A Multi-platform Information Management System of the Total Life Cycle for Medical Equipment

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ABSTRACT

Objective: To establish a total life cycle information management system for medical equipment based on our hospital's actual situation.

Methods: Per the definition of the total life cycle for the particular item of medical equipment, the function modules were designed and distributed according to different staff postings and then implemented on the WeChat public account-a series of API and services to develop custom features, a mobile app, and a computer web browser.

Results: After implementation, the system can cover a series of management stages of the entire life cycle for medical equipment and the information exchanged among various stages. The relevant staff in different posts can operate the medical equipment management information on any of the three platforms.

Conclusion: The improvement and efficiency aid staff in various settings in managing medical equipment and medical behaviors and patient safety is increased..

Keywords – *Medical equipment, Information system, Multi-platform.*

INTRODUCTION

Large-scale hospitals have a wide variety of scientific and medical equipment which requires efficient information management systems. Traditional management methods cannot cover and connect the devices at various stages effectively while they are in hospital circulation. Traditional medical device management methods have the following drawbacks**:**

- Data are not interconnected. There is an information island between the functional modules of medical

device information management because each function module has different application sequences, different software vendor solutions, and different technical levels in different periods. There is also a failure of unification in planning and construction leading to differences in system architecture, data formats, protocol standards, and network environment among functional modules. The system function modules are independent of each other, making it impossible to implement or partially implement data sharing.

- Data management is not integrated. Traditional management methods focus on bidding procurement, contract management, installation and acceptance, fixed asset files, maintenance and measurement, and scrapping. Therefore, traditional management systems are generally established in these areas. However, for planning and budgeting, market research and inquiry, usage evaluation, routine maintenance, inspections and preventive maintenance, adverse event monitoring and recalls are usually underestimated leading to a relative lack of management information modules for the devices.

- The data processing error rate is high. As data in device management modules cannot share or partially share information, and if the device management information among the modules is inconsistent, data will not be accurately provided. For example, a device in a Chinese hospital management system has four ledgers: (1) Financial management department general ledger; (2) Fixed assets management department ledger; (3) Procurement ledger; and (4) Medical equipment maintenance unit account. Since the four ledgers' management information is not entirely interconnected, it may cause data discrepancies if login is on different systems and may also cause management information inconsistency with the physical object. The management information of the equipment may be lost due to poor management, mostly when recorded in paper format.

- Data processing is not timely. For traditional equipment, information management at various stages is stored in different system modules and storage media, such as Client/Server architecture mode database, Excel spreadsheet, or paper files. Accessing and updating real-time information on devices requires operating on different systems at different times. Also, equipment maintenance, inspections, measurements, etc., need to be executed regularly, but traditional management methods cannot achieve dynamic setting plans and automatic expiration reminders effectively.

- Data statistics and reporting functions are imperfect. The statistical data of various devices are fuzzy, and muti-latitude measurement and comparison data are scarce. Monitoring of the running status of equipment is not clear or intuitive.

With the needs of modernization and the intelligent refinement development of hospitals and the need to review China's 3A grade and Healthcare Information and Management Systems Society (HIMMS), medical equipment management urgently needs an integrated information management system to break the barriers among the original modules and realize information interconnection among modules and systems. The total product life cycle (TPLC) method is a holistic approach that considers all of the steps and processes in the evolution of a device from conception to obsolescence and integrates information and knowledge across pre-market and post-market activities. David W. Feigal proposed that TPLC of a medical product included phases such as concept, prototype, preclinical, clinical, manufacturing, marketing, commercial use, and obsolescence. Combining the perspectives from different science disciplines was widely accepted in the medical devices field.[1] According to the characteristics of equipment management in China's medical institutions and the medical technology management of our hospital, we divided the total life cycle information management system for medical equipment (TLCIMSME) in the hospital into the following stages: (1) Equipment demand, planning, and budget as the starting point; (2) Market research, bidding procurement, and contract management as the initial stage of equipment life; (3) Receiving, installation, and acceptance, personnel training, fixed asset file management, use management, application evaluation, daily maintenance, inspection and preventive maintenance, metering maintenance, and monitoring and analysis of adverse events are used as application stages; and (4) Recalls, scraps, and updates as the later stages. According to the four stages, the medical equipment life cycle information management system should be fully covered and all stages can be interconnected. Each user of the system can log in to the system to manage medical equipment information at any time or place and get statistics and report information intuitively.

METHODS

The TLCIMSME had to be designed to interconnect functional modules and other relevant information

systems in the hospital. The TLCIMSME was designed and implemented from multiple perspectives, including logical general view, hierarchical system structure, life cycle timing diagram, functional module diagram, and three-platform operation diagram.

CONNECTING MEDICAL EQUIPMENT MANAGEMENT SYSTEMS AND OTHER RELATED INFORMATION SYSTEMS IN THE HOSPITAL

The information systems related with medical equipment management system in our hospital have are Office Automation (OA) system, medical equipment preliminary marketing research system, third-party tender evaluation system, intensive care system, Laboratory Information System (LIS, Picture Archiving and Communication Systems [PACS]), outpatient and inpatient electronic medical record system, fixed asset management system and finance system. The medical equipment information management system should interconnect with these related systems (Figure 1).
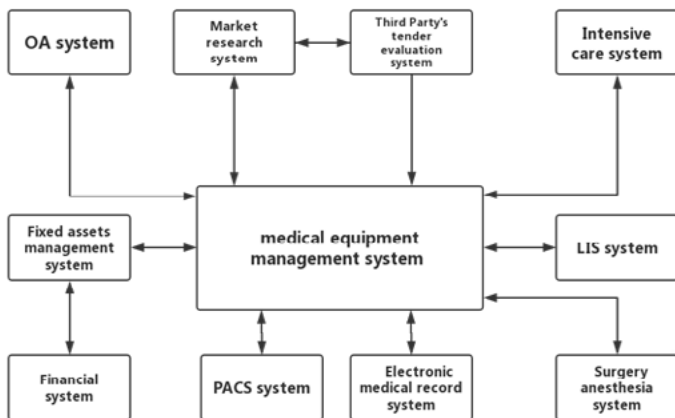

FIGURE 1. Connecting medical equipment management systems and other related information systems in the hospital.

MEDICAL EQUIPMENT MANAGEMENT SYSTEM LAYERED STRUCTURE

1. User interface layer. This layer, containing all user pages, is responsible for interacting with the outside world, receives business requests from the Application Programming Interface (API), forwards the request to

the business logic layer for processing, and returns the final result.

2. Business logic layer. This layer is responsible for processing requests submitted by users. The requests are submitted to the data access layer and the results are passed back to the user interface layer. Windows Communication Foundation (WCF) is used to pass messages between the user interface layer and the business logic layer.

3. Data access layer. This is a bridge between the business logic layer and the database. Pass the request to the database and return the results to the business logic layer[2] (Figure 2).
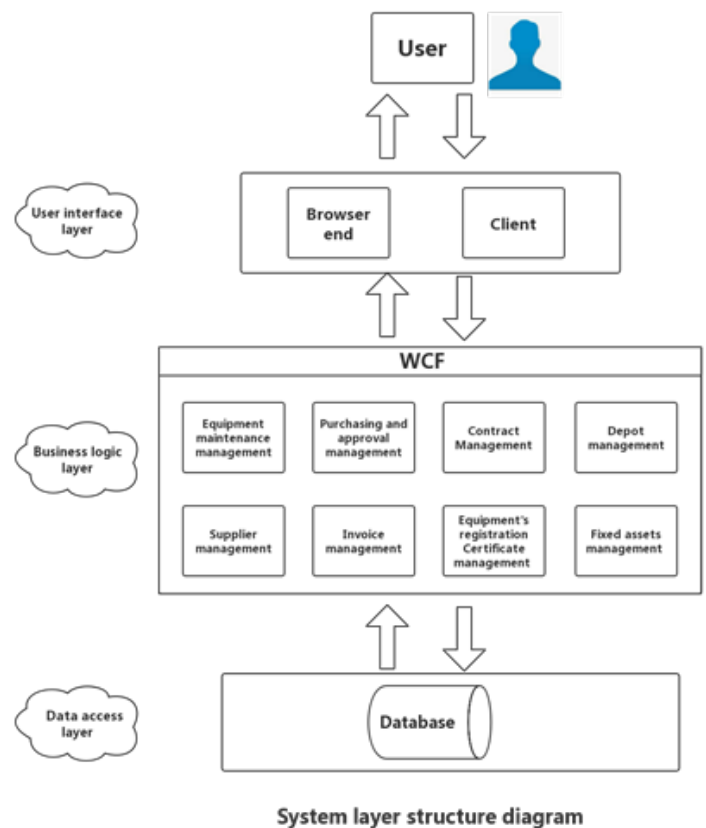

System layer structure diagram

FIGURE 2. Medical equipment management system layered structure.

FUNCTIONAL ORGANIZATION STRUCTURE

1. The starting point of the lifeline. When the medical equipment demand departments fill in the application form and submit the demands, a serial number

is generated to track the equipment. Information such as the application department, equipment name, quantity, budget, and basic equipment configuration and functional requirements are transmitted to the tendering stage.

2. Initial stage of equipment. The hospital generally entrusts a third-party bidding company to tender according to a hospital's needs (refer to the provisions of the national bidding documents) and determines the bid supplier, equipment brand, model, quantity, and price. This information is transmitted to the hospital procurement stage. Our hospital and the winning supplier sign the purchase and sale contract following the winning bid information.

3. Equipment application stage. Then the clinical medical engineer, the manufacturer engineer, department staff, and the fixed asset manager install, test, and accept the medical equipment together according to the contract. After acceptance, the fixed asset administrator will file the equipment information into the assets system. After training medical engineers and equipment operators, the equipment can be used. Clinical medical engineers then conduct risk assessment of the equipment in the system, develop preventive maintenance measures and content and cycle, inspection plans and daily maintenance plans and later execution, additional measurement plans and a measurement equipment file are prepared for the metering equipment and executed later. If the equipment fails, the equipment user can initiate application by two-dimensional code of the fixed assets which is created during the acceptance. Medical engineers also receive the repair information through the system to execute and fill in the maintenance report form. When an adverse event occurs, both the equipment users and the clinical engineers can report through the system, and the fixed asset administrator also counts the medical device by scanning the two-dimensional code.

4. Late stage of the equipment. When a medical device recall occurs, all the models and batch numbers of the equipment involved are queried in the system, and the recall procedure is executed. When the medical device is scrapped, the device user, the fixed asset administrator, and the clinical medical engineer operate and

record the event together in the system. When updating the equipment, the system can be used to check and analyze the medical equipment repair, inspection, and maintenance data records and determine whether the equipment needs to be updated. In this way, a medical device completes the closed-loop management of the entire life cycle[3] (Figure 3).
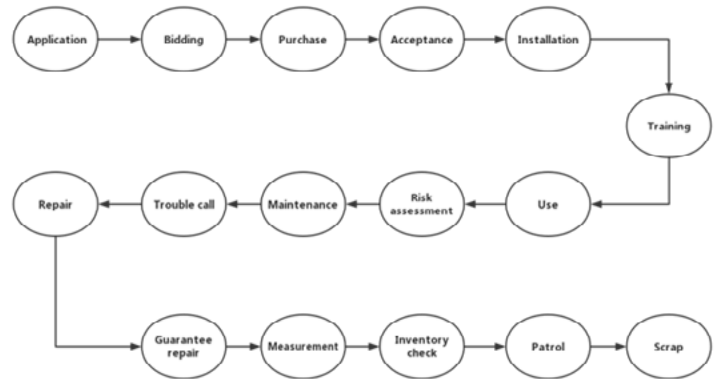

FIGURE 3. Equipment lifeline sequence diagram.

PERSONNEL POSITIONS FOR MEDICAL EQUIPMENT MANAGEMENT

Medical equipment personnel positions are divided into equipment section chiefs, equipment operators, purchasers, fixed asset administrators, gaugers, and clinical medical engineers[4] (Figure 4). The medical equipment department chief mainly obtains statistics and reports on various types of equipment management information from a macroscopic perspective. The requirements include statistics on the hospital's entire assets, statistics on the asset distribution in various hospital departments, the proportion of risk levels and another 16 asset statistical analysis charts such as usage rate and asset brand statistics.

The equipment operators use the system for routine maintenance and inquiry to repair.

The purchaser mainly uses the procurement management module, including summary demanding application and approvals, procurement demonstration and plan, entrusting the third-party tendering company, signing purchase and sales contracts and conducting contract management and invoice management.

The fixed asset manager is responsible for equipment acceptance, documentation, asset label printing, asset allocation, borrowing, inventory, and scrapping.

The gauger is responsible for the metering of medical equipment in the hospital according to annual plans, including compiling the inventory of the metering instruments, drawing up the annual metering plan for the instruments, recording the metering files, and ensuring consistency between accounting books and physical inventory.

Clinical medical engineers utilize three modules: repair, maintenance, and quality control management.[5] Functions of the repair module include online receipt of repair orders, online dispatch, repair stations, online work orders, online approval, warranty management, equipment faults library, spare parts inventory management, and maintenance invoice management. The maintenance module includes inspection and preventive maintenance, as well as daily maintenance. The quality control management module includes medical device risk assessment, medical device performance testing and planning, measurement management, and adverse event management. After logging on to the system, personnel in different positions can set the corresponding function modules' operation rights, and the information between each function module can be interconnected.

THREE PLATFORM TERMINALS

The system makes full use of the popular mobile app technology and computer network technology to provide three kinds of platform for user interaction: a public WeChat account, a mobile app, and PC web pages.[6] The underlying data of the three platforms are interactive and interoperable.

Public WeChat Account

WeChat is a multi-purpose messaging and social networking app developed by Tencent. It has been called China's "app for everything" and a "Super App" because of a wide range of functions and platforms. Almost every Chinese person has a WeChat account.[7] WeChat supports developers registering a public account, which can interact with users and provide them with services. This system has developed a public account named "gzfezx" as the interaction ports and equipment operators can register user account through the public account and then scan two-dimensional code on the assets to record daily maintenance information and submit a repair application of medical equipment.

Mobile App

A mobile app is a computer program designed to run on a mobile device such as a phone/tablet or watch. The
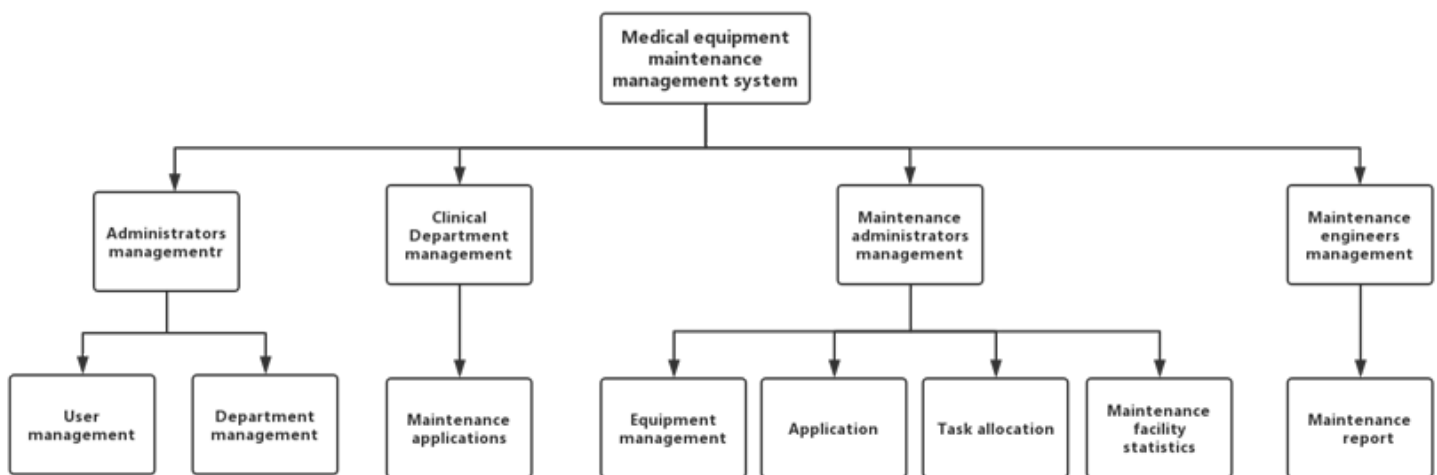

FIGURE 4. The personnel positions for medical equipment management.

system is specially developed named Medical Equipment Information System⬚MEIS⬚App. Equipment operators, fixed asset managers, gaugers, clinical medical engineers, and equipment chiefs can log in on the MEIS App to implement the modules in their rights distributed. It will not be detailed here.

PC Web Pages

The PC web pages adopt the traditional browser/server⬚B/S⬚based architecture mode, and the equipment asset manager, metering staff, equipment chief, and clinical medical engineer can login through Uniform Resource Locator⬚URL⬚to access the web server for medical device management information interaction. After login on the URL, modules can be found based on their right, and it will not be expanded. The configuration environment for the PC Web Pages is as follows:

- Database: MySQL database: simple operation, friendly interface, multi-user database management system;
- Development language: PHP language: cross-platform, efficient execution, supports almost all popular databases and operating systems;

- Server operating system: LINUX operating system: occupying small resources, safe and stable.

IMPLEMENTATION RESULTS

Medical Device Life Cycle Line

Selecting either device and clicking allows the user to display the events of the device by time axis. The events include the installation date, the date of repair, routine maintenance, inspections, preventive maintenance date, metering date, and transfer cases. Clicking on each item expands the details of each item. Double-clicking the device name queries the fixed asset details, device pictures and graphically displaying the medical device overview, including normal usage, number of repairs, maintenance costs, and maintenance hours. The users can also analyze maintenance, quality control analysis, and benefits analysis for the device selected.

Equipment Repair Process

The clinical department's equipment manager scans the Quick Response⬚QR⬚code of asset management using
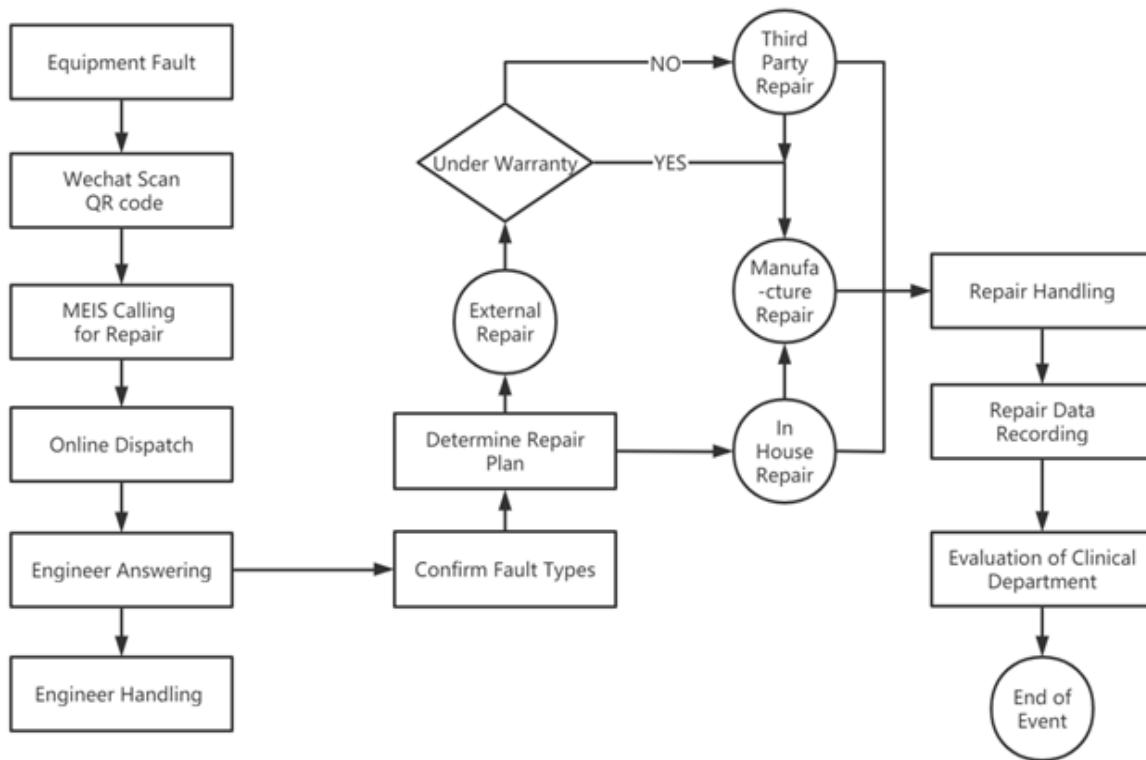

FIGURE 5. Equipment repair process.

the smartphone app to apply for repair which is transmitted to the server. The team leader who is responsible for repair dispatches engineers according assigned jobs. The engineers will judge the equipment fault type and then carry out an independent repair or inform the manufacturer or a third-party company to repair as needed. After the maintenance is completed, the engineers fill in the maintenance report, the related clinical department scores the maintenance situation, and then finally, the process ends (Figure 5).

Purchasing Module

This management module includes purchase application, purchase review, procurement plan, equipment selection demonstration, procurement announcement, negotiation record, contract management, acceptance, installation, and invoice management. Clicking on each item to allows access specific information. Other modules include maintenance, quality control, maintenance, adverse event management, metering management and equipment benefit analysis. The system also has a distribution map for life support devices that can monitor status such as the amount, type, distribution, fault condition, and intact rate of equipment in the hospital.

THREE INTERFACING PLATFORMS

Public WeChat Account

This port is mainly provided for clinical departments. After clinical department equipment managers log in, the system automatically matches all the department's devices to their accounts. The equipment administrator can perform daily maintenance or submit repair applications for all department equipment by scanning a code. For equipment with a borrowing time of 3 days or less, the borrower can operate through the temporary maintenance menu. For equipment that is not in the department when scanning the code, instructions are given for borrowing or asset transfer procedures before maintenance. Under this interface the system can remind the user of the number of daily maintenance orders. After clicking the reminder, the user can check the detailed information and carry out maintenance. The equipment administrator can also check the number of equipment items in the department that are under repair. Also, the equipment administrator can

also perform asset transfer and repair applications after logging in and can perform daily inspections and view inspection records and statistical analysis.

Mobile Phone App

This app supports both Android and Apple operating systems. This port is intended for use by clinical engineers, fixed asset managers, gaugers, and equipment management chiefs. After the clinical engineers log in, they can check the maintenance status of all clinical departments. They can inspect the equipment according to departments. They can also perform preventive maintenance and produce reports in the system for the equipment according to the plan. The clinical engineers can process the repair applications initiated by the clinical departments and record at this interface; the metering staff can perform metering and performance testing management after logging in; the common items can be statistically graphed. Asset administrators can also perform inventory management on the devices with this app.

PC Web Pages

PC Web Pages allow clinical engineers, fixed assets administrators, metering staff, and medical equipment departments to operate and achieve detailed statistics and graphical reports. The computer maintenance and management module has three menus: routine maintenance, inspection, and preventive maintenance. The routine maintenance menu can be queried according to the device name, type of care, the use of the department and templates of routine maintenance can also be set up. The inspection menu can set the inspection task and remind the inspection time. After an inspection, an electronic report form is generated and archived. The preventive maintenance menu can alert devices that are due for expiration, set up preventive maintenance plans, and execute and set up a personalized template and match. The system can also provide abundant graphical reporting features such as the distribution of equipment failure types,[8] statistics of value of equipment assets over time, and the total number of repairs according to the department.

CONCLUSION

The MEIS system comprehensively utilizes the public WeChat public account the mobile phone app and web pages based on the B/S structure to modularize the design of the medical device life cycle, and the work-flow moves through various staff positions in the equipment department to realize optimal equipment management and interconnect information resources in multiple modules allowing users to share and break the information resources "island" situation. Interconnection between various management modules mutual authentication information ensures accurate information is extracted. The management data also updates to the cloud server, the security of device management information is guaranteed, and the risk of information loss is greatly reduced.

The system uses the two-dimensional code-fixed asset tag as the interactive medium between the staff and the medical devices. All the three platforms can scan the fixed asset two-dimensional code to read and write the device management information in real time.

The system can output a variety of equipment management information statistical charts, including statistical analysis functions of assets from 16 different angles, including value, use department, equipment risk level, normal usage rate, and statistical analysis by asset brand. Also, 23 different statistical analysis functions are available, including maintenance and maintenance costs, fault type, the type of maintenance, repair application departments distribution, Top 20 clinical departments by the number of malfunction statistics, graphical daily maintenance, inspection and preventive maintenance profiles by department, and by type of equipment. The system also enables cost analysis of large medical devices and provides analytical reports and statistical analysis of medical device adverse events and metrology.

DISCUSSION

The MEIS system's promotion and use standardize the workflow in the daily maintenance, inspection, and preventive maintenance of medical equipment. The system platforms can be planned in advance and then implemented according to the plan to ensure the workflow's smooth progress. Simultaneously, the devices can be effectively monitored in real-time on three different platforms to ensure the quantity of maintenance.

The promotion of the MEIS systems has improved user interaction and experience. The combination of the QR code and smartphones enables the user to operate through the scan code login platforms under the 4G mobile network and the WIFI network, which greatly assists the users of each role.

The traditional medical equipment management system is based on a fixed asset management system and a medical equipment maintenance system, paper processing, and Excel form management for the initial stage, application stage, and final medical equipment stage. The MEIS system realizes electronic management of data at each stage of the life cycle, which aligns with the hospital's paperless development process and HIMMS review requirements.

Of course, there are still some issues at present. For example, if the manufacturer does not provide a standardized, unified data interface such as a Digital Imaging and Communications in Medicine (DICOM) protocol port, it will make the device dynamic data collection difficult. Thus, the user cannot analyze the benefit of a single medical device effectively. The hospital environment is complex, equipment is scattered, the network communication conditions can be poor, and the hospital networking infrastructure can be weak. Also, the overall program cost can be high which could delay the use of the MEIS system. However, with the hospital's intelligent development needs, these problems can be solved gradually.

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