Practical Exploration of the Impact of Internet of Things Systems on Operating Efficiency in Anesthesia and Operation Centers

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BACKGROUND

- Kang et al. [1] used DEA and SFA models to compare the health system efficiency between China and ASEAN countries, finding that both China and most ASEAN countries face issues of low health system efficiency; however, low- and middle-income countries outperformed high-income countries.
- From 2012 to 2021, the overall utilization efficiency of medical and health resources in China showed a downward trend. The decline was more significant in eastern and western regions than in the central region, and for most of the period, the utilization efficiency presented a decreasing pattern of "east > west > central". A study by Zhang et al.[2] indicated that the smart management level of tertiary hospitals in Beijing is unbalanced and needs improvement.
- Beijing Jishuitan Hospital Affiliated to Capital Medical University currently has three campuses: Xinjiekou, Xinlongze, and Huilongguan. The new building of the Huilongguan Campus opened in January 2025, and the relocation and adjustment of medical units across campuses were carried out from January to April 2025. Seizing the opportunity of the new building construction, the Anesthesia and Operation Center implemented smart operating room construction in the new building to improve pure technical efficiency and scale efficiency.

METHOD

1. ESTABLISHMENT CROSS-DEPARTMENTAL TEAM

Member Composition: The interdisciplinary team includes medical staff from the Anesthesia and Operation Center, technical personnel from the IT Department, and IoT system Development engineers.

Clear Responsibilities: Clinical medical staff focus on sorting out core perioperative processes and propose clinical demands for safety and efficiency optimization; IT Department personnel are responsible for the connection of in-hospital information systems and data security management; IoT Development personnel are responsible for the deployment, commissioning and functional iteration of the IoT system.

2. IMPLEMENTATION PATH OF THE IOT SYSTEM

To achieve non-sensing data collection, precise tracking, during surgical processes, and to build a fully perceptible IoT system, the specific measures are as follows:

Construction of a Full-Scope Bluetooth Positioning Network in OR Center: Bluetooth base stations were implemented in the smart operating rooms and associated areas (including operating rooms, patient turnover rooms, post-anesthesia care units, equipment warehouses, etc.) in OR center of the Huilongguan Campus, forming a seamless positioning network. Surgical patients are equipped with positioning cards to track their real-time location and time within the OR center; core medical equipment (such as C-arms, ultrasound, surgical microscopes, endoscopes, navigation systems, and robotic equipment) are affixed with Bluetooth positioning tags to dynamically update the deployment status and idle positions of equipment across operating rooms.

METHOD

IC Card for Medical Staff Identification : All medical staff were provided with exclusive IC cards, which serve as credentials for accessing smart lockers in the Changing Area of the OR center and are real-time linked to the IoT system. After logging into the system via IC card swiping, the on-duty and off-duty times of medical staff are automatically synchronized to the platform, enabling precise matching of personnel work trajectories with surgical processes and providing behavioral data support for subsequent efficiency analysis.

Surgical Gowns with RFID Tags: Each set of surgical gowns is embedded with a reusable RFID tag for washing, which stores a unique identification code of the surgical gown.

3. DATA COLLECTION AND COMPARATIVE ANALYSIS

3.1 Study Design and Subjects

Control Phase (Traditional Data Collection Period): 26 operating rooms in the Xinjiekou Campus were selected as the research objects, and operational data of the OR center from October 2024 to March 2025 were collected. Data during this phase were mainly obtained through traditional methods such as manual recording and in-hospital system click entry, forming the baseline data group "before IoT application".

Intervention Phase (IoT Data Collection Period): 26 operating rooms in the new building of the Huilongguan Campus were selected as the research objects, and operational data from May 2025 to October 2025 were collected. Data during this phase were automatically collected through the aforementioned IoT system (Bluetooth positioning, IC card identification, RFID tracking), forming the intervention data group "after IoT application".

Quality Control: Both phases involved 26 operating rooms, with no significant differences in the distribution of surgical departments, medical staff configuration, or surgical type structure, eliminating interference from hardware environment or personnel changes on efficiency data.

3.2 Outcome Indicators

First-Case On-Time Starts (FCOTS): Defined as the proportion of first-case surgeries where the skin incision time is on or before the scheduled start time. This indicator directly reflects the timeliness of surgical process initiation and is one of the core metrics for measuring surgical scheduling efficiency. Delays can cause a chain reaction on subsequent surgeries and reduce the overall daily surgical efficiency. [3] A surgery is considered delayed if the skin incision time is after the scheduled first-case start time.

Operating Room Utilization (ORU): The "daily utilization rate per operating room" was collected, calculated as: (Effective daily usage time per operating room / 9 hours) × 100%, where "9 hours" is the standard daily operating time per room. The monthly average utilization rates of the two phases were compared. This indicator reflects the adequacy of operating room resource utilization; an increase indicates more rational comprehensive scheduling of operating rooms.

RESULTS

Dimension	Traditional Data Collection Mode	IoT System Data Collection Mode
Real-Time Performance	Relies on manual recording or system click entry and post-hoc aggregation; data is delayed, fails to reflect process status in real time, and cannot support timely intervention.	Real-time data collection based on Bluetooth Angle of Arrival (AoA) positioning technology; second-level non-sensing collection and update of information such as patient entry/exit, medical staff on-duty status, equipment location, and operating room usage status; real-time adjustments to work based on data.
Accuracy	Manual recording is prone to omissions and errors, leading to statistical deviations; equipment location accuracy is not guaranteed.	Automatic data collection without manual intervention; exact usage time of operating rooms and post-anesthesia care units is accurate to the minute; equipment positioning error is controlled within 0.5 meters; data accuracy exceeds 99%.
Supervision & Decision Support	Data is erroneous, delayed, or incomplete; only post-hoc review is possible; real-time supervision is difficult; decisions lack precise data support.	Real-time data can be directly used for dynamic supervision, dynamic resource allocation adjustment, and timely early warning; rapid equipment positioning data assists in equipment scheduling decisions and improves resource turnover efficiency.

FIGURE 1

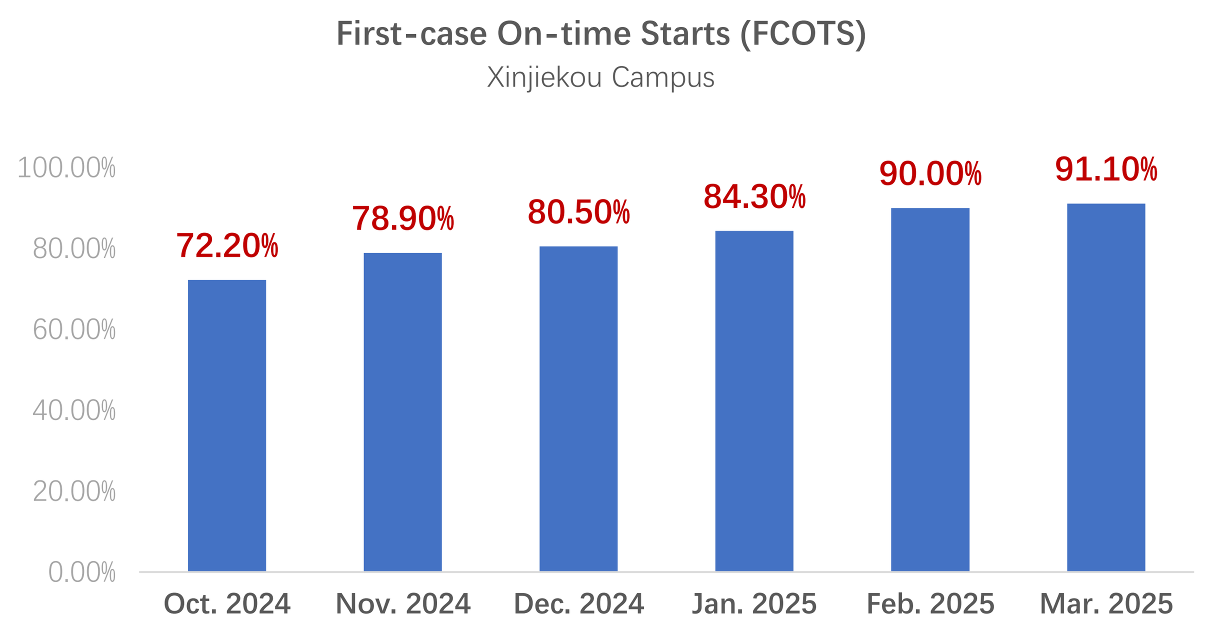

Figure1: FCOTS for 26 ORs in Xinjiekou Campus within 6 months

FIGURE 2

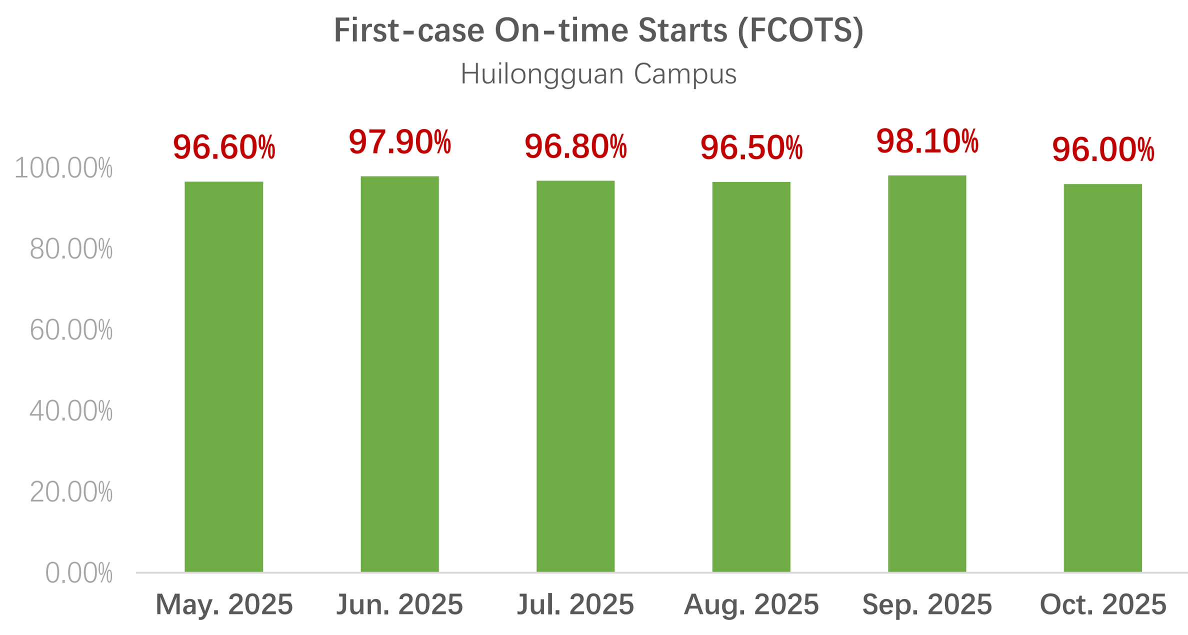

Figure 2: FCOTS for 26 Ors in Huilongguan Campus within 6 months

FIGURE 3

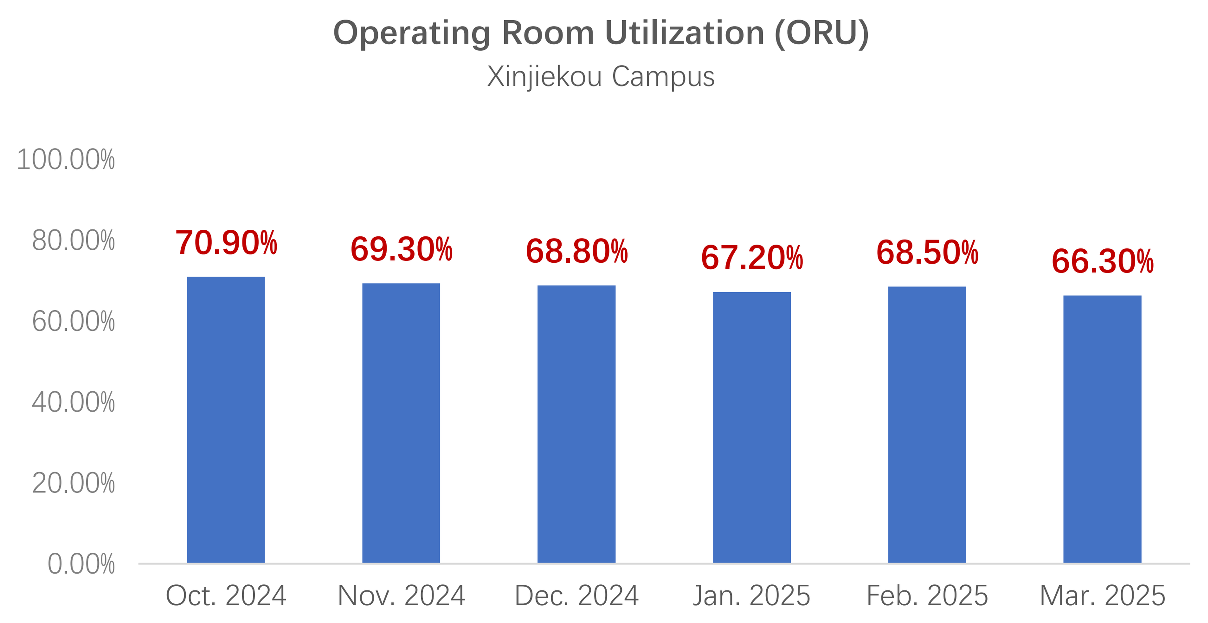

Figure3: ORUR for 26 ORs in Xinjiekou Campus within 6 months

FIGURE 4

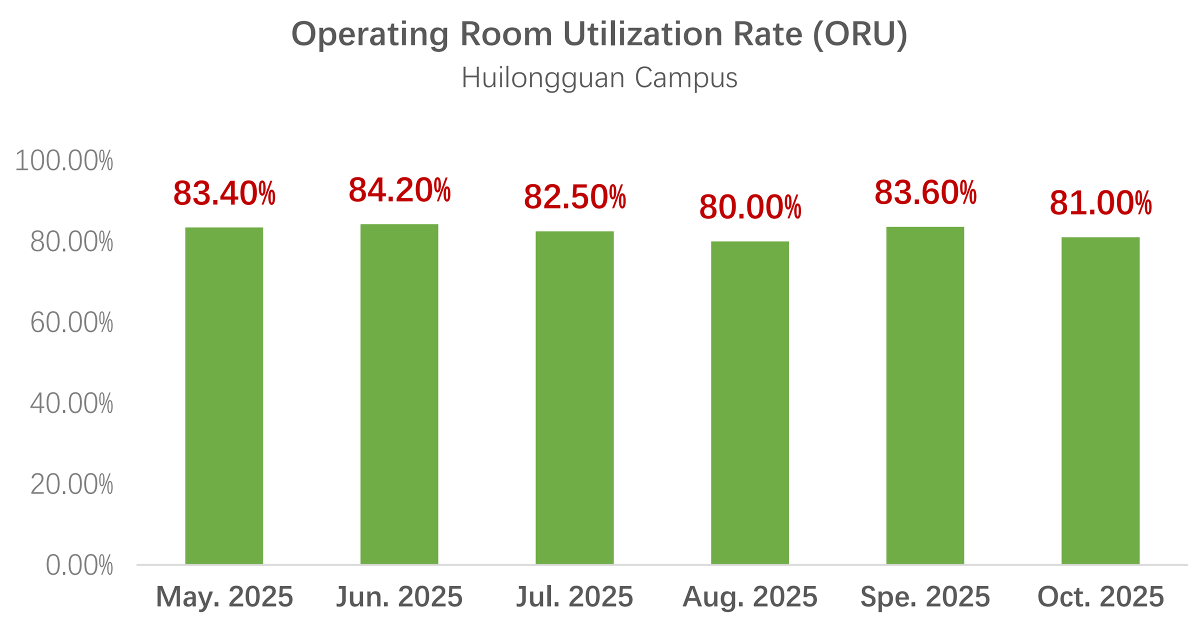

Figure 4: ORUR for 26 Ors in Huilongguan Campus within 6 months

CONCLUSIONS

- By introducing the IoT system and constructing core evaluation data, this study effectively improved the efficiency and accuracy of surgical processes. The real-time data collection capability of IoT technology not only significantly enhanced data accuracy and timeliness but also provided strong support for dynamic supervision of surgical processes and optimization of resource allocation.
- The improvement in first-case on-time start (FCOTS) rate reflects enhanced surgical scheduling efficiency. Meanwhile, the increase in daily utilization rate per operating room further demonstrates the potential for optimizing operating room resource utilization.
- This study only describes efficiency improvement and has not conducted in-depth exploration of key indicators such as safety and patient experience in surgical processes. Future research can further expand evaluation dimensions to comprehensively assess the integrated impact of IoT systems on surgical processes. Additionally, with the continuous development of IoT technology, it is expected to provide more possibilities for surgical process optimization.

CONTACT INFORMATION

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