blood collection system, seamlessly connecting with hospital HIS and LIS system, the process is as follows: patient self-help check-in → system automatic sorting

and calling number → intelligent tube preparation and automatic labeling → nurses' secondary verification → venous blood collection → automatic specimen transmission and sorting → real-time reception by the laboratory department. The details are as follows:

(1) Self-service check-in system

The self-service check-in system can realize the function of patients' self-service number taking. This system does not need to guide the operation of the doctor, the patient can take the number in the corresponding time period to the check-in machine after the payment of the blood collection order and appointment, the check-in machine supports the diagnosis and treatment card and ID card, enter the medical record number and scan the bar code of the appointment order to realize the multiple ways to take the number, and the successful check-in immediately prints the numbering paper, which corresponds to the patient's main identifying information (name, gender, age, medical record number) and queuing situation, and the patient waits at the window with the numbering paper to call for blood drawing. The patient will wait at the window with the numbered paper to call for a blood draw. When a patient fails to get a number, the reason for the failure will be displayed so that the patient can get the first information support.

(2) Automated call system

The automated sequencing and calling system is designed for patient triage, with the following primary functions: automatic patient sequencing with unique numbering to prevent call confusion; voice-based system calls displaying the current call number and patient information on the screen; multi-source patient prioritization: based on patient condition and age, the system sets up general calls, emergency calls, compassionate calls, peripheral blood calls, and emergency calls. Emergency calls and compassionate calls are dedicated to patients requiring urgent blood tests or elderly and frail individuals, avoiding physical discomfort (e.g., hypoglycemic syncope) caused by prolonged fasting. Peripheral blood calls are reserved for patients requiring only complete blood count (CBC) tests, allowing them to proceed directly to Window 1 for collection by laboratory staff. Emergency calls are reserved for special cases, with each source displaying the waiting queue to facilitate secondary triage. This multi-source design achieves intelligent diversion of outpatients for blood collection, reducing waiting time and preventing overcrowding and chaotic queues. Nursing staff can call patients via tablet devices, with corresponding blood collection window information displayed above to guide patients intuitively, eliminating concerns about call numbers and enabling them to queue confidently in the waiting area. Sample rollback function: nurses can perform rollback for duplicate items or items unnecessary for collection due to other reasons, ensuring closed-loop processing between the automated blood collection system and the hospital information system.

(3) Intelligent tube preparation system

The intelligent tube preparation system is designed for barcode generation, automatic tube selection, and automatic labeling, enabling automated tube dispensing after patient calling. While nursing staff call registered patients awaiting blood collection, the integrated tube preparation and labeling machine automatically generates barcodes, assigns collection tubes based on patient information, prints barcode labels, and automatically adheres them onto test tube trays. The bidirectional output design allows simultaneous blood collection by staff on both sides. After retrieving the trays, nursing staff verify patient information and procedures before proceeding with collection. Vacuum collection

tubes are stored in drawer-style units, with 8 slots accommodating 100 tubes for large-capacity storage of various specifications. These tubes feature a tube orientation recognition system, eliminating the need for directional separation during tube addition and simplifying operation. The vacuum collection tubes also incorporate patented concave butyl rubber stoppers, completely resolving issues of uneven vacuum pressure in vacuum tubes and ensuring blood collection quality. Standardized tube labeling eliminates manual labeling irregularities (e.g., wrinkles, skewing, or cornering), facilitating smooth automatic reading by subsequent testing equipment and reducing equipment alarms and re-labeling. The automated tube preparation system significantly enhances blood collection speed for nursing staff and simplifies the cumbersome procedures of traditional blood collection.

(4) Transmission and sorting system

The transmission and sorting system is used for specimen transmission, specimen sorting and scheduling, and specimen monitoring, realizing real-time immediate delivery of collected specimens. The speed of automated processing of vacuum blood collection tubes is 4 s/tube, which is fast and efficient. After the end of blood collection, the nursing staff directly put the blood collection tube into the high-speed transmission and transportation belt, and the specimen is automatically transmitted to the Laboratory Department for specimen testing through the transportation belt. The high-speed conveyor belt has the characteristics of high throughput and no “traffic jam”, and can continuously transport blood collection tubes without interruption. Compared with the traditional manual transportation, the conveyor belt protects the specimen from being shocked and damaging the test results during transportation [12]. Through the seamless connection of the transmission module, the system can automatically sort the specimens, and the chain combination of transmission and sorting guarantees the quality and safety of the specimens. Real-time monitoring of specimens in the collection of specimens lost or delayed delivery to affect the quality of the test can be traced and adjusted as needed, including single-item time limit warning according to the type of specimen time limit warning, time limit warning of the type of patients, etc. for transmission monitoring, if the specimen overtime transmission when the display is highlighted and the alarm, to avoid specimens lost tube overtime.

(5) Integrated management system

The integrated management system empowers administrators with operational permissions for data maintenance, query statistics, data analysis, and permission allocation, enabling effective configuration and control by both users and administrators. Key functionalities include: Data Maintenance: Managing client IP access, project tracking, user information, and interface configurations; User Permission Management: Controlling login access, personnel permissions, and interface access; Statistical Report Management: Providing data analysis, comprehensive queries, and workload tracking, which helps departments and management teams obtain accurate, real-time data to enhance intelligent management capabilities. Regarding equipment maintenance, the outpatient department has established a WeChat communication group for automated blood collection technology to facilitate issue feedback. The communication members primarily include nursing staff, laboratory personnel, and information technology engineers. When system issues such as failed call number generation, barcode printing failure, or tube dispensing machine malfunction occur, nursing staff may upload photos or videos to the communication group. Engineers promptly review the submissions and provide remote guidance, ensuring immediate analysis of fault causes, accelerated repair timelines, and avoidance of prolonged patient waiting.

(6) Interface docking module

The interface docking module monitors and records all the interfaces connected to the system. All systems interact in real time and synchronize various data, ensuring the integrity and uniformity of the data. Self-service check-in machine in the card reading according to the patient information to call the corresponding interface, query the valid test information, determine the timeliness of the appointment project, according to the number of source categories to generate queuing sequence number, check-in failure to be related to the prompts or by the staff to deal with. The nurse selects the number source corresponding to call the patient at the same time automatic tube preparation machine automatically generates bar code information, labeling out of the tube. The patient goes to the corresponding window to collect blood, and if the patient fails to arrive after repeated calls, he/she is regarded as having passed the number and needs to take the number again. The nurse completes the collection or puts the collected specimen into the collection conveyor belt and the conveyor belt automatically transfers it to the Laboratory Department, and the whole blood collection process ends.

2.2.3. Measures to manage quality and safety of care

Establish a blood collection specimen registration ledger to record non-compliant specimens and adverse events; strictly implement the “three checks and eight verifications”, aseptic techniques, and shift handover protocols; uniformly utilize disposable retractable safety needles; optimize the waiting environment by enforcing air disinfection and hospital infection control measures; develop emergency response plans for needle phobia, hypoglycemia, and equipment malfunctions to enhance emergency management capabilities.

2.3. Observation indicators

2.3.1. Average blood collection time per tube

Before the application of intelligent blood collection system, the average blood collection time t1 includes: the medical guide to take the collection order number printing barcode label time (T1) + collection nurse checking tube preparation time (T2) + collection and specimen sorting time (T3) after the collection of the whole process of the total time divided by the total number of specimens, to get the average time of blood collection per tube. After the application of intelligent blood collection system average blood collection time t2 from the patient self-service number, nurse end call, intelligent blood collection system ready tube, the nurse checking the project to the collection of the completion of the time used divided by the total number of specimens, to get the blood collection time per tube.

2.3.2. Classification of blood specimen quality issues

The quality problems of blood specimens in the study were categorized as: specimen retention problems (wrong sample retention, no specimen, no fasting blood collection, low specimen volume), barcode problems (substandard, reuse, error, no charge) and delivery problems (expired, timeout, sample coagulation).

2.3.3. Adverse events of venous blood collection

Mainly record the adverse events occurred in the process of outpatient venous blood collection, such as puncture failure, patient reaction, equipment failure, etc.

2.3.4. Assessment of patient satisfaction

Patient satisfaction is recorded and analyzed through self-compiled questionnaires by the department at each stage.

2.4. Statistical methods

Data analysis was conducted using SPSS 23.0 software. Measurement data were expressed as $\overline{x} \pm s$, and the independent sample *t*-test was used for comparison between groups. Counting data were expressed as the number of cases and composition ratio (%), and the χ^2 test was used for comparison between groups. A *p* value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of blood collection process time between the two groups

The observation group's time for reporting for number, specimen delivery and total process was significantly shorter than that of the control group, and the difference was statistically significant ($p < 0.001$); the difference in the average blood collection operation time between the two groups was not statistically significant ($p > 0.05$), as shown in **Table 1**.

Table 1. Comparison of time for each stage of blood collection between the two groups (min, $\overline{x} \pm s$)

Groups	Number of examples	Check-in number pick-up time	Mean time to blood collection	The time of specimen submission	Total process time
Control group	21300	21.35 ± 9.37	6.25 ± 2.54	3.01 ± 1.13	30.67 ± 13.87
Observation group	23958	10.25 ± 3.56	4.88 ± 1.35	1.25 ± 0.78	16.43 ± 5.54
t/Z	–	-10.146	1.520	-10.822	-6.532
p	–	< 0.001	0.145	< 0.001	< 0.001

3.2. Comparison of blood sample quality between the two groups

The observation group showed significantly lower rates of barcode issues, submission issues, and total error rates compared to the control group ($p < 0.05$), with statistically significant differences. The rate of retention issues decreased but remained statistically insignificant ($p > 0.05$), as shown in **Table 2**.

Table 2. Comparison of the quality of blood specimens between the two groups [cases (%)]

Groups	Total number of specimens	Barcode issues	Blood collection issues	Send specimens for inspection issues	Total
Control group	136274	25 (0.183)	18 (0.132)	8 (0.058)	51 (0.374)
Observation group	176989	4 (0.022)	2 (0.011)	1 (0.005)	9 (0.050)
χ^2	–	10.264	3.401	4.012	3.238
p	–	0.007	0.065	0.047	0.051

3.3. Workload and quality of care improvement

After the implementation of smart blood collection, the total number of blood samples collected increased by 27.81%, and the number of blood samples collected rose by 27.84%. The average monthly blood collection hours decreased by 14.91%. The error rate of blood collection tube usage dropped from 3.8% to 0.7%.

Patient satisfaction rose from 88% to 96%.

3.4. Adverse events related to blood collection

The total incidence of adverse events such as puncture failure, patient discomfort, equipment failure and complaints in the observation group was significantly lower than that in the control group, and the safety of blood collection and the comfort of patients were significantly improved.

4. Discussion

4.1. Intelligent blood collection system optimizes service processes and significantly improves blood collection efficiency

The smart blood collection system replaces manual repetitive operations with automation and informationization to achieve process reengineering and efficiency improvement [13,14]. Self-help check-in simplifies patient check-in, automatic numbering realizes orderly triage, intelligent tube preparation and labeling reduces nurses' manual operation time, and automatic specimen transmission eliminates manual transfer. This study shows that the total process time is shortened from 30.67 min to 16.43 min, which is a significant decrease in the working time under the simultaneous growth of outpatient volume and specimen volume, indicating that the intelligent blood collection system can effectively release nursing manpower, improve the overall operational efficiency of outpatient clinics, and alleviate the pressure of oncology clinics for blood collection.

4.2. Intelligent blood collection system reduces the error rate of specimens and guarantees the quality of tests

The quality of blood specimens is the core guarantee for the accuracy and reliability of test results [15]. In manual modes, issues such as barcode errors, non-standard labeling, substandard collection, and delayed submission are particularly prominent. The intelligent blood collection system reduces human errors at the source through automatic HIS/LIS information docking, intelligent matching of blood collection tubes, standardized labeling, full-process scanning verification, real-time specimen tracking, and timeout alerts, achieving closed-loop quality control before testing [16]. In this study, the total error rate of specimens decreased from 0.374% to 0.050%, with a significant reduction in the error rate of blood collection tubes, effectively lowering the rate of repeated blood collection, conserving medical resources, and enhancing medical safety levels.

4.3. Intelligent blood collection system improves the medical experience and increases patient satisfaction

Oncology patients need to collect blood for a long time and repeatedly, which requires higher waiting time, environmental comfort, operation safety and humanistic service [17,18]. Intelligent blood collection system can shorten the fasting waiting time and reduce the risk of hypoglycemia and fainting through hierarchical number diversion, reduce the crowding, overcrowding and anxiety by voice calling and large screen display, and reduce the pain and stress reaction of patients by the comfortable waiting environment, standardized operation and application of safe blood collection needles. Stress reaction of patients can be effectively reduced. The whole process is convenient, transparent and orderly, which significantly improves patients' experience and satisfaction and helps build a harmonious doctor-patient relationship.

4.4. Intelligent blood collection system promotes nursing management standardization and informatization

Intelligent blood collection system realizes the standardization of blood collection process, homogenization of operation and data management, reducing human differences and management loopholes [19]. The system is deeply integrated with the hospital information platform, and it can collect real-time data on workload, process time-consuming, specimen quality, adverse events, etc., which can provide an objective basis for departmental quality monitoring, efficiency analysis and performance assessment, and promote the transformation of outpatient care from traditional experience management to refined and intelligent management. It can promote the transformation of outpatient nursing from traditional experience management to refined and intelligent management, which is in line with the requirements for the high-quality development of modern hospitals and the construction of intelligent hospitals.

5. Shortcomings and prospects

This study is a single-center retrospective study and has certain limitations. During the operation of the system, occasional network delays, equipment failures and other issues still require continuous optimization of system stability and emergency maintenance mechanisms. In the future, multi-center and prospective studies can be carried out to extend the observation period, further evaluate the application value of the intelligent blood collection system in terms of cost-effectiveness, nurses' workload, and long-term service quality, and continuously improve the intelligent blood collection service system.

6. Conclusion

Smart blood collection system applied to outpatient blood collection in oncology hospitals can effectively optimize the blood collection process, shorten the service time, reduce the error rate of specimens, reduce the adverse events, improve the nursing efficiency and patient satisfaction, and significantly improve the quality of outpatient blood collection nursing care and management level, which is a mature practice of smart healthcare in outpatient nursing care scenarios, and is worthy of popularizing and applying in the blood collection centers of all levels of outpatient hospitals.

Funding

Sun Yat-sen University Cancer Center Youth Excellence Program (Project No.: PT2108040)

Disclosure statement

The authors declare no conflict of interest.

References

[1] Li F, Song X, Zhang L, 2016, Application of Risk Management in Outpatient Blood Collection in a Tertiary Hospital. China Medical Ethics, 29(5): 855–857.

[2] Du L, Shi X, 2012, Common Safety Problems and Countermeasures in Outpatient Venous Blood Collection. Inner

Mongolia Traditional Chinese Medicine, 31(11): 162–163.

[3] Liu L, Chen X, Lin S, et al., 2017, Application of Standardized Infection Management in an Outpatient Blood Collection Center. Chinese Journal of Hospital Infection, 27(11): 2622–2624.

[4] Chinese Society of Laboratory Medicine, Chinese Medical Association, 2020, Chinese Expert Consensus on Management of Substandard Venous Blood Specimens. Chinese Journal of Laboratory Medicine, 43(10): 956–963.

[5] Sun S, Zhang G, Zhang X, 2024, Research on Optimization and Countermeasures of Venous Blood Collection Process in Large Hospitals Based on Hazard Analysis and Critical Control Points and Process Reengineering Theory. China Medicine Herald, 21(12): 173–177.

[6] Li C, Liu C, 2013, Application of Fully Automatic Intelligent Blood Collection System in Outpatient Management. Inner Mongolia Traditional Chinese Medicine, 32(32): 52–53.

[7] Chen Z, Lu M, Chen D, et al., 2020, Clinical Study of Automatic Identification and Localization Technology of Blood Vessels by an Automated Venous Blood Collection Robot. Chinese Journal of Clinical Pharmacology, 36(19): 3148–3150.

[8] Luo J, Mao W, Wang L, et al., 2023, Safety Evaluation and Cost-Effectiveness Analysis of Manual and Intelligent Venous Blood Collection in Outpatient Areas. China Nursing Management, 23(3): 326–330.

[9] Yin H, Quan F, Zhang X, et al., 2023, Application of Mobile Intelligent Blood Collection System. Journal of Nursing, 38(5): 114–116.

[10] Xiao H, Guo P, Jiang Y, 2021, Application Effect of Intelligent Blood Collection Management System in Outpatient Blood Collection Nursing Work. Medical Theory and Practice, 34(23): 4216–4218.

[11] Wang S, Zhang J, Jiang Q, et al., 2022, A Study on the Content Adjustment and Clinical Application of the Guidelines for the Collection of Venous Blood Specimens. Nursing Research, 36(2): 341–344.

[12] Chinese Branch of Laboratory Medicine, Chinese Medical Association, 2020, Unqualified Venous Blood Specimen Management. Chinese Journal of Laboratory Medicine, 43(10): 956–963.

[13] Wang Y, Ruan H, Ruan Y, et al., 2025, Intelligent Blood Collection Robot: Key Technologies, Clinical Applications, and Future Challenges. Frontiers in Bioengineering and Biotechnology, 13: 1587114.

[14] Luo J, Mao W, 2024, Efficiency and Cost-Benefit Analysis of the Manual and Intelligent Venous Blood Sampling in Outpatient Area of Hospital. Studies in Health Technology and Informatics, 315: 665–666.

[15] Yuan S, Chen Y, Cai X, et al., 2021, Consensus on Safe Collection of Venous Blood Specimens in Adults. Chinese Journal of Infection Control, 20(9): 775–781.

[16] Wang C, Gu M, Zhu J, et al., 2025, Evaluation of the Improvement in Specimen Hemolysis by Automatic Blood Collection Robot. Chinese Journal of Laboratory Medicine, 48(8): 1080–1084.

[17] Ke Y, Kou X, 2021, Analysis of the Application Effect of Humanistic Care Nursing in the Rehabilitation of Tumor Patients. Chinese Pharmacology Bulletin, 37(11): 1630.

[18] Jiang H, Wei X, Li Q, et al., 2018, Effects of Caring Touch on Depression and Pain in Elderly Oncology Patients and on Nurses' Humanistic Care Quality. China Chronic Disease Prevention and Control, 26(12): 930–933.

[19] Wang C, Gu M, Zhu J, et al., 2023, Clinical Application of a Fully Automated Blood Collection Robot and Its Assessment of Blood Collection Quality of Anticoagulant Specimens. Frontiers in Medicine, 10: 1251963.