ORIGINAL RESEARCH

Analysis of the Role of Informatization, Based on Data Analyses, in Hospitals to Improve Hospital Management

Zhi Yao, MD; Yifeng Guo, MD; Min Li, MD

ABSTRACT

Context • The informatization of the medical system is increasingly closely linked with people's daily life. As people pay more and more attention to the quality of life, it's very necessary to closely integrate the management information and clinical information systems to promote the steady improvement of a hospital's service level. In the process of modernization Chinese hospitals, comprehensive promotion of hospital informatization is very important.

Objective • The study intended to examine the role in China of informatization for hospital management, analyze its shortcomings in that role, and explore its role based on an analysis of hospital data, and propose effective measures to continuously improve the level of informatization, promote the steady improvement of hospital management and services, and fully demonstrate the application advantages of information construction.

Design • The research team discussed: (1) China's informatization, including hospitals' roles, current informatization, the information community, and medical and information-technology (IT) staff; (2) methods of analysis, including system composition, theoretical basis, definition of the problem as well as data evaluation, collection, processing, mining and model evaluation and knowledge presentation; (3) the procedures the team followed to perform a case study, including types of hospital data and the process framework, and (4) the study's results from informatization based on data analysis, including satisfaction surveys for outpatients, inpatients, and medical staff.

Setting • The study took place at Nantong First People's Hospital in Jiangsu Province in Nantong, China.

Conclusions • In the process of hospital management, it's imperative to strengthen hospital informatization, which can continuously strengthen a hospital's service capacity, ensure good-quality medical service, further improve the discipline of the database construction, enhance the satisfaction of employees and patients, and achieve a high-quality and benign development for the hospital (*Altern Ther Health Med.* 2023;29(3):172-185).

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In an era of digital economies, informatization has gradually become an important issue in the process of continuous reform of hospitals, to improve their overall levels. The focus of informatization in the medical industry is the construction of data-management systems in hospitals, and the degree of informatization can directly affect the development of a country's medical industry. Hospital informatization can provide a large amount of data that can be the basis for national health management and can ensure the connectivity and accuracy of health information.

The study intended to examine the role in China of informatization for hospital management, analyze its shortcomings in that role, and explore its role based on an analysis of hospital data, and propose effective measures to continuously improve the level of informatization, promote the steady improvement of hospital management and services, and fully demonstrate the application advantages of information construction.

China's Informatization Development

Research in China on informatization began in the 1980s. Although the hospitals started the informatization late compared to USA it has developed very rapidly based on the government's encouragement and support of the hospitals and its support and promotion of national policies.

At the end of 2019, the emergence of the novel coronavirus triggered a large-scale global crisis. The epidemic increased the requirements for scientific development; data reporting; analysis and statistical evaluations; isolation, prevention, and control; early risk warning; and information sharing at home and abroad. All of these needs strongly demonstrated the importance of hospital informatization.

In response to this major, infectious epidemic, hospital informatization provided an important emergency guarantee and solution for public health. In the coming decades, hospital informatization will become a key area of development in China. To achieve high-quality development, the health system must rely on help from hospital informatization.

In the process of public-hospital reform, medical information services are not only the most efficient way to strengthen the process but also a crucial component.[2] Medical information services can have a direct impact on the progress of China's medical reform. Public hospitals are the main component of China's medical system, and information reform is an important subject on which the government will focus attention during the period of the Fourteenth Five Year Plan.

On June 4, 2021, the General Office of the State Council issued the *Opinions on Promoting the High Quality Development of Public Hospitals,* which put forward new requirements for promoting the high-quality development of public hospitals and better meeting of the people's growing demands for medical and health services. Operation of a hospital with high quality has four aspects: structure adjustment, efficiency increase, quality improvement, and cost control.

Based on the current information environment in China, the General Office of the State Council pointed out that the construction of public hospitals must comply with three principles to establish a new system of public hospitals in China: (1) comprehensive improvement of the overall quality of China's medical service industry, (2) a commitment to building national and provincial, advancedgeneral hospitals and specialized hospitals, and (3) the creation and improvement of a system for major epidemic prevention and control, with urban public hospitals in the leading role and county-level public hospitals as the focus.[3]

To promote the informatization of public hospitals, China has formulated a system of comprehensive standards, to improve the current systemsand finally realize a top-level design for medical informatization nationally by strictly managing the informatization of public hospitals from the perspective of professional data standards, system-function improvements, and information-technology specifications.

This effort has established a database for a national medical-information network, provided information-technology (IT) support, and strengthened the comprehensive application of informatization in clinical practice. IT and traditional, clinical medical activities can operate together to ensure that public hospitals provide more standardized medical services for people.

After more than 40 years of informatization, hospitals in China have now built a comprehensive hospital management information system (MIS) and have entered the stage of intelligent application of clinical diagnosis and treatment data. Hospital informatization not only facilitates paperless and standardized clinical management and administrative business but also contributes to improving the quality of doctors' diagnoses and treatment services and patients' medical experiences.[4]

Due to the building of China's medical information platform, hospitals have been able to provide more authoritative and high-quality services for patients, provide a strong guarantee for the improvement of doctor-patient satisfaction and the improvement of the medical-service environment, and play a role in boosting the healthy China strategy that the Chinese government formulated.[5] In the context of the rapid development of international information technology, China's medical industry needs to focus on deepening reform in the information field.

The overall improvement of the informatization of domestic hospitals, especially public hospitals, has become the top priority at this stage. To establish a professional and efficient information-based medical system nationwide and realize information transparency and data sharing, it's necessary to consolidate the construction foundation, ensure information security, and improve data quality, which is the correct planning direction for the sustainable development of China's medical industry.

China's policy for medical informatization has gradually and smoothly transitioned to accelerated development, which has now turned into a new strategic stage of active and comprehensive promotion.

Hospitals' Roles

Hospital management is a management activity for the hospital economy, which can maximize income and minimize expenditures, improve their social and economic benefits, test and measure the hospital's management level, and promote the improvement of the hospital-management system.

Hospitals must integrate informatization into people's daily medical treatments and deeply influence the reform and development of China's medical industry. Only by accelerating the overall level of informatization of public hospitals at all levels can hospital informatization become an important part of China's future development.

Each hospital in a medical system should adhere to the developmental concepts of data standardization, service innovation, information accuracy, and quality priority and combine their information-related policies to create an advanced information system within each hospital that can interact with a secure network architecture between hospitals.

Hospitals' information infrastructures—management systems, software systems, hardware systems, medical equipment, and other aspects—must improve. For example, hospitals need to formulate and strictly implement a management information system (MIS) and be able to adjust it reasonably at any time according to national policies. In addition, the transformation of the regular interface between multiple software programs can provide a strong guarantee for the information platform's degree of integration. Hospitals also need to update medical equipment regularly to visualize and digitize inspection and test contents of laboratory results.

A fully functional health information system (HIS) is a criterion that developed countries can use to measure whether a hospital's comprehensive strength is excellent. Its existence is also widely recognized as the basic condition for determining whether a hospital has an internationally advanced level of medical care andtechnology and whether it holds a leading position in the industry.[1]

Information technology is important to the development of the medical industry; it can support the steady improvement of medical technology, the continuous optimization of medical services, the efficient operation of medical activities, and the building of modern hospitals through resource sharing and information integration.

At the same time, it's necessary to strengthen the clinical business and specialty development of public hospitals, create innovative medical-service methods, and enhance the data-processing and information-support capabilities of public hospitals. Public hospitals should strengthen their information construction, give full play to the advantages of data-based intelligence, and focus on the construction of intelligent management systems, intelligent service systems, electronic medical record (EMR) systems, and other information systems.

To improve patients' satisfaction with the medical system, hospitals should use: (1) cloud computing; (2) big data—Large amounts of unstructured or structured data from various sources; (3) the Internet of Things—A huge network formed by combining various information sensing devices with the network, enabling the interconnection of people, machines and things at any time and any place; (4) fifth generation (5G) mobile communications, and (5) other information technologies.

In addition, public hospitals should encourage and promote the establishment of smart hospitals to allow wider use of Internet-based online consultation and telemedicine. The intelligent, medical, wearable devices and auxiliary diagnosis-and-treatment systems that some public hospitals have adopted can greatly improve the efficiency of diagnosis and treatment at hospitals. They should be the reform focus of public hospitals in the next era and promoted nationwide.

Current Informatization

At present, China's hospital-management informatization has gradually transitioned from initial informatization to integrated informatization. The state requires hospitals to constantly consolidate the development foundation of hospital informatization in the process of medical reform, which can realize the comprehensive development of hospitals according to the requirements and guidance of national policies.[12]

Hospitals should put the actual needs of patients first to truly achieve the purpose of benefiting the people. At the same time, it's necessary for the hospital to formulate strategic objectives that conformity its own development direction, take the development of hospital informatization as a driving force, and adhere to the continuous improvement of medical-service quality.[13]

Figure 1. Current Methods of Hospital Informatization in China

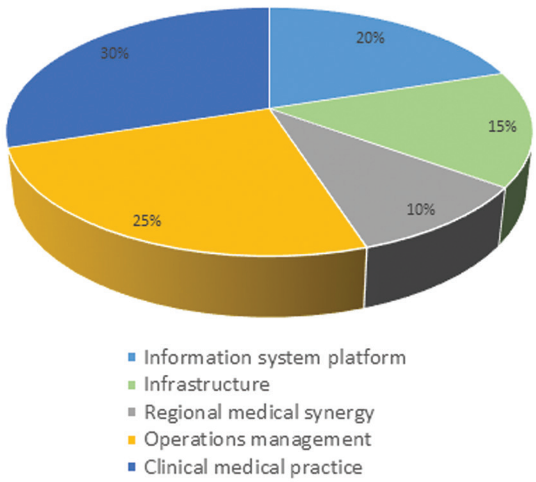
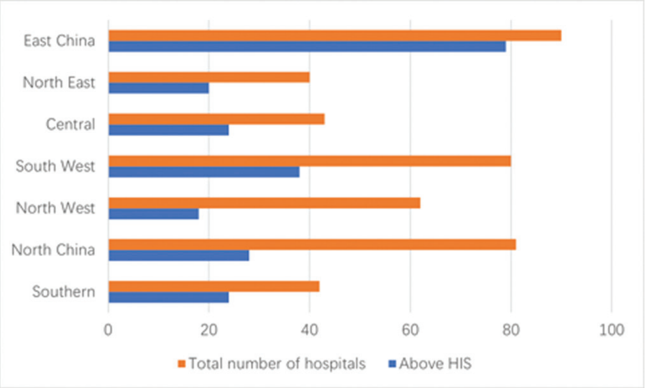


Figure 2. Regional Differences in Managerial Hospital Informatization in China.[7] The blue bars show the total number of hospitals in a region, and the orange bars show the number that have HIS.



Abbreviations: HIS, health information system

The development of an hospital information system is no longer limited to information transmission in a particular year but has gradually become part of clinical practice, which has changed the previous digital hospital construction from charge centered to patient centered. At the same time, the understanding of hospital construction and digital reform has gradually improved, making the construction of functional hospitals gradually valued.[6] Figure 1 shows the current governmental areas of emphasis for hospital informatization in China: (1) information system platforms (20%), (2) infrastructure (15%), (3) regional medical synergy (10%), (4) operations management (25%), and (5) clinical medical practice (30%).

Figure 2 shows the differences in hospital informatization in different regions of the country. At present, the informatization in hospitals in China is about 35%, and the hospital informatization in East China has reached about 80%; however, informatization in the northwest region has lagged behind other regions at about 20%.[7]

Table 1. Informatization of Medical Institutions in China

Hospital Grade	Total Hospitals n	Hospitals with HIS n (%)
Provincial and ministerial hospitals	932	84
Municipal hospitals	3085	40
County and district hospitals	11915	34
Subdistrict township hospitals	The township hospitals in economically developed areas are generally managed by computers	

Abbreviations: HIS, health information system.

In China's current process of informatization, 80% of secondary hospitals and all tertiary hospitals have carried out informatization, and the current informatization is mainly based on the HIS system.[8] The HIS system has been continuously recognized bycurrent medical development and construction.

Doctors and nurses have gradually become accustomed to the new system, and the current system has gradually transitioned to the intelligent handheld terminal.[9] The clinical information system (CIS) is gradually deepening optimizing in content. The picture archiving and communication system (PACS), radiology information system (RIS) and other systems have also gradually become mature. Hospital staff widely use electronic medical records (EMRs) as well as the whole surgical anesthesia and the corresponding intensive care systems.[10]

Since 2007, the whole digital hospital integration in China has gradually improved, but many problems and deficiencies still exist in many places, and the current development is slow.[11] Table 1 shows the informatization of medical institutions in China. Of the 932 provincial and ministerial hospitals, 784 have HIS (40.07%); of the 3085 municipal hospitals, 1236 have HIS (84.12%); and of the 11 915 county and district hospitals, 4052 have HIS (34.01%).

Information Community

Afzal et al proposes that the primary task of local governments, if the country wants to comprehensively promote the informatization of the medical system, is to promote the reform and implementation of policies on the construction of the medical consortium, and on that basis, establish a systematic, hierarchical, diagnosis-and-treatment system based on the actual situation of hospitals in various provinces and cities.[14]

Afzal et al said that the reason why informatization is crucial to hospital development is that it can improve patient satisfaction and improve the service level and medical-technology level of medical workers. At the same time, the information system can become an information community among hospitals, which can serve patients together, plan and manage uniformly, and form a community of interests and responsibilities.

The formation of the information community is important for promoting medical-technology sharing, telemedicine assistance, and regular meetings or alliance activities of various specialties. With the help of this information-sharing mechanism, hospitals can develop helpful medical-group behaviors, such as remote consultation; strengthen the supply of medical services; and improve the fairness of medical services.[15]

The Chinese governmentshould reform the policy of medical-insurance payments, rely on a complete medical-information platform, and realize instant settlement of bills for patients seeking medical treatment in different places.[16]

Medical and IT Staff

From the perspective of team building, hospitals in all provinces in China are currently short of staff, and high-quality, compoundIT talent. At this stage, the information practitioners in major hospitals have generally improved their technical level compared with the past and have a good grasp of basic computer-software functions and hardware-maintenance technology. However, they often lack the ability to combine clinical experience, patient needs, and technical information.

At the same time, IT staff don't understand the core management model in hospitals and aren't familiar with the administrative business process.[16] Modern hospitals are increasingly rich in the demand for IT staff and have put forward higher management requirements in medical, administrative, financial and other aspects.[17]

One survey found that some hospitals didn't formulate specific plans in terms of employee training and introduction to roles, which directly restricted the hospital informatization.[18] After investigation and research, the researchers found that the root cause was that the management mode of most hospitals in China is relatively backward and lacks a mechanism for the introduction and training for high-quality, IT talent in future planning, which has caused great limitations to hospital informatization.

Informatization has become an important support for hospitals' scientific research work. While improving the efficiency of data processing and analysis, it ensures the smooth progress of daily work and expands the new service scope of the medical industry.[19] Medical staff can not only obtain rich medical knowledge but also access to patients' health-management medical records, high-definition medical images, and the latest clinical data. Informatization also can realize plans for real-time teaching and training for surgery and treatment through video broadcasts, including regional-medical and remote-service practices, which have played a supporting role in the intellectualization and modernization of hospital science and education work.[20]

Each department of the hospital has changed greatly in the process of information construction, and the key role of the information system runs through a hospital's whole operational process. Information systems play an important role in business operations, providing support for daily work and a guarantee for improved work efficiency.[21]

For the future construction of the hospital information system, departments at all levels should start from the actual problems, deeply study their causes, propose effective solutions, and summarize the corresponding strategies and guidelines. This process has extremely far-reaching significance for scientifically grasping the direction of future hospital informatization, reasonably planning the phased tasks of hospital information, and promoting the development of hospital information.

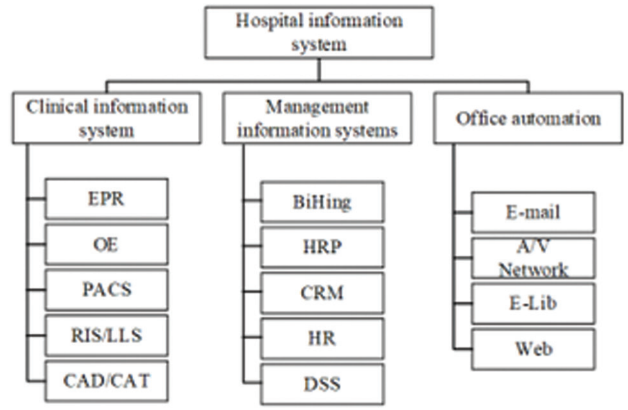
Methods of Analysis

After decades of development of hospital management informatization in China, medical institutions at all levels in all regions have experienced a similar development path, from a focus on drug and financial management at the core that has gradually developed to a focus on collecting and preserving patients' case information. At the same time, informatization isn't limited to an individual hospital but gradually has expanded to entire regions. In general, the development of hospital management informatization has roughly gone through three stages.[22] First, the regional medical information networks developed, the Grants Management Information System (GMIS); second, the clinical networks developed, the CIS; and third, the management networks developed, the HIS.

System Composition

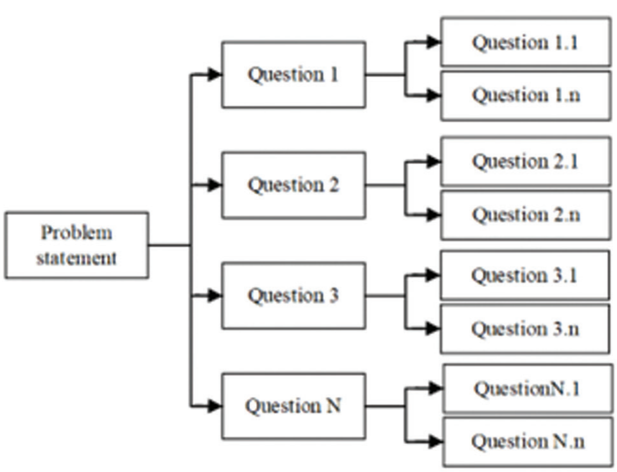
HIS outpatient- and clinician-nurse workstations entered the network in 2011 and went online in July 2012, with 47 subsystems including outpatient, pharmacy, materials, equipment, surgery, anesthesia, and resident care, among which the doctor-nursing workstation is Browser Server (BS) architecture.[23] Since 2012, hospitals have successively improved the all-in-one card intelligent management system, official website, and self-service equipment.[24] Since 2013, hospitals have developed a number of systems: laboratory information system (LIS), EMR, PACS, medical record management, triage call, and anti-statistics system. Hospitals have replaced or launched, after a full demonstration, official websites, the official WeChat system, office automation (OA), hospital sense management(the prevention and control of infections and the protection of team members from infection), medical record tracing, and other systems. Figure 3 shows the composition of hospital information system.

Figure 3. Composition of Hospital Information System



Abbreviations: A/V, audio/visual; BiHing,Business Intelligence Hospital Information System; CAD/CAT, computer aided detection/ computerized tomography; CRM, customer relationship management; DSS, decision support system; E-Lib, electronic health records -library; EPR, electronic patient record; HR, human resources; HRP, healthcare reimbursement plan; OE, order entry; PACS, picture archiving and communication systems; RIS/LLS, radiology information system/ Link-local Signaling

Figure 4. Example of Logic Tree Analysis



Theoretical Basis of Data Analysis

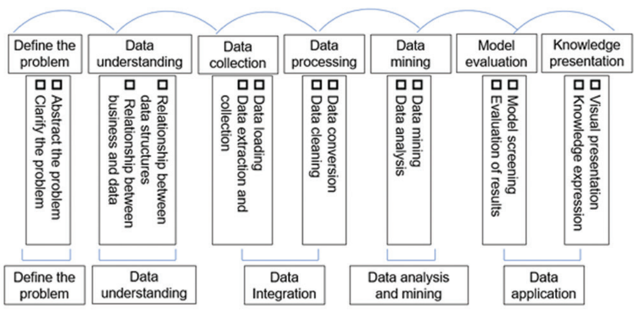
Data analysis theory can provide comprehensive macro guidance and early task planning for specific data-analysis tasks: (1) understanding the specific problems requiring analysis, (2) determining the methods to perform the analysis, and identifying the indicators that determine which specific analysis methods and specific details to use.

The basic content of data analysis can be roughly divided into three methods: (1) analysis of the correlation between transactions, such as by using logic tree analysis or correlation factor analysis[25]; (2) statistical analyses, such as analysis of variance (ANOVA) and principal component analysis (PCA); and (3) predictive analyses, such as Bayesian statistics and linear regression.

Logic tree analysis. Logic tree analysis is a typical tree-analysis method. The specific process takes a known problem as the tree's root node and then considers the problems related to it. For every time point, the related problem becomes a child node to the parent node with the current problem as the parent node, and with the process repeatinguntil solution of the problem, as Figure 4 shows.

Logic tree analysis conforms to the human thinking mode. It deconstructs a big problem that can't be solved directly into a small problem that can be solved directly, level by level based on prior knowledge, and then merges the solutions level by level. Because this mode requires a certain prior knowledge, analysts often use it to explore the deep cause of things on the basis of that prior knowledge.

Figure 5. Basic Process of Data Analysis and Mining



Analysts should consider some issues when using logic tree analysis to analyze data. First, the connection between nodes is due only to correlation, so a practical relationship should exist between the nodes. Second, because the problems involved may be numerous and detailed, the analysts should summarize the same problems as an analysis node to avoid repeated analysis of the problems. At the same time, to avoid the omission of related problems, the analysts should be familiar with all the problems and consider them as comprehensively as possible before the analysis.

ANOVA. ANOVA is a statistical concept, used to test the significance of the difference between the mean of two or more groups. Because of the complexity of a situation, the analysts must include many factors in the occurrence of any particular outcome. Some of these factors are independent and some are interdependent. ANOVA is a method to find out the factors that have a great impact on the occurrence of things as well as the relationship between the factors, without sufficient prior knowledge.

PCA. PCA is a multivariate method of statistical analysis that selects the few important variables by linear transformation of multiple variables. When using statistical analysis to study multivariable problems, the complexity of the problem will increase with an increase in the number of analyzed variables.

To reduce complexity, analysts naturally hope to reduce the number of variables and also hope to obtain more comprehensive information. In many cases, a certain degree of similarity and overlap can exist between two variables in the information reflected. The analysts can meet the above requirements by converting multiple variables with similarity and overlap into one variable, using PCA.

As a basic method of mathematical analysis, analysts have widely used PCA in the practical application of mathematical modeling, mathematical analysis, demography, molecular dynamics, and other disciplines. It's a commonly used multivariate-analysis method.

Actual data analysis and mining. The theoretical knowledge of data analysis and mining introduced above is the cornerstone of the actual work and the technical support for the most critical steps in system-engineering practice. Analyzing and mining data is only one step in an actual project of data analysis and mining. A lot of preparatory work must occur before analyzing and mining the data, and a lot of evaluation and presentation work must occur after it. Figure 5 shows the basic process.

Definition of the Problem

As the first stage of data-analysis-and-mining engineering, the system engineers must first clearly define the objects of analysis and mining and should set clear goals. Then they must determine the practical application problems that they need to solve and convert them to data-mining system-engineering problems. Finally, they must examine the practical problems requiring solutions combined with the corresponding engineering problems to determine the following related factors: (1) determine the evaluation criteria that they will use to evaluate the model, (2) establish the amount of data they will need, (3) obtain that data, and (4) decide what the relevant factors are.

Data Evaluation

As the last stage before the real start of the engineering practice, the main task is to understand the relationship between specific business activities and specific data. In this stage, the system engineers must: (1) find all content and data related to the specific businesses and (2) understand the attributes of that data and the information that the data expresses. If necessary, they must combine that specific understanding with specific data sources.

Data Collection

On the basis of the completion of the first two stages, the next step is to collect the data needed for the data analysis and mining. When collecting data, the system engineers must pay attention to the following issues: (1) collect only the data related to the data-analysis-and-mining applications, (2) clarify the similarities and differences in the information that data from different data sources express, and (3) at the same time, avoid duplication and redundancy as much as possible.

Data Processing

The data-processing stage is also called data preprocessing. Due to the characteristics of a specific business, data generally has various problems, such as different formats and data clutter. Therefore, the system engineers need to preprocess the collected data in an early stage to ensure that the data is of high quality, so as to obtain good analysis-and-mining results.

The preprocessing of data includes: (1) eliminating the default value in the data; (2) eliminate duplicate records and redundancy; (3) eliminate irrelevant records, such as fields irrelevant to the analysis and mining; (4) eliminate data-definition inconsistency and complete data-type conversion; (5) eliminate data-value inconsistencies; and (6) eliminate outdated data.

Because the quality of data can seriously affect the results of analysis and mining, data collection and processing is the key step in determining whether the entire data-analysis-and-mining project can draw correct and effective conclusions. According to engineering-practice statistics, the workload of the above two steps will generally reach 60% or even 70% of the total engineering-practice workload.[26]

Data Mining

This stage is the core stage of all the processes. different users often need to perform data mining and data analysis at the same time and processes may cross each otherin practical projects. In programming the system, the system engineers mainly choose algorithms that correspond to the specific tasks of data analysis and mining and to determine the rules, patterns, and trends in the processed data, to allow users to obtain knowledge. The selected algorithm mainly considers two factors: (1) the selection of relevant algorithms for analysis and mining need to occur based on the characteristics of the business and the data, and (2) adoption of the corresponding mining algorithm must occur based on the different requirements of users or actual running systems.

Model Evaluation

The system engineers must evaluate and screen the knowledge discovered in the previous stage according to the evaluation criteria established in the first stage. They must eliminate irrelevant and redundant knowledge, and at the same time, compare the discovered knowledge with the expected standard. If the result deviates greatly from the expected goal, they must redesign or adjust the algorithm. If the deviation is small, they must adjust the relevant parameters of the algorithm. If the result is ideal, they should return to the data-preparation stage, expand the data set, verify the data until the data set reaches a certain required size and still meets the expected standard, and then proceed to the next stage.

Knowledge Presentation

Because the analysis and mining of data aims to solve practical problems of users from the first stage, the main task in this stage is to display the knowledge that can solve problems to the users in a way that they can easily understand, such as knowledge representation or visualization technology. The basic process of data analysis and mining is essentially the process of data evolution, as Figure 6 shows.

First, the system processes the original data into a form that can better describe the information required by users. Then, the users can discover the knowledge contained in the information by mining it. Finally, the users can promote the knowledge to an intelligent level through understanding and analyzing the knowledge, to play a role in reality.

In the management of modern enterprises (Figure 7), a scientific and reasonable management process demands that enterprise-level managers need to be able: (1) first to understand the overall operation of the enterprise in an all-round way, (2) then to develop enterprise-level management-decision plans and strategic objectives, and (3) finally, to

Figure 6. Data Evolution Process

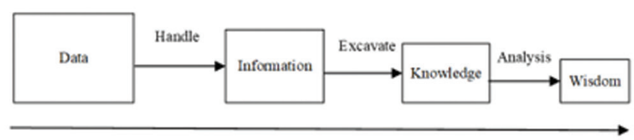
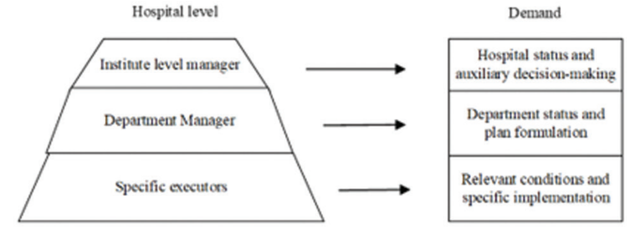


Figure 7. Scientific Management Plan of Hospitals



delegate actions to each relevant department. Department level managers must formulate specific implementation plans based on a department's actual situation and then delegate actions to specific implementation personnel.

The specific executors must complete the specific implementation work according to their own conditions and the specific conditions of the surrounding businesses related to their own businesses. Modern hospital management adopts the enterprise management mode, so a scientific and reasonable plan that can assist the hospital in management should be able to provide different support services for different levels.

PROCEDURES: CASE STUDY

Types of Hospital Data

Because the main purpose of the analysis and mining of hospital data is to assist a hospital's business management, the data source is mainly HIS data. The auxiliary data sources included LIS and daily business-processing systems, which involve management and inspection.

The main data source used in this case study was the hospital information system that a provincial tertiary hospital uses. This system includes outpatient management, inpatient management, inspection management, drug management, surgery management, medical-record management, medical insurance, equipment management, cost accounting, personnel management, material management, and other modules, basically covering all of the hospital's basic businesses.

Because the actual business system and process of the hospital are quite complex and changeable and the personnel responsible for daily data entry into the system are nonprofessionals, data in an actual hospital management system are generally incomplete, redundant, and fuzzy, with many meaningless components. To upgrade the system, the research team needed a deep understanding of the hospital's business processes and the data structure in the database.

Then, they had to start the second step of the project, data understanding. To sort out the correspondence between the business and data, they must examine the tables in the

Table 2. Correspondence Between Business Information and Specific Tables of Data

Business Information	Database Table Structure
Outpatient management	Visit-record form
Inpatient management	• Log table for patients' in/out transfers and status changes • Statistical record table for empty beds per day • Master-record table for patient hospitalizations
Inspection management	Inspection master-record and item-record forms
Device management	Information table for hospital-resource allocation
Operation management	Operation-record, operation-name, and operation-information forms
Diagnostic management	Diagnostic-comparison-record, diagnostic-record, and diagnostic-classification-record forms
Case management	Patient-master-index and patient-in-hospital master-record tables
Medical order management	Medical-order-record, dispensing-record, and drug prescription master-record and details-record forms
Outpatient charge management	Outpatient diagnosis-and-treatment expense-item and billing-record tables
Inpatient charge management	Inpatient settlement-master, expense-detail, and inpatient-expense records

Figure 8. Overall Flow Chart of Data Analysis and Mining Project for Hospitals

Abbreviations: HIS, health information system; LIS, laboratory information system.

data source. From an understanding of the relevant documents and materials of the HIS and an analysis of the hospital's business and of actual hospital data, the research team could roughly divide the business into six parts: (1) outpatient and impatient management; (2) inspection and test management; (3) device management; (4) operations management; (5) management of medical records, diagnosis, and medical orders; and (6) management of outpatient and inpatient charges. The information in the business tables in the database correspond to those parts, as Table 2 shows.

Outpatient and inpatient management mainly manages the patients' visits, admissions, discharges, transfers, departmental transfers, and changes in hospitalization status. Inspection and test management mainly records the issuance of doctors' requests for inspections,such as admissions, discharges and tests for patients and implements them.

Medical records, diagnostic, and medical-order management mainly manages a patient's own information, a doctor's diagnostic information for the patient, and the patient's medication information after issuance of a doctor's order. Outpatient and inpatient charge management mainly records the doctor's billing information, the patient's payment and settlement information, and the patient's hospitalization details.

Operation management records the details of an operation, and equipment management mainly manages the allocation of large equipment and some resources in the hospital.

The Process Framework

After determining the problems to be solved and the data to be collected, system engineers must: (1) first collect and process the data, (2) then use the collected data set as the data source to carry out analysis and mining, and (3) finally show the knowledge obtained.

At present, the vast majority of decision support systems are built mainly using data warehouse technology, combined with data comprehensive processing technology. Data warehouse technology is a very powerful construction tool for building a unified data source by collecting and processing data. Therefore, the system engineers use it to complete the generation of a unified form of a data source.

On the basis of the unified data source, the engineers then determine the display of the data analysis and mining and of the knowledge. Figure 8 shows the overall process framework of the research.

The whole process framework includes four parts: data source, data warehouse, data analysis and mining, and information presentation. As the source of all data in data analysis and mining, the data source can be a database of the hospital's current information systems, such as HIS, MIS, and LIS databases, or users can manually input data. The data sources that the research team used were the HIS and LIS databases in the hospital data section and some manually prepared Excel tables.

The data warehouse is a very important part of this work as a unified data source for subsequent data analysis and mining that can perform theme-oriented analyses on historical data. It's built through the process of data extraction, conversion, and loading by integrating scattered data distributed in various systems, distinguished according to different professional concerns.

As a very important part of any analysis, the data analysis and mining system processes or models the data according to the corresponding analysis methods or analysis models, through different scenarios and topics to produce a dataset that reflects the results of analysis or mining information.

As the last step in data analysis and mining, the information presentation system visually presents the data analysis' conclusions through various portals for information presentation, such as interactive information boards, online queries, indicator comprehensive analysis, analysis reports, and thematic reports, based on the hospital's unified business model.

RESULTS: CASE STUDY

Informatization Based on Data Analysis

People often believe that effective informatization is just the result of the leadership's good vision. In fact, it's difficult to carry out informatization in a hospital system because the investment is often high, the cycle for receiving returns is long, and the economic benefits aren't obvious. Therefore, hospitals are often unwilling to put informatization in a key position. At the same time, the hospital's head often is too busy to devote him- or herself to the informatization, which makes the changes to the medical process not thorough enough and the cooperation of various departments not high enough, with the collaborative work not being carried out smoothly.

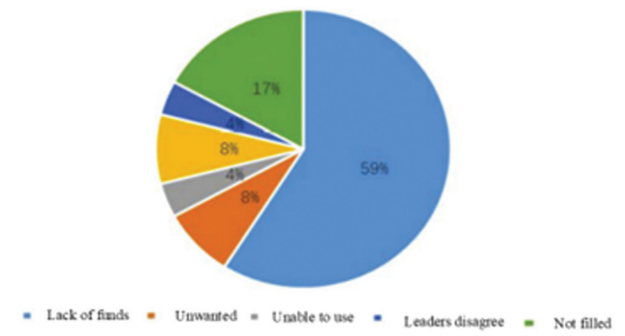
The current study chose HIS construction in hospitals for its analysis, to show hospitals that the current reasons affecting the in-depth implementation of HIS, include such obstacles as leaders' neglect and limited funds and time. In general, these reasons fit into two categories, namely, insufficient understanding of information systems and lack of funds (Figure 9).

The current investment in hospital informatization in China is far from meeting the required standard. Since informatization is inseparable from science and technology, the demand for capital investment is large. However, it's different from medical equipment and other projects that can see rich returns in the short term, and hospital leaders often ignore its hidden benefits, which leads to a slow process of informatization.

At the initial stage of construction, the hospital needs to invest a lot of money and can mistakenly believe that they can reduce the investment in the middle and later stages if the system engineers do a good job in the first step. However, informatization must occur continuously, and constant investment is an important guarantee that ensures the quality of the informatization. Jonsson et al estimates that if the investment will be at least tens of millions of yuan if a Grade III Grade A hospital wants to establish a complete and sound information system internally.[27] The above discussion shows that the investment required for hospital informatization can't be completely dependent on the administrative appropriation that the government provides. After all, the amount of investment is relatively large, and the hospital needs to bear more than half of it. However, in the face of that huge investment, most hospitals are deterred, making it impossible to carry out the informatization smoothly, which can force many projects already under construction to stop because the follow-up funds can't be available in time.

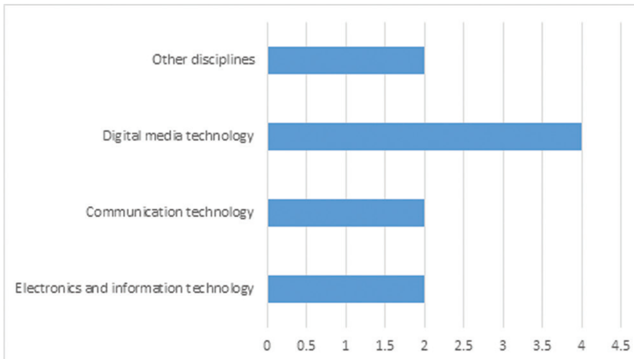
In addition, due to the slow recovery of economic benefits from informatization, hospitals are reluctant to *waste* funds on information construction. In an unsuccessful case

Figure 9. Main Factors Affecting HIS Construction in Hospital not filled:not enough to use



Abbreviations: HIS, health information system.

Figure 10. Professional background of employees in the IT department



of the informatization at one provincial hospital, the hospital launched the all-in-one card project with the agricultural bank of china in 2012 at the same time as the launch of their HIS.

The research before the project's launch indicated that self-service equipment could effectively solve the problem of patients' queuing to make payments. The average self-service registration and payment volume had accounted for only 1.1%-1.8% of the outpatient service in the prior five years. The analysis was wrong in its estimate of patients' acceptance of and ability to operate the self-service equipment.

That hospital serves 1.96-million people in a city, of which the agricultural population accounted for 74.5%.[28] More than 90% of the patients' family members didn'tknow how to operate self-service equipment, even with training by staff. It also was difficult to get the system to accept a rechargeat the hospital and patients had to wait a few hours to see a doctor between 2012 and 2016 In addition, the internet bank's medical communication system at that time excluded the use of other bank accounts, and the operational interface wasn't friendly enough. At present, the bank is redoing the system.

The improvement in the developmental speed of informatization, in addition to material support in terms of funds, is also inseparable from the support of talented staff. At present, the professional and technical talents at the hospital in

Table 3. Number of Beds Per IT Employee

Economically Developed Regions	Beds Per IT Employee n	Moderately Developed Regions	Beds Per IT Employee n	Economically Underdeveloped Areas	Beds Per IT Employee n
Beijing	77.8	Fujian Province	88.9	Anhui Province	149.3
Guangdong Province	83.2	Hebei Province	122.3	Gansu Province	167.3
Jiangsu Province	127.3	Heilongjiang	136.4	Guangxi	155.6
Inner Mongolia	92.8	Hubei province	156.8	Guizhou Province	141.3
Shanghai	94.2	Jilin Province	187.4	Hainan	72.8
Tianjin	93.8	Liaoning Province	159.6	Henan Province	172.8
Zhejiang Province	135.6	Ningxia	107.4	Hunan Province	138.1
		Shandong Province	144.5	Jiangxi Province	118.2
		Shanxi Province	109.4	Qinghai Province	120.8
		Shaanxi Province	116.5	Sichuan Province	119.9
		Chongqing City	79.7	Xinjiang	72.8
				Yunnan Province	155.7

Abbreviations: IT, information technology.

the current study aren't only unable to meet the needs of informatization in terms of quantity but also in terms of quality. Groh-Wargo et al indicates that more than 80% of US hospitals have more than 10 information professionals, while 30% of the hospitals have more than 50 information professionals.[28] In contrast, the number of internal information professionals at hospitals in China is very limited. More than 50% of Chinese hospitals have IT-related professionals in their information departments, and more than 20% of hospitals have IT-related professionals in their information departments.[29] However, less than 10% of hospitals in the information sector have medically related professionals in the majority, and only about 1% of hospitals in the information sector have medically related professionals. Table 3 shows the number of beds per IT employee; See Figure 10 for the professional background of employees in the IT department.

At present, the hospital examined in the current study has 1010 beds, 10 people in the IT department, with none having a medical-knowledge background, eight being from IT-related disciplines such as electronics and information technology, communication technology, digital media technology, and two being from other disciplines, with an average of 100 beds per person.

After a system is online, the user departments make many demands, and system developers often find various reasons to shirkThe hospital's own engineering and technical personnel areimmature, and the unwillingness to spend money to obtain people to help is common in all systems.

As terminal operators all hope to gain the maximum freedom of operation, they are psychologically resistant to maintaining information security outside the scope of their duties. Hospitals have limited means for training and education, and the awareness of information security includes only hospital leaders and information departments. The overall awareness of medical personnel isn't strong.

Satisfaction Analysis Based on Data Analysis

Applying the data-analysis method to satisfaction surveys about hospital informatization can systematically uncover uncertain and difficult-to-quantify contents and problems and can clearly present the results for various groups. This analysis used the current study's representative, provincial public hospital as an example to determine the factors influencing satisfaction with the hospital's informatization from the perspective of patients and medical staff.

The research team used the entropy weight method to calculate the weight of each variable. The smaller the entropy value, the greater the impact of the value on the results. If the entropy values of an variable were all equal, then the variable didn't play a role in satisfaction. In the calculation, the evaluator must first calculate the variables' weight vector A by the entropy weight method, and finally conduct a fuzzy-vector comprehensive evaluation and analysis through the formation of the weight matrix to obtain the membership of the five satisfaction levels: very satisfied, quite satisfied, generally satisfied, quite dissatisfied, and extremely dissatisfied.

Outpatients' satisfaction. Table 4 summarizes the results of 100 satisfaction questionnaires that outpatients completed, and Table 5 shows those outpatients' satisfaction based on the entropy weights.

The indicators' weights were: (1) online appointment registration—8.2%, (2) intelligent triage guidance—15.2%, (3) internal and external hospital navigation—6.8%, (4) queuing broadcast call—7.4%, (5) self-service terminal service—10.6%, (6) intelligent machine drug delivery—8.5%, (7) inspection and inspection appointment—8.2%, (8) Internet service—16.6%, (9) support of electronic vouchers—11.5%, and (10) promotion of information—8.2%.

The maximum value of an indicator's weight was for Internet service at 16.6%, and the minimum value was for hospital navigation at 6.8%. This shows that the surveyed outpatients paid the most attention to Internet service in the informatization of the hospital.

Table 4. Outpatient Satisfaction Survey (N = 100)

Questions	Very Satisfied %	Quite Satisfied %	Generally Satisfied %	Quite Dissatisfied %	Extremely Dissatisfied %
Online appointment registration	16	34	32	18	5
Intelligent triage guidance	19	28	44	2	2
Navigation inside and outside the hospital	4	27	33	20	8
Queue broadcast call	17	23	30	10	7
Self-service terminal service	35	22	27	12	9
Intelligent machine dispensing	2	26	30	9	28
Check inspection appointment	30	15	19	37	4
Internet Services	5	24	48	10	8
Support electronic voucher	3	20	49	24	9
Promotion information push	31	26	23	11	4

Table 5. Evaluation of Outpatient Satisfaction Calculated by Entropy Weight Method (N = 100)

Questions	Information Entropy	Information Utility Value	Weight
Online appointment registration	0.812	0.193	0.082
Intelligent triage guidance	0.644	0.358	0.152
Navigation inside and outside the hospital	0.839	0.166	0.068
Queue broadcast call	0.829	0.174	0.074
Self-service terminal service	0.752	0.254	0.106
Intelligent machine dispensing	0.805	0.198	0.085
Check inspection appointment	0.812	0.194	0.082
Internet services	0.609	0.394	0.166
Support electronic voucher	0.736	0.269	0.115
Promotion information push	0.809	0.196	0.082

The weights of the indicators that affected outpatient satisfaction with the informatization of the hospital were A = 0.08, 0.15, 0.068, 0.074, 0.106, 0.085, 0.082, 0.166, 0.115, and 0.082. The evaluation matrix obtained from the results of the 100 questionnaires and drawing with SmartArt:

$$R = \begin{bmatrix} 0.15 & 0.33 & 0.31 & 0.17 & 0.04 \\ 0.20 & 0.29 & 0.45 & 0.03 & 0.03 \\ 0.03 & 0.26 & 0.31 & 0.15 & 0.25 \\ 0.18 & 0.24 & 0.32 & 0.19 & 0.07 \\ 0.34 & 0.21 & 0.26 & 0.11 & 0.08 \\ 0.03 & 0.27 & 0.31 & 0.10 & 0.29 \\ 0.29 & 0.14 & 0.18 & 0.36 & 0.03 \\ 0.06 & 0.25 & 0.49 & 0.11 & 0.09 \\ 0.02 & 0.19 & 0.48 & 0.23 & 0.08 \\ 0.32 & 0.27 & 0.24 & 0.12 & 0.05 \end{bmatrix} \quad (1)$$

Finally, the research team calculated the weighted average for the 10 indicators and 5 satisfaction levels. The fuzzy-vector calculation method was B | A | R. Table 6 shows he values for the membership matrix.

The membership of the five satisfaction levels were 0.157, 0.246, 0.359, 0.145, and 0.093, for very satisfied, quite satisfied, generally satisfied, quite dissatisfied, and extremely dissatisfied, respectively. The weight of generally satisfied among the five levels was the highest, which allows definition of the maximum membership rule: The outpatients were generally satisfied with the effectiveness of the informatization.

Inpatient satisfaction. Table 7 summarizes the results of 100 satisfaction questionnaires that inpatients completed, and Table 8 shows those inpatients' satisfaction based on the entropy weights.

The weight of the indicators were: (1) residents' electronic health records—10.2%, (2) mobile phone payment check list—11.9%, (3) telemedicine collaborative consultation—10.4%, (4) hierarchical diagnosis and treatment two-way referral—6.6%, (5) electronic medical insurance reimbursement in different places—6.7%, (6) intelligent hospital online consultation—8.5%, (7) nutritious meal ordering beside the bed—15.0%, (8) intelligent distribution of static drugs—6.6%, (9) face recognition for epidemic prevention and control—14.2%, and (10) personal privacy protection of patients—8.4%.

The maximum value of an indicator's weight was for nutritious meal ordering beside the bed (15.0%), and the minimum value was for two-way referral of hierarchical diagnosis and treatment (6.6%). This shows that the surveyed inpatients paid the most attention to the nutritious meal ordering beside the bed in the informatization of the hospital.

The weights of the indicators that affected inpatient satisfaction with the informatization of the hospital were

Table 6. Matrix for Membership and Satisfaction (N=100)

Variables	Very Satisfied	Quite Satisfied	Generally Satisfied	Quite Dissatisfied	Extremely Dissatisfied
Membership	0.1571563597	0.2458309454	0.3591836788	0.1449652769	0.0928637399
Normalized (Weight)	0.158	0.247	0.361	0.146	0.094

Table 7. Inpatient Satisfaction Survey (N=100)

Questions	Very Satisfied %	Quite Satisfied %	Generally Satisfied %	Quite Dissatisfied %	Extremely Dissatisfied %
Electronic health records of residents	13	29	33	21	9
Mobile payment check list	36	23	28	3	5
Telemedicine collaborative consultation	27	16	18	20	24
Two way referral of graded diagnosis and treatment	22	24	27	17	5
Remote reimbursement of electronic medical insurance	37	13	19	33	3
Online consultation in smart hospital	19	30	24	11	11
Nutritional meal order by bed	23	31	19	24	8
Intelligent distribution of static drugs	4	12	15	51	13
Face recognition for epidemic prevention and control	24	40	16	21	4
Patient privacy protection	29	34	19	11	2

Table 8. Evaluation of Satisfaction of Inpatients Calculated by Entropy Weight Method (N=100)

Questions	Information Entropy	Information Utility Value	Weight
Electronic health records of residents	0.769	0.233	0.102
Mobile payment check list	0.728	0.275	0.119
Telemedicine collaborative consultation	0.763	0.241	0.104
Two way referral of graded diagnosis and treatment	0.849	0.154	0.066
Remote reimbursement of electronic medical insurance	0.849	0.155	0.067
Online consultation in smart hospital	0.798	0.202	0.085
Nutritional meal order by bed	0.648	0.352	0.150
Intelligent distribution of static drugs	0.842	0.158	0.066
Face recognition for epidemic prevention and control	0.663	0.335	0.142
Patient privacy protection	0.812	0.21	0.084
Electronic health records of residents	0.802	0.196	0.083

A = 0.102, 0.119, 0.104, 0.066, 0.067, 0.085, 0.150, 0.066, 0.142,and 0.084. The evaluation matrix obtained from the results of 100 satisfaction questionnaires was:

$$R = \begin{bmatrix} 0.12 & 0.28 & 0.32 & 0.20 & 0.08 \\ 0.37 & 0.24 & 0.29 & 0.04 & 0.06 \\ 0.26 & 0.15 & 0.17 & 0.19 & 0.23 \\ 0.23 & 0.25 & 0.28 & 0.18 & 0.06 \\ 0.36 & 0.12 & 0.18 & 0.32 & 0.02 \\ 0.20 & 0.31 & 0.25 & 0.12 & 0.12 \\ 0.22 & 0.30 & 0.18 & 0.23 & 0.07 \\ 0.05 & 0.13 & 0.16 & 0.52 & 0.14 \\ 0.23 & 0.39 & 0.15 & 0.20 & 0.03 \\ 0.30 & 0.35 & 0.20 & 0.12 & 0.03 \end{bmatrix} \quad (2)$$

Finally, the research team calculated the weighted average for the 10 indicators and 5 satisfaction levels. The fuzzy-vector calculation method was B | A | R. Table 9 shows the calculations for the membership matrix:

The membership satisfaction levels were 0.225, 0.245, 0.219, 0.219, and 0.092, for very satisfied, quite satisfied, generally satisfied, quite dissatisfied, and extremely dissatisfied, respectively. The weight of quite satisfied among the five levels was the highest, which allows definition of the maximum membership rule: The inpatients at the hospital were quite satisfied with the effectiveness of the hospital informatization.

Satisfaction of medical staff. Table 10 summarizes the results of 100 satisfaction questionnaires that medical staff completed, and Table 11 shows the medical staff's satisfaction based on the entropy weights.

The indicators' weights were: (1) mobile terminal rounds—21.0 %, (2) rational drug use guidance—9.5%, (3) intelligent scheduling and calling—10.0%, (4) online training

Table 9. Results of Membership and Satisfaction (N = 100)

Variables	Very Satisfied	Quite Satisfied	Generally Satisfied	Quite Dissatisfied	Extremely Dissatisfied
Membership	0.2245674659	0.2453573701	0.2192322117	0.2185908562	0.0922520962
Normalized (Weight)	0.226	0.247	0.218	0.218	0.093

Table 10. Satisfaction Survey of Medical Staff (N = 100)

Questions	Very Satisfied %	Quite Satisfied %	Generally Satisfied %	Quite Dissatisfied %	Extremely Dissatisfied %
Mobile terminal rounds	27	39	18	11	10
Guidance on rational drug use	22	19	35	7	12
Intelligent scheduling and calling	13	21	21	35	15
Online training examination	9	23	29	32	2
Scientific research data platform	32	22	33	12	6
Online follow-up of patients	23	32	34	4	2
Surgical appointment management	30	14	42	7	12
Report voice input	8	10	54	23	10
Clinical auxiliary decision-making	16	21	38	9	1
Medical image analysis	27	31	23	18	6

Table 11. Satisfaction Evaluation of Medical Staff Calculated by Entropy Weight Method (N=100)

Variables	Information Entropy	Information Utility Value	Weight
Electronic health records of residents	0.657	0.345	0.121
Mobile terminal rounds	0.767	0.235	0.083
Telemedicine collaborative consultation	0.698	0.302	0.106
Two way referral of graded diagnosis and treatment	0.799	0.203	0.072
Remote reimbursement of electronic medical insurance	0.789	0.211	0.073
Online consultation in smart hospital	0.728	0.272	0.094
Nutritional Meal Order by Bed	0.705	0.297	0.104
Intelligent distribution of static drugs	0.498	0.504	0.177
Face recognition for epidemic prevention and control	0.661	0.337	0.117
Patient privacy protection	0.842	0.160	0.055

Table 12. Results of Membership and Satisfaction (N=100)

Variables	Very Satisfied	Quite Satisfied	Generally Satisfied	Quite Dissatisfied	Extremely Dissatisfied
Membership	0.1924015138	0.2189196672	0.3430220757	0.1566557401	0.0890010030
Normalized (Weight)	0.193	0.218	0.342	0.158	0.088

examination—8.5%, (5) scientific research data platform—8.0%, (6) online consultation in smart hospital—10.5%, (7) surgical appointment management—10.5%, (8) report voice output—9.0%, (9) clinical auxiliary decision-making—10.5%, and (10) medical image analysis—2.5%.

The maximum value of an indicator weight was%, and the minimum value was f%. This shows that the surveyed medical staff paid the most attention to the informatization of the hospital.

The weights the indicators that affected the satisfaction of clinical medical staff were A = 0.121, 0.083, 0.106, 0.072, 0.073, 0.094, 0.104, 0.177, 0.117, and 0.055. The evaluation matrix obtained from the 100 satisfaction questionnaires was:

$$R = \begin{bmatrix} 0.26 & 0.38 & 0.17 & 0.10 & 0.09 \\ 0.23 & 0.20 & 0.36 & 0.08 & 0.13 \\ 0.12 & 0.20 & 0.20 & 0.34 & 0.14 \\ 0.10 & 0.24 & 0.30 & 0.33 & 0.03 \\ 0.31 & 0.21 & 0.32 & 0.11 & 0.05 \\ 0.24 & 0.33 & 0.35 & 0.05 & 0.03 \\ 0.29 & 0.13 & 0.41 & 0.06 & 0.11 \\ 0.07 & 0.09 & 0.53 & 0.22 & 0.09 \\ 0.17 & 0.22 & 0.39 & 0.10 & 0.12 \\ 0.26 & 0.30 & 0.22 & 0.17 & 0.05 \end{bmatrix} \quad (3)$$

Finally, the research team calculated the weighted average for the 10 indicators and 5 satisfaction levels. The fuzzy-vector calculation method was B | A | R. Table 12 shows the values for the membership matrix.

The membership degree of the five satisfaction levels were 0.192, 0.219, 0.343, 0.157, and 0.089, for very satisfied, quite satisfied, generally satisfied, quite dissatisfied, and extremely dissatisfied, respectively. The weight of generally satisfied among the five levels was the highest, which allows definition of the maximum membership rule: The clinical medical staff were generally satisfied with the effectiveness of informatization.

The three sets of evaluations. The survey's respondents were "generally satisfied", "relatively satisfied" and "generally satisfied." The provincial public hospital in the example still needs to summarize the respondents' experiences, seize opportunities, make rational use of national rules and policies, and achieve long-term development in informatization.

In addition, the evaluation indicators to which the respondents paid the most attention were Internet service, nutritious meal ordering beside the bed. These indicators provide the exact direction that the provincial public hospital should go in its informatization.

CONCLUSION

In the process of hospital management, it's imperative to strengthen hospital informatization, which can continuously strengthen a hospital's service capacity, ensure good-quality medical service, further improve the discipline of the database construction, enhance the satisfaction of employees and patients, and achieve a high-quality and benign development for the hospital.

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