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Research on the Application of Digital Intelligence-Based Total Quality Management System in Healthcare Quality Management

Jinhong Yang, Zhuo Liu, Weilin Du, Narengaowa Dai, Dongxue Qu, Liying Lv*
Xing'an League People's Hospital, China

***Corresponding author:** Liying Lv, 516785571@qq.com

Abstract: *Objective:* To explore the application effect of a digital intelligence-based total quality management (TQM) system in the continuous improvement of quality in tertiary public hospitals. *Methods:* A public tertiary Grade A general hospital in a certain region was selected as the research site, with January to December 2024 as the control period and January to December 2025 as the observation period. A three-tier architecture of "data collection—quality control early warning—data analysis" was adopted to establish a digital intelligence-based TQM system, covering 42 clinical departments across the hospital. It involved the collection of core data such as performance monitoring indicators for tertiary hospitals, accreditation data for graded hospitals, implementation of core medical systems, and quality control indicators for key specialties. Changes in key quality indicators before and after the system's implementation were compared, and healthcare personnel satisfaction was evaluated through questionnaires. *Results:* After one year of system operation, the information extraction rate for performance monitoring indicators in tertiary hospitals increased from 30.35% to 91.07% ($P < 0.05$), the information extraction rate for accreditation data in graded hospitals rose from 56.1% to 98.6% ($P < 0.05$), the implementation rate of core medical systems increased from 89.1% to 98.6% ($P < 0.05$), and the information collection rate for quality control indicators in key specialties improved from 10.3% to 61.2% ($P < 0.05$). The satisfaction score of healthcare personnel regarding quality management increased from 78.3 ± 8.5 to 86.9 ± 6.2 ($P < 0.05$). *Conclusion:* The digital intelligence-based TQM system can effectively promote the transformation of healthcare quality management from post-event traceability to pre-event prevention and in-process control, enhance management efficiency, achieve information extraction of indicators, and facilitate continuous improvement in healthcare quality. It holds significant practical importance for promoting high-quality development in hospitals.

Keywords: Digital intelligence; Total quality management; Healthcare quality; Quality control early warning; Continuous improvement

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1. Introduction

Healthcare quality is the core aspect of hospital management, directly relating to patient safety, treatment outcomes, and social credibility. In recent years, the national health authorities have repeatedly issued policies requiring healthcare institutions to establish a comprehensive healthcare quality management system, strengthen

quality control throughout the entire process, including all elements, with the participation of all staff, and promote the digital and intelligent transformation of healthcare quality management [1]. With the continuous popularization of hospital information systems, systems such as HIS, EMR, LIS, and PACS have accumulated vast amounts of clinical data. However, most hospitals still adopt traditional quality control modes of manual collection, post-event summarization, and periodic inspections [2], which suffer from shortcomings such as data lag, inconsistent standards, delayed problem identification, and inadequate follow-up on rectifications.

The digital intelligence-based total quality management (TQM) system combines TQM theory with modern information technology to construct a quality control system covering the entire clinical process through automatic data collection, intelligent analysis, real-time early warning, and closed-loop rectification [3]. Research on the construction and application of this system helps address current pain points in healthcare quality management, enhances the level of refined hospital management, and provides references for healthcare institutions to advance smart quality control construction.

2. Related concepts and theoretical foundations

2.1. Digital intelligence and healthcare quality management

Digital intelligence, built upon digitization, achieves in-depth mining of data value through technologies such as artificial intelligence and big data analysis, enabling management to shift from passive response to proactive prediction. In the healthcare field, digital intelligence-based quality control emphasizes data-driven decision-making and the use of intelligent algorithms as tools to achieve early identification, intervention, and improvement of quality issues.

2.2. Total quality management theory

2.2.1. Total quality

Management emphasizes the participation of all staff, control throughout the entire process, coverage of all elements, and continuous improvement, with the core following the PDCA cycle: Plan, Do, Check, Act [4]. The digital intelligence system provides a technological carrier for the PDCA cycle, enabling each link to be monitored, traced, and evaluated through data.

2.2.2. Digital intelligence-based total quality management system

The digital intelligence-based TQM system is an integrated platform supported by a data mid-platform, based on a quality control rule library, and centered on intelligent early warning and closed-loop management. Its goal is to achieve standardization of quality control indicators, automation of data collection, real-time risk early warning, and closed-loop rectification processes.

2.3. Overall design of the digital intelligence-based total quality management system

Full process coverage: Implement a two-tier hospital-department management and three-tier quality control model involving the hospital quality management committee, functional departments, and departmental quality and safety management teams, achieving full-chain quality control.

Data-driven: Achieve information extraction of performance monitoring indicators for tertiary hospitals, accreditation data for graded hospitals, and quality control indicators for key specialties, reducing manual reporting and enhancing data authenticity and objectivity.

Intelligent early warning: Set target and early warning values for key monitoring indicators, with primary early warning lines providing timely reminders to shift the focus forward.

Closed-loop management: Promptly push identified problem data to the responsible departments for timely rectification, with regular effect reviews to achieve continuous improvement.

Information security: Strictly protect patient privacy and data security to ensure information safety.

3. Materials and methods

3.1. Research site and timeframe

The research site was a tertiary Grade A general hospital in northeastern Inner Mongolia, with 1,460 authorized beds, 42 clinical departments, approximately 70,000 inpatient admissions annually, and around 18,500 surgical procedures annually. January 1, 2024, to December 31, 2024, served as the control period (before system implementation), and January 1, 2025, to December 31, 2025, as the observation period (during system operation).

3.2. System interface display

The digital intelligence-based TQM system was deployed and designed using a three-tier logical architecture [5].

3.2.1. Data collection layer

Establish data exchange interfaces with various systems to enable real-time connection with in-house data sources such as the Electronic Medical Record (EMR) system, Hospital Information System (HIS), anesthesia information system, nursing management system, Pharmacy Administration Support System (PASS), and Laboratory Information System (LIS). This facilitates the automatic aggregation of multi-dimensional data including workload, operational efficiency, human resources, negative indicators, hospital infection monitoring, and quality control indicators for various specialties, with a data collection coverage rate of ≥86% and a delay time of ≤10 minutes.

3.2.2. Quality control early warning and data analysis

Construct a data early warning model with set early warning lines covering key performance indicator (KPI) categories such as medical safety, healthcare quality, medical record quality, operational indicators, and satisfaction, with a total of 21 early warning rules configured [6]. Early warning information is promptly pushed to the responsible management departments and relevant clinical departments, supporting closed-loop rectification tracking management. Simultaneously, it provides trend analysis of indicators, horizontal benchmarking among similar departments, and longitudinal comparisons within departments over the years, with drill-down queries by time, department, and personnel to help managers quickly identify weak links in quality management and intervene [7].

3.2.3. Module displays

A nine-grid display module is formed, with each module allowing drill-down to display different interfaces. See **Figure 1**.

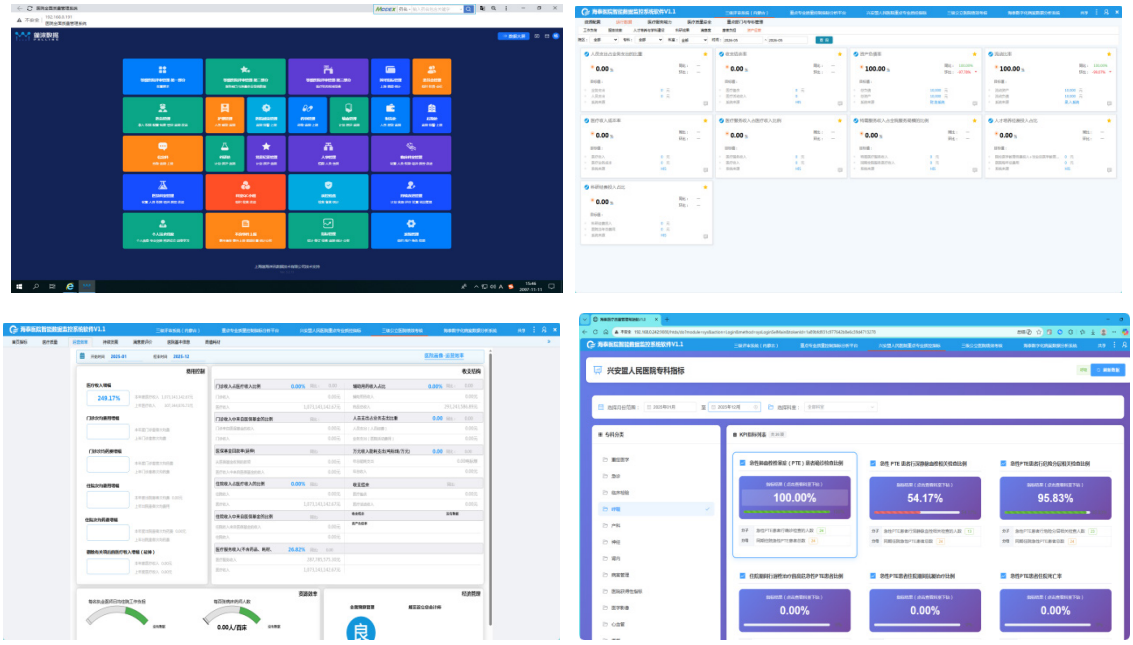

Figure 1. Nine-grid display module

3.3. Observation indicators

The primary observation indicators include: (1) Information extraction rate of performance monitoring indicators for tertiary hospitals; (2) Information extraction rate of accreditation data for graded hospitals; (3) Implementation rate of core medical systems; (4) Information collection rate of quality control indicators for key specialties; (5) Satisfaction of medical personnel with quality management (using a self-designed scale with a maximum score of 100).

3.4. Statistical methods

Statistical analysis was performed using SPSS 26.0. Measurement data conforming to a normal distribution were described as mean ± standard deviation (SD), and comparisons between groups were made using independent sample *t*-tests. Count data were expressed as rates or composition ratios, and comparisons between groups were made using the χ^2 test. A P-value < 0.05 was considered statistically significant.

4. Main applications of the digital intelligence system in healthcare quality management

4.1. Construction of the hospital quality management system

The digital intelligence-based TQM system has established a dedicated function for a two-tier hospital-department management and three-tier quality control model. It divides the quality control into three levels: the Hospital Quality and Safety Management Committee, quality control in various functional departments, and quality control in clinical departments. Quality control tasks are assigned level by level, with responsibilities allocated to each department, and rectification records are kept for traceability. A complete closed-loop rectification model has been constructed [8].

4.2. Realization of data monitoring and transformation of the quality control model

In the data-driven TQM system, key quality supervision indicators and operational indicators are incorporated

into departmental assessments (KPIs) [9], linking quality assessment results to performance evaluations to enhance the initiative and enthusiasm of medical personnel in participating in quality management. Simultaneously, by analyzing data such as bed occupancy rates, average length of stay, and patient satisfaction, resources can be promptly adjusted and optimized to improve operational efficiency.

4.3. Risk early warning and management of hospital safety (adverse) events

This system enables real-time monitoring of negative indicators such as surgical complications, unplanned readmissions, unplanned reoperations, and hospital-acquired infections, facilitating early identification of potential safety risks. It promptly reminds departments to proactively report hospital safety adverse events, prompting hospital administrators to shift from passive handling of adverse events to proactive prevention of latent risk [10].

5. Analysis of usage effects

5.1. Significant improvement in quality management efficiency

The replacement of manual reporting with data information collection has substantially reduced the workload associated with statistics, summarization, and verification. The response speed for quality management has significantly increased, and management costs have markedly decreased.

5.2. Continuous improvement in healthcare quality and formation of a closed-loop quality management model

The process of identifying problems, issuing indicator warnings, departmental rectification, supervision and review by functional departments, and full traceability ensures that rectifications are not merely formalities, continuously driving improvements in healthcare quality. Surgical complications are well-managed, the rate of multidisciplinary discussions before level IV surgeries has gradually increased, the proactive reporting rate of medical adverse events has risen, and risk early warning capabilities have been strengthened, ensuring patient safety.

5.3. Increased efficiency in automated collection of quality control data and significant improvement in core monitoring indicators

As shown in **Table 1**, after the system's implementation, the function of information extraction of data has been realized, and all key indicators related to the implementation of core systems have shown significant improvements: the information extraction rates of performance monitoring indicators for tertiary hospitals, accreditation data for graded hospitals, implementation rates of core medical systems, and information collection rates of quality control indicators for key specialties during the observation period were significantly higher than those during the control period. The average satisfaction score during the observation period was higher than that during the control period, with all indicators showing a P-value of < 0.001 between groups, indicating highly statistically significant differences. This confirms that the digital quality control system can substantially enhance the efficiency of automated collection of quality control data, standardize the implementation of clinical systems, and improve the satisfaction of medical personnel with quality management.

Table 1. Comparison of key quality indicators before and after system implementation

Quality indicator	Control period (2024)	Observation period (2025)	χ^2 test	*P* value
Information extraction rate of performance monitoring indicators for tertiary hospitals (%)	30.35 (17/56)	91.07 (51/56)	8.15	<0.001
Information extraction rate of hospital accreditation data (%)	26.1 (304/1172)	78.6 (921/1172)	16.17	<0.001
Implementation rate of core medical systems (%)	89.1 (16/18)	98.6 (17.7/18)	25.08	<0.001
Information collection rate of quality control indicators for key specialties (%)	10.3 (77/746)	61.2 (457/746)	265.43	<0.001
Satisfaction score (points, $\bar{x}\pm s$)	78.3±8.5	86.9±6.2	t=18.28	<0.001

6. Problems encountered during the construction of this system and the countermeasures adopted

6.1. Existing problems

6.1.1. Difficulty in breaking down data silos

There are too many business systems with inconsistent standards, varying definitions, and dispersed interfaces, making data integration challenging. Additionally, there is insufficient application of structured medical record templates [11].

6.1.2. Inadequate protection of data and information security

The system involves all sensitive data of the hospital, posing risks of data loss and leakage during transmission, storage, and use [12].

6.2. Optimization countermeasures

6.2.1. Strengthening data governance and breaking down information barriers across departments

Establish unified data standards and a data platform across the entire hospital, promote the construction of integrated systems, and enhance data quality and sharing capabilities.

6.2.2. Strengthening the construction of data security systems

Implement hierarchical and categorized data management, assign responsibilities to specific departments, and adopt measures such as encryption, de-identification, and access control based on the classification results to ensure the reasonable and compliant use of data [13].

7. Results and conclusion

This study constructed and applied a three-tier digital and intelligent comprehensive quality management system encompassing "data collection layer—quality control warning and data analysis—display of various modules." After one year of clinical practice and validation, the application of this system has improved the construction of the hospital's three-level quality control system, achieved integrated and informative display of various types of data, and implemented a warning mode that shifts the focus of quality control upstream. As a result, the quality connotation has significantly improved, and the participation and satisfaction of medical staff in quality management have markedly increased. Therefore, the study indicates that the digital and intelligent comprehensive quality management system

can effectively drive the transformation of the hospital's quality management model from "experience-driven" to "data-driven," serving as an important technological pathway for achieving continuous improvement in medical quality and possessing good value for clinical promotion and application.

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The authors declare no conflict of interest.

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