Research on the Application of "AI Technology + Precision Medicine" in Ultrasound Intelligent Information Management Systems

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Abstract: This study explores the application of "AI Technology + Precision Medicine" in ultrasound intelligent information management systems, aiming to standardize and optimize medical processes and investigate methods for managing ultrasound diagnostics and treatment. The study constructed an intelligent ultrasound management system and compared metrics from May to October 2020 (before system operation) with those from November 2020 to March 2021 (after system operation). Key metrics included the average time to complete ultrasound orders (hours), the average daily actual completed workload (sites/cases), the average patient waiting time (minutes), the pre-exam waiting time (hours), and patient satisfaction. After the implementation of the ultrasound intelligent management system, the completion time for ultrasound orders decreased from (71.36 ± 12.62) hours to (19.65 ± 3.25) hours; the average daily actual completed workload increased from (1652.38 ± 102.36) to (2385.46 ± 126.47); the average patient waiting time dropped from (42.36 ± 8.69) minutes to (21.56 ± 4.62) minutes; the pre-exam waiting time reduced from (27.02 ± 8.85) hours to (4.84 ± 0.97) hours; and the patient satisfaction rate increased to 91.26%. The ultrasound intelligent management system helps healthcare professionals optimize scheduling processes, increase ultrasound order completion rates, reduce patient waiting time, accelerate bed turnover rates, and enhance patient satisfaction.

Keywords: Precision Medicine; AI Technology; Ultrasound Examination; Appointment; Intelligent Information Management System

1. Introduction

The National Health Commission, in its *Action Plan for Further Improving Medical Services (2018-2020)*, clearly emphasizes the need to innovate new models of medical services, embracing new concepts and adopting new technologies to meet the evolving demands of the public for medical services. This aims to make healthcare more convenient and comfortable, thereby enhancing the public's sense of satisfaction[1]. The number of patient visits in our hospital increased from 1.852 million in 2015 to 2.605 million in 2020, marking a 40.7% growth. Medical imaging examinations, as a critical step in the patient's treatment process, have also seen a significant annual increase, with ultrasound examinations reaching a peak of 2986 scans in some instances. However, due to limitations in resources such as machines and personnel, along with procedural inefficiencies, the traditional ultrasound examination workflow and platform in our hospital often lead to overcrowding and confusion, with patients arriving early, queuing multiple times, and competing for appointment slots. Long appointment cycles and excessive waiting time have frequently led to patient complaints, contributing to unnecessary doctor-patient conflicts and diminishing the overall patient experience[2]. Precision Medicine, a concept emerging from the intersection of bioinformatics and big data science, revolves around the integration of

medical science with big data, utilizing real-world data to solve clinical problems[3]. Additionally, with the rapid development of information technology, artificial intelligence (AI) has gradually been integrated into the healthcare sector, leveraging tools such as communication, big data, and cloud computing to address existing hospital issues[4]. Since May 2020, our hospital has collaborated with various departments to establish an intelligent information management system under the concept of "AI Technology + Precision Medicine", starting with ultrasound examinations and gradually expanding to include CT, MRI, and other diagnostic tests. The following report presents the specific findings, offering potential insights for scheduling and practical implementation in medical imaging examinations.

2. Construction of the Ultrasound Intelligent Information Management System

2.1 Establishment of the Development Team

In May 2020, a research and development team for the ultrasound intelligent information management system was established, consisting of 16 members from departments including the hospital's vice president, nursing department, inpatient service center, information center, and ultrasound department. The nursing department was responsible for overall coordination; the inpatient service center managed the work systems and processes for comprehensive ultrasound appointment scheduling; and the information center handled the development, debugging, and maintenance of the system, which was eventually implemented and debugged in the ultrasound department.

2.2 Technical Support

The system adopts a B/S (Browser/Server) architecture, using Java language and the medical supervisions from the hospital information system (HIS) as the data source. It uses a MySQL database and Javaweb technologies such as Spring, MyBatis, and SpringMVC, along with HTML5, CSS3, and JavaScript for the web interface. The server runs on the CENTOS 7.3 operating system, and the client side of the system can be run on Chrome browser. Authorized medical staff can log into the system via the internet, which ensures ease of use and stability.

2.3 Module Design of the Ultrasound Intelligent Information Management System

The system manages the entire process of a patient's ultrasound examination, from appointment to completion, with four main modules: 1) Appointment Slots Management: Managed by the information center, this module handles the distribution and maintenance of appointment slots. It currently manages 2646 slots, divided into outpatient (28.65 ± 5%), inpatient (69.10 ± 5%), and green channel (2.25 ± 0%) categories. 2) Appointment and Management System: Managed by the inpatient service center, it integrates both "distributed appointments" and "centralized appointments". 3) Ultrasound Department Workflow Management and Tracking: This module monitors and manages the workflow within the ultrasound department. 4) Data Statistics: The system collects data on daily ultrasound order completion times, actual completed workload, average patient waiting time, and pre-exam waiting time for analysis.

2.3.1 Appointment slots management

The intelligent information system connects to the HIS intranet, automatically importing all ultrasound orders from the hospital. The appointment slots are configured based on the hospital's specific available resources of medical instruments and assigned to appropriate groups, with each group given different rules governing slot generation based on real-time situations. A timer is set to generate appointment slots of designated time daily, and real-time adjustment inconsistent with rules is allowed for the purpose of flexibility. Timely adjustment could also be made based on patient flows. To redirect slots, appointments are categorized into outpatient, inpatient, and green channel slots (the green channel refers to urgent cases that require rapid medical intervention). This classification management system ensures optimal use of hospital resources.

2.3.2 Appointment and management system

The ultrasound intelligent information system offers both distributed and centralized appointment options. Distributed appointments include five methods: in-clinic appointment, inpatient doctor HIS system appointment, cashier window appointment, outpatient self-service machine appointment, remote appointment via mobile devices. These options provide patients with comprehensive one-stop

appointment services. On the second floor of the outpatient clinic, a dedicated ultrasound appointment reception desk has been established to manage appointments, rescheduling, and cancellations. The hospital has also developed standardized appointment processes and provided staff training to improve service quality. An intelligent navigation system was developed to enhance the patient experience, and flowcharts were distributed to patients and their families to streamline the examination process. Additionally, a smart notification service was introduced to inform patients of their appointment and queue status, further optimizing the appointment process.

2.3.3 Workflow management and tracking in the ultrasound department

The system synchronizes all ultrasound orders across the hospital in real-time to the ultrasound reservation intelligent management system. After completing the appointment, patients arrive at the ultrasound department within their scheduled time slots. Patients can check in via a sign-in machine up to 20 minutes prior to their appointment. Once checked in, the system automatically imports the patient's information, such as name and examination site, and assigns the patient to the appropriate examination room. The queue status is displayed on a waiting screen for patients to track their place in line.

2.3.4 Data statistics

1) The system automatically tracks daily demand for ultrasound exams and the number of completed exams to minimize unfinished orders. 2) It calculates the average patient waiting time and the average time to complete orders, continuously improving service quality and patient satisfaction. 3) It also extracts and summarizes pre-exam waiting times, improving bed turnover rates and enhancing hospital workflow efficiency.

3. Application and Evaluation of the Ultrasound Intelligent Information Management System

3.1 Operation Design of the System

The ultrasound intelligent information management system acts as a seamless bridge between inpatient service centers, outpatient clinics, inpatient departments, and medical technology examinations, integrating various departments. Before implementing the system, the development team retrospectively analyzed historical data from May to October 2020, identifying existing problems. Based on this data and the real situations of the hospital, the system was designed to provide plans that aims to deepen the hospital's distinct strength of simplicity, efficiency, affordability and effectiveness, so as to optimize services, improve management, and provide high-quality value-based medical care to patients.

1) Appointment Slots Pool Setup: The survey data is organized on a weekly basis and shows periodic changes. On Mondays, the number of ultrasound orders is the highest, while the daily order volume exhibits a slow downward trend, with Sundays reflecting the lowest order volume of the week. However, the trend of variation among outpatient, inpatient, and green channel patients differs throughout the week. For outpatient patients, the daily ultrasound order volume remains relatively stable from Monday to Friday, peaking on Saturday and Sunday. In contrast, inpatient patients experience a continuous decline in ultrasound order volume from Monday to Sunday. The ultrasound orders for green channel patients remain relatively stable throughout the week. Based on this, the original number of slots in the appointment slots pool is set at 2,646, and a reasonable allocation is made according to Table 1 for the proportions of ultrasound orders among outpatient, inpatient, and green channel patients. Additionally, the ultrasound department has established a new work model of "fixed scheduling + flexible scheduling" based on the weekly variation trend, ensuring that daily minimum demands are met while appropriately increasing human resources on Tuesdays and Wednesdays according to the daily change trends.

Table 1. Composition of Ultrasound Orders in Our Hospital

Source of Orders	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Outpatient	19.74%	20.66%	22.30%	21.37%	23.38%	27.24%	22.05%
Inpatient	78.52%	77.36%	75.61%	76.53%	74.53%	62.70%	52.64%
Green Channel	1.74%	1.98%	2.10%	2.10%	2.10%	2.20%	2.20%

2) Refined Distribution of Appointment Slots: Data analysis showed that the peak time for outpatient ultrasound orders was between 8:26 and 8:30 a.m. each day. To reduce overcrowding and a shortage of available appointment slots for outpatient ultrasound patients, the outpatient

ultrasound work start time was shifted from 9:00 a.m. to 8:30 a.m. This adjustment also marked the end point for fasting-related ultrasound orders, which corresponds to a total demand time for fasting ultrasound orders of (2.03 ± 0.56) hours. Based on this, a flexible scheduling mechanism was established in the ultrasound department to reduce patient fasting waiting times. Detailed distribution of appointment slots for different time periods can be found in Table 2.

Table 2. Distribution of Appointment Slots by Time Period

Time Period	Slot Distribution
06:30-08:30	Fasting patients and inpatients over 80 years old (including fasting ones)
09:00-11:00	Slots are distributed between outpatients and inpatients at a ratio of 4:1
11:00-12:00	Slots are distributed between outpatients and inpatients at a ratio of 1:5
14:00-15:00	Slots are distributed between outpatients and inpatients at a ratio of 1:4
15:00-17:00	Slots are distributed between outpatients and inpatients at a ratio of 1:5

3) Refined Division of Ultrasound Department Personnel: In our hospital, the ultrasound department is divided into several specialized groups based on the expertise and type of procedures, including the abdominal group, superficial group, cardiac group, vascular group, intracavitary group, obstetrics and gynecology group, and interventional group. Based on data from the survey regarding the actual demand for ultrasound orders in different specialties and the time required, the number of examination rooms for each specialty group was adjusted. Specifically, one examination room was reduced from the obstetrics and gynecology group, while one room each was added to the cardiac group and superficial group. Doctors in the ultrasound department are categorized into four levels (I, II, III, and IV) according to their skill level, years of experience, and professional title. Detailed classification is shown in Table 3.

Table 3. Doctor Classification Standards

Doctor Level	Classification Standards
Resident Physician	Bachelor's degree or above, within 1 year of work experience
Attending Physician	Bachelor's degree, 1-5 years of experience; Master's degree, 1-3 years of experience
Associate Chief Physician	Bachelor's degree, 5-10 years of experience; Master's degree, 3-6 years of experience
Chief Physician	Bachelor's degree, ≥10 years of experience; Master's degree, ≥6 years of experience

4) Refined Patient Classification: to further promote a simplified, efficient, affordable and effective service model under the guidance of precision medicine, a patient classification system was developed. This system considers both the severity of the patient's condition and the urgency of their need for an ultrasound examination, while also respecting the patient's subjective preferences. The classification criteria were developed through a multi-department brainstorming process. Detailed patient classification guidelines are provided in Table 4.

The ultrasound intelligent information management system was completed and put into operation in November 2020. It was initially trialed for five months in the inpatient service center and ultrasound department of our hospital. During this period, based on feedback from various departments across the hospital, the information center continuously adjusted and refined the system, gradually optimizing its functionality. Currently, the system is running smoothly. The specific operational procedures are illustrated in Figure 1.

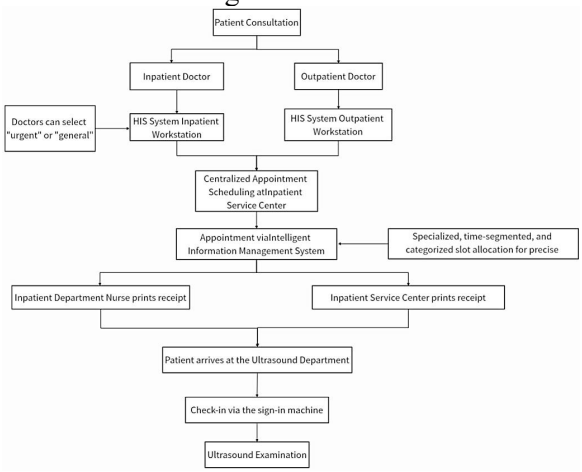

Figure 1. Workflow Diagram of the Ultrasound Intelligent Information System

Table 4. Patient Classification Guidelines

Patient Classification	Classification Standards	Completion Time	Doctor Level
I	1) Critical patients: In unstable condition that is rapidly changing and possibly life-threatening, with severe	Within 0.5 hours	Associate Chief or Chief Physician

	prognosis (e.g., acute confusion, multiple trauma); 2) Emergency patients, emergency surgery patients; 2) Difficult or referred patients		
II	1) Patients without immediate life-threatening signs but with potential for serious disease progression or complications requiring urgent diagnosis and treatment; 2) Day surgery patients; 3) Patients preparing for discharge	Within 6 hours	Attending or Associate Chief Physician
III	1) Stable patients with clear symptoms, but without immediate danger; 2) Elective surgery patients	Within 12 hours	Resident or Attending Physician
IV	1) General patients; 2) Scheduled surgery patients	Within 24 hours	Resident or Attending Physician

3.2 System Assurance

Collaborative management and quality control across multiple departments, as detailed in Table 5.

Table 5. Multi-Department Collaboration Management Responsibilities

Department	Key Management Points	Collaboration Points
Nursing Department	Satisfaction surveys	Design survey forms, conduct monthly real-time surveys, gather feedbacks, and optimize processes to improve the system
Information Department	System development and maintenance	Develop and maintain the intelligent information system, design the in-hospital navigation system
Inpatient Service Center	Process optimization	Distribute examination flowcharts, optimize signage, and provide smart reminders to patients about appointment and queue status
Ultrasound Department	Full resource utilization	Implement a “fixed + flexible shift arrangement” model based on historical data to adjust resources according to demand
Clinical Departments	Examination education	Educate patients on examination times, locations, and procedures, emphasizing the 20-minute-in-advance check-in requirement to avoid long waiting.
Medical Department	Quality control	Establish a quality evaluation system with detailed indicators, and conduct regular assessments of departments

3.3 Evaluation Indicators and Data Collection Methods

The evaluation compared the period before the ultrasound intelligent management system was implemented (from May to October 2020) with the period after its implementation (from November 2020 to March 2021). The metrics assessed included: the average time (h) taken to complete ultrasound orders, and the average daily number (units/parts) of completed ultrasound tasks. A convenience sampling method was used to select patients who completed ultrasound examinations in these periods: 3,559 patients before system implementation and 3,621 patients after. The following were compared between the two groups: average patient waiting time (min), average preoperative examination waiting time (h), and patient satisfaction. Average ultrasound order completion time is defined as the time difference between when the doctor places the order and when the ultrasound task is completed. Average daily task completion refers to the average number of parts or units completed by ultrasound technicians between 00:00 and 24:00 each day. Patient waiting time is the difference between the check-in time and the time the patient is called for their appointment. Average preoperative examination waiting time is the time interval from a surgical patient’s hospital admission to the start of their first examination. Data before the system implementation were extracted from the HIS system, check-in system, and ultrasound department machines, while data

after the system's implementation were retrieved from the ultrasound appointment intelligent management system. Patient satisfaction was surveyed by nurses from the inpatient service center asking both groups the single question "Are you satisfied with the ultrasound appointment and examination process?". Patients could choose either "Satisfied" or "Not Satisfied".

3.4 Statistical Methods

SPSS 22.0 was used for statistical analysis. The measurement data are expressed as mean ± standard deviation, and comparisons between the two groups were made using independent samples t-tests. Count data were expressed as frequency and percentage, and comparisons between groups were made using the chi-square test. A P-value <0.05 was considered statistically significant.

4. Results

4.1 Comparison of Ultrasound Order Completion Before and After System Implementation

The average time to complete ultrasound orders decreased from (71.36 ± 12.62) hours before the implementation of the system to (19.65 ± 3.25) hours after. The average daily task completion increased from (1652.38 ± 102.36) units before the implementation of the system to (2385.46 ± 126.47) units after.

4.2 Comparison of Patient Waiting Times Before and After System Implementation

The results show that after the implementation of the ultrasound appointment intelligent management system, the average patient waiting time decreased to (21.56 ± 4.62) minutes, which is significantly lower than the pre-implementation time of (42.36 ± 8.69) minutes. The average preoperative examination waiting time decreased from (27.02 ± 8.85) hours to (4.84 ± 0.97) hours. The differences between the groups were statistically significant (P < 0.05), as detailed in Table 6.

Table 6. Comparison of Patient Waiting Time Before and After the Implementation of Ultrasound Appointment Intelligent Management System (χ±s)

Group	Number of Patients	Average Patient Waiting Time (min)	Average Preoperative Waiting Time (h)
Before	3559	42.36 ± 8.69	27.02 ± 8.85
After	3621	21.56 ± 4.62	4.84 ± 1.97
t-value		145.24	147.15
P-value		0.001	0.002

4.3 Comparison of Patient Satisfaction Before and After the Implementation of the Ultrasound Intelligent Management System

According to the statistical results, the patient satisfaction rate after the implementation of the ultrasound intelligent management system increased to 91.26%, which is significantly higher than the 84.09% before the system was implemented. The difference between the two groups was statistically significant (P < 0.05), as shown in Table 7.

Table 7. Comparison of Patient Satisfaction before and after the implementation of Ultrasound Appointment Intelligent Management System [n(%)]

Group	Total Number	Satisfied Patients (%)	Dissatisfied Patients (%)
Before	3559	3045 (84.09%)	576 (15.91%)
After	3621	3248 (91.26%)	311 (8.74%)
x^2 value			85.191
P-value			0.001

5. Discussion

In the healthcare service system, medical examinations play a crucial role. As a supplementary clinical service, medical examinations assist physicians in quickly and effectively determining patients' conditions and are pivotal for disease diagnosis[5]. Ultrasound, in particular, is increasingly in demand due to its convenience, affordability, and quick reporting time. As a result, it has become one of the busiest areas in hospitals with high patient volumes[6]. However, this also brings challenges such as heavy workloads for ultrasound staff, intense competition for appointments, and overcrowded, chaotic waiting areas[7]. Patients often experience long waiting time and wasted time, which reduces their satisfaction and can lead to conflicts between patients and healthcare providers. Therefore, optimizing the workflow for ultrasound patients is critical. In line with directives from the National Health Commission, hospitals in China are encouraged to leverage new technologies such as "Internet+", AI, and big data during the "14th Five-Year Plan" to improve hospital

information systems, streamline processes, carry out precise supervision and systematic design, ensure efficient and safe healthcare services, and reduce conflicts between patients and healthcare providers[8,9].

5.1 Enhancing Diagnostic Efficiency through Internet Technology Integration

The ultrasound intelligent information management system integrates the entire process from the issuance of medical orders to the completion of ultrasound examinations, addressing the previously disjointed systems at various stages. By incorporating the intelligent management system into each step of the ultrasound examination process—connecting outpatient and inpatient doctors, inpatient service centers, ultrasound departments, and technicians—the workflow is optimized, improving overall efficiency and enhancing patient experiences. After the implementation of the ultrasound intelligent management system, the time to complete new ultrasound orders decreased from 71.36 hours to 19.65 hours, and the average daily completed workload increased from 1,652.38 to 2,385.46 examination parts, demonstrating a significant improvement in diagnostic efficiency and medical equipment utilization.

5.2 Precision Appointments Improve Patient Flow and Save Time

The intelligent ultrasound information system's scheduling and management, led by the inpatient service center, enables precise appointment setting based on patient preferences and actual needs. This system addresses issues such as missed appointments and overcrowding. Results show that the average patient waiting time was reduced from 42.36 minutes to 21.56 minutes, and the average preoperative examination waiting time dropped from 27 hours to 4 hours. These improvements enhance inpatient turnover rates and improve service quality, reinforcing the hospital's brand image.

5.3 Patient-Centered Approach Enhances Satisfaction

Our hospital's service philosophy has always been centered on prioritizing patient needs. The primary goal of developing the intelligent information management system was to resolve issues such as difficulties in making appointments, long waiting times, and poor patient experiences. Through optimized workflows and coordinated efforts across departments, patient satisfaction increased from 84.09% to 91.26% after implementing the intelligent system.

6. Conclusion

The intelligent information management system has effectively standardized the medical examination process by leveraging information technology. It optimizes examination service processes, improves diagnostic efficiency and equipment utilization, and enhances patient satisfaction by reducing waiting time and improving the overall healthcare experience. However, there are two aspects of the current system that require improvement: 1) The inpatient service center could further refine appointment scheduling based on the patient's examination purpose and the severity of their condition. For instance, pink could indicate reserved VIP slots, blue for inpatient appointments, purple for outpatient appointments, red for critical conditions, yellow for subacute conditions, and green for general conditions. 2) It is suggested that the appointment system be extended to allow longer booking periods, such as enabling pregnant patients to schedule their next prenatal exam during their current visit. Although the intelligent information system has improved efficiency, it is essential to prevent system failures from disrupting normal medical operations. Therefore, an emergency response plan should be established and refined to effectively manage the adverse effects of system malfunctions. During system operation, issues such as duplicate orders, patients booking multiple slots, and missed appointments frequently occur, leading to resource waste. Whether a blacklist system can be implemented to address this issue remains a subject for further discussion.

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