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Original Article

Artificial intelligence-based perioperative safety verification system improved the performance of surgical safety verification execution

Xinran Yu, Zhiqin Wang, Jinyan Wu, Dongfang Weng

Operating Room, Hangzhou Children's Hospital, Hangzhou 310000, Zhejiang, China

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Abstract: Objective: To explore the application effect of the artificial intelligence-based (AI-based) perioperative safety verification system in the performance of safety verification execution in urological and general surgeries. Methods: The surgical checklists of 141 urological and general surgical patients from September to December 2019 in Hangzhou Children's Hospital were selected as the control group, and 71 surgical checklists for urological and general surgeries that the applied AI-based perioperative safety verification system from August to September 2022 were chosen as the experimental group. We compared the execution rate and standardization rate of safety verification as well as the satisfaction of surgeons, nurses, and anesthesiologists between the two groups. Results: The execution rate and standardization rate of surgical safety verification in the experimental group were higher than those in the control group (both P<0.05). In addition, the satisfaction of surgeons, nurses, and anesthesiologists was also higher in the experimental group (all P<0.05). Conclusion: The AI-based perioperative safety verification system can improve the execution and standardization rates of surgical verifications, and also enhance the satisfaction of surgical participants.

Keywords: Urological surgery, surgical verification, artificial intelligence-based perioperative safety verification system, standardization rate, satisfaction

Introduction

The latest industry regulations have stipulated surgical safety verification as one of the most important safety goals to minimize the risk of errors in surgical procedures [1, 2]. During the clinical surgical process, especially in departments with surgeries characterized by "speed, efficiency, and simplicity" such as urology, the large number of surgeries and the tight time increase the risk of medical errors, such as wrong identifying of patients, operating on the wrong site, or inadequate preoperative preparation [3, 4]. Therefore, perfecting the preoperative safety verification process is particularly important, as it can effectively reduce the risk of potential medical incidents [5].

Currently, there are several issues in the implementation of the "Surgical Safety Checklist", such as reliance on paper records, being a formality, and post-hoc record additions, as well as low immediate involvement of operating room nurses, anesthesiologists, and surgeons, with verification not coming in time and unclear allocation of responsibilities [6, 7]. Additionally, reminders for critical verification points during surgery, systematic institutional learning, and standard operating procedures also need further improvement.

In the current era, artificial intelligence and network information technology are increasingly and commonly applied in all industries. Medical informatics has also been comprehensively deployed and applied in the healthcare industry [8, 9]. Utilizing an AI-based perioperative safety verification management and quality control system can effectively implement the "Surgical Safety Checklist", serving as a reminder and regulatory tool, achieving safe management practices and medical procedures, thereby enhancing medical safety [10, 11]. Based on this, this study aimed to compare the effects

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of perioperative safety checks on patients undergoing urological and general surgeries before and after the introduction of AI applications, with the aim of providing more research evidence and targets for improving surgical safety.

Materials and methods

General information

The study collected data of the Surgical Safety Checklist and related participants before and after the application of the AI-based perioperative safety verification system. The control group was comprised of surgical safety checklists from 141 urological and general surgical patients who underwent surgery from September to December 2019. The experimental group included another 71 surgical safety checklists from urological and general surgical patients from August to September 2022, receiving the AI-based perioperative safety verification system.

This study was approved by Hangzhou Children's Hospital's ethics committee. All the patients provided the informed consent.

Inclusion criteria: 1. Patients undergoing urological or general surgeries; 2. Patients with complete safety checklist data; 3. Patients without any disputes. Exclusion criteria: 1. Patients with incomplete or missing safety checklist data; 2. Emergency surgery patients.

Methods

Methods for data collection in the control group

The primary participants were the circulating nurses, surgeons, and anesthesiologists. The main assessment aspects included the initiative and timeliness of those involved in the surgical check, whether they signed off in a timely manner, and whether each item was checked systematically.

Methods for data collection in the observation group

AI-based perioperative surgical safety verification system: The AI-based perioperative surgical safety verification system was applied to clinical tests after repeated debugging and confirmation of accuracy by the IT department. Given that the system is currently in the testing phase, it uses mobile phones to simulate PDAs and uses iPads to simulate display screens and anesthesiologist's computer terminal. The clinical operation process under its assistance was shown in **Figure 1**.

The connection route between the AI-based system and other devices includes hardware devices such as multimedia displays mounted on the walls of the operating room (equipped with an AI system, camera, and voice input function), anesthesiologist's computer terminal, and the circulating nurse's PDA terminal.

Commands clicked on the computer at the anesthesia system terminal are transmitted to the multimedia display. The circulating nurse uses the PDA to scan the QR code on the patient's wristband, and the information is then transferred to the multimedia display. The voice assistant Xiao Zhi collects the information, converts it into voice broadcast, and performs information verification. After the information is confirmed to be correct, the anesthesia system automatically starts the timer, and presents it on the multimedia display screen. Subsequently, the relevant medical staff initiates the check at each time point they need. The multimedia displays the surgical safety checklist which is searched, recorded and checked by the AI-based system. See **Figure 2**.

In the anesthesia system, after the "Prepare for surgery" button on the left side of the interface was clicked (**Figure 3**), the patient information would be displayed on the multimedia display screen (**Figure 4**). At the same time, the right side of the interface revealed the patient's surgical checkpoint records, with pre-verification points displayed in black and post-verification points in red (**Figure 5**). The software interface of the multimedia display included patient information and a "Pre-Surgery Preparation Center" screen (**Figure 6**), indicating statuses of "waiting for patients to enter the operating room", "in preparation for surgery", and "preparation completed". Upon the patient entering the operating room, the status updated to "patients enter the operating room", "in surgery", and "patients exit the operating room" (**Figure 7**), and the interface would display the time of patient entering the operating room, surgery starts, and patient exiting the operating room according to the respective status. Each section's completion would be marked

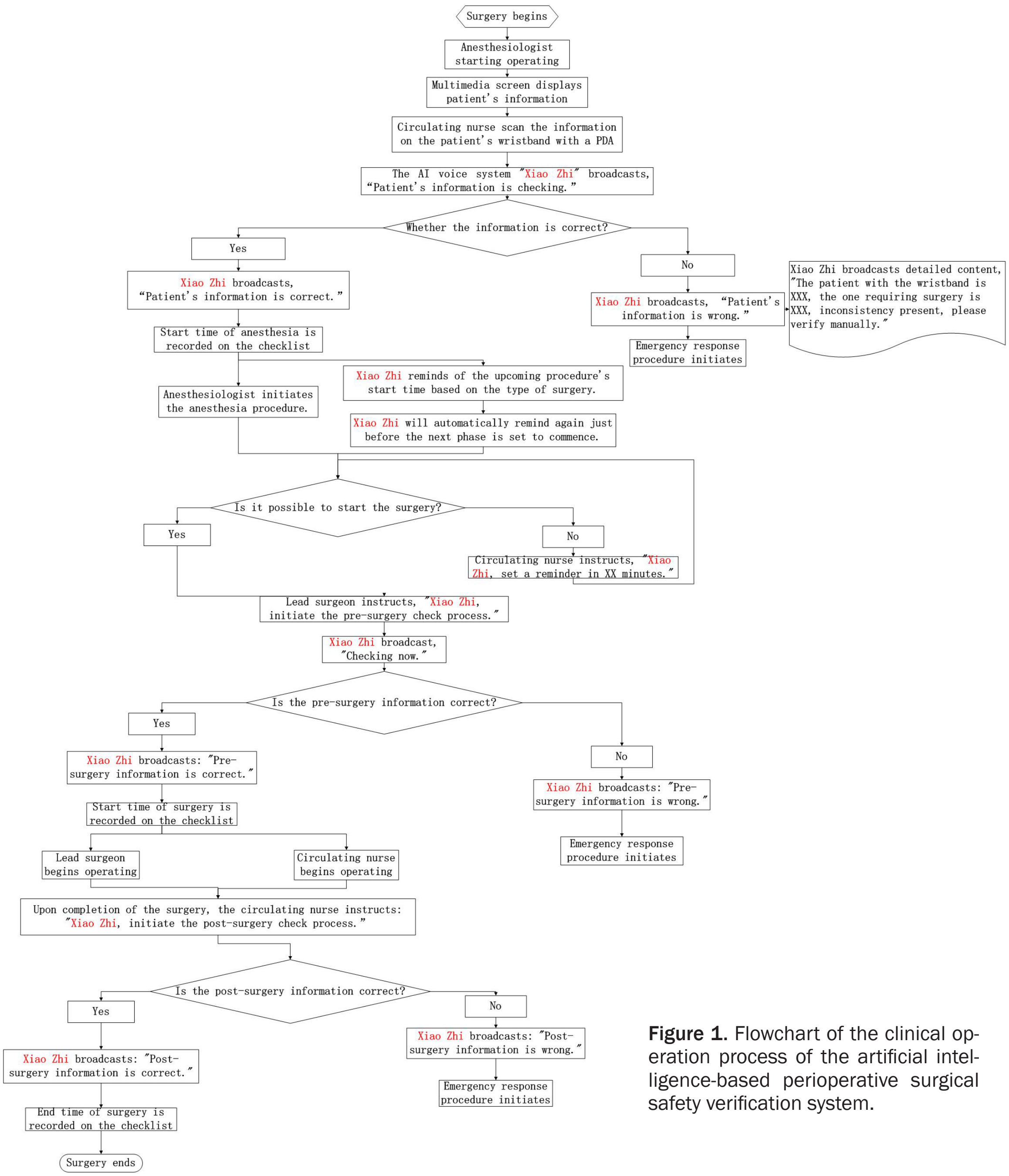

Figure 1. Flowchart of the clinical operation process of the artificial intelligence-based perioperative surgical safety verification system.

with the corresponding time points to fulfill the circulating nurse's prompt needs.

Outcome measures

Outcome measures included the execution rate and standardization rate of surgical safety check and the comfort level of patients.

By reviewing historical records, the execution rate of the surgical safety checklist for the control group is calculated. By retrieving the background voice records, the execution of the "Surgical Safety Checklist" for each surgical patient in the observation group is checked to evaluate the accuracy of the execution rate. Furthermore, by examining the records from the recovery room, the standardization rate of the checklist for both groups of patients was assessed. Lastly, by reviewing the nursing adverse event log, the incidence rate of patients entering the wrong surgery room for both

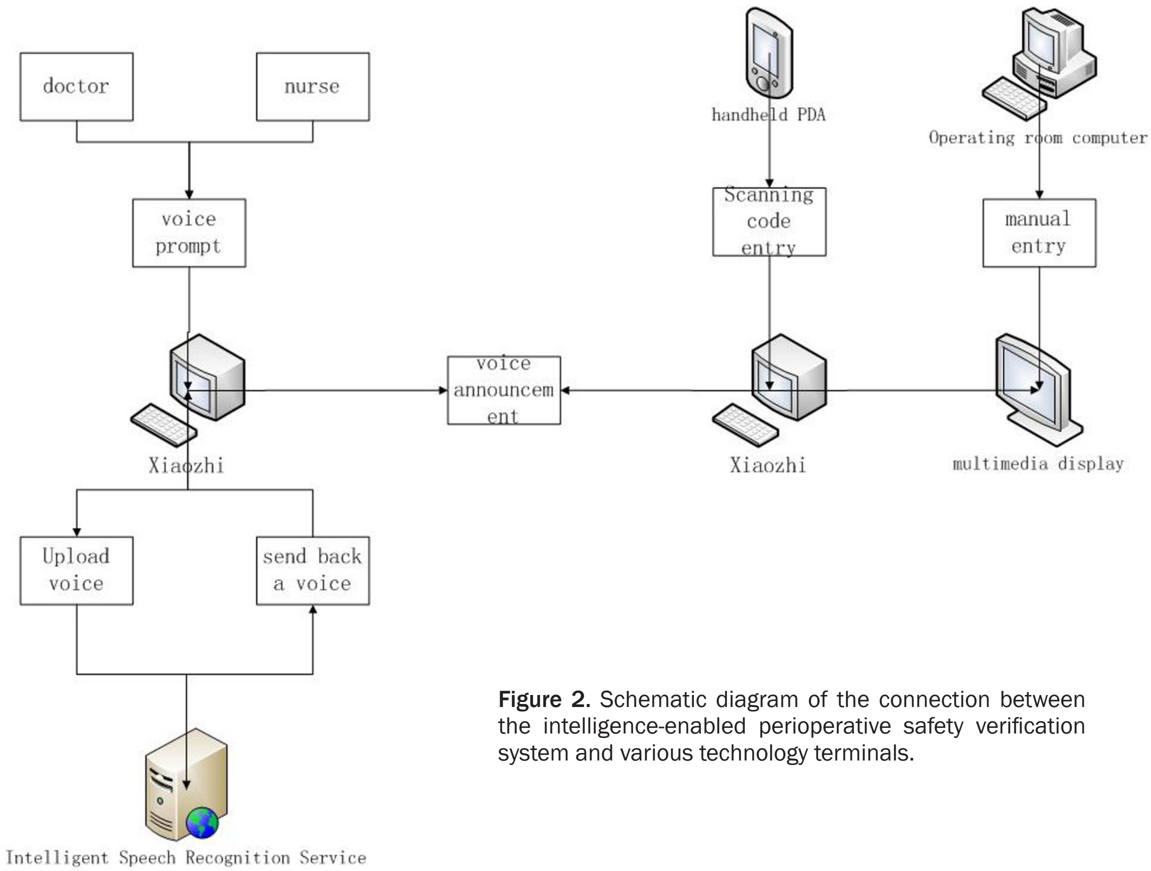

Figure 2. Schematic diagram of the connection between the intelligence-enabled perioperative safety verification system and various technology terminals.

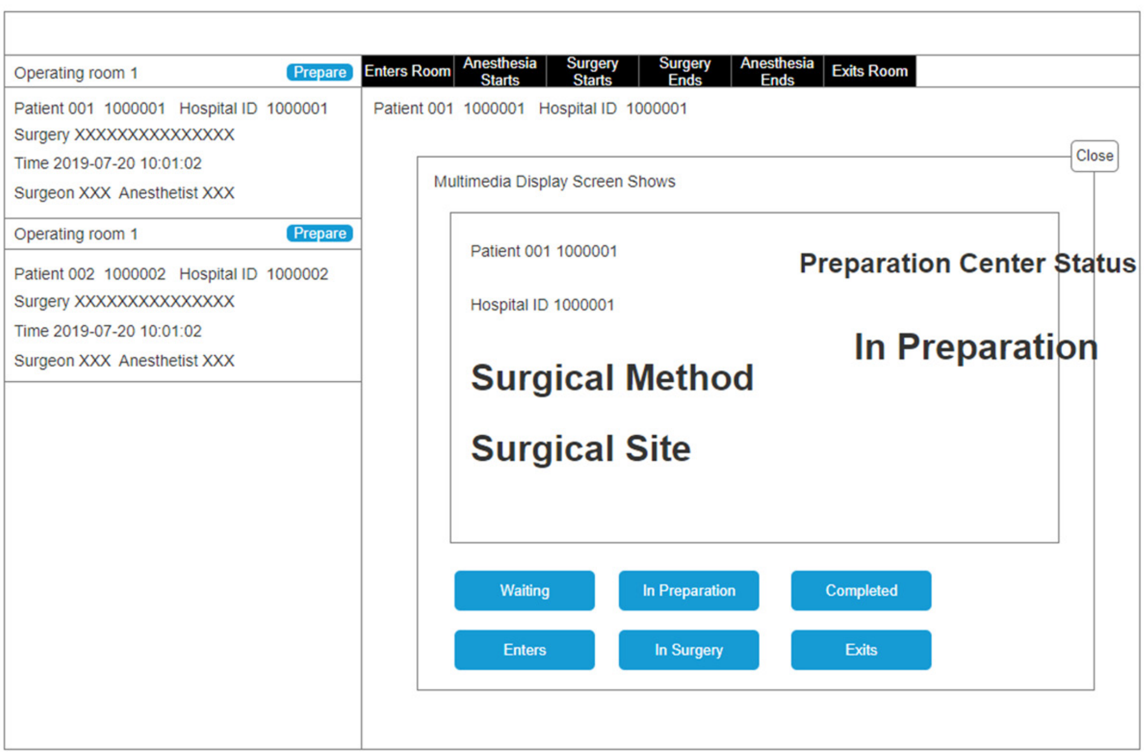

Figure 3. Anesthesia terminal before patient entering the operating room.

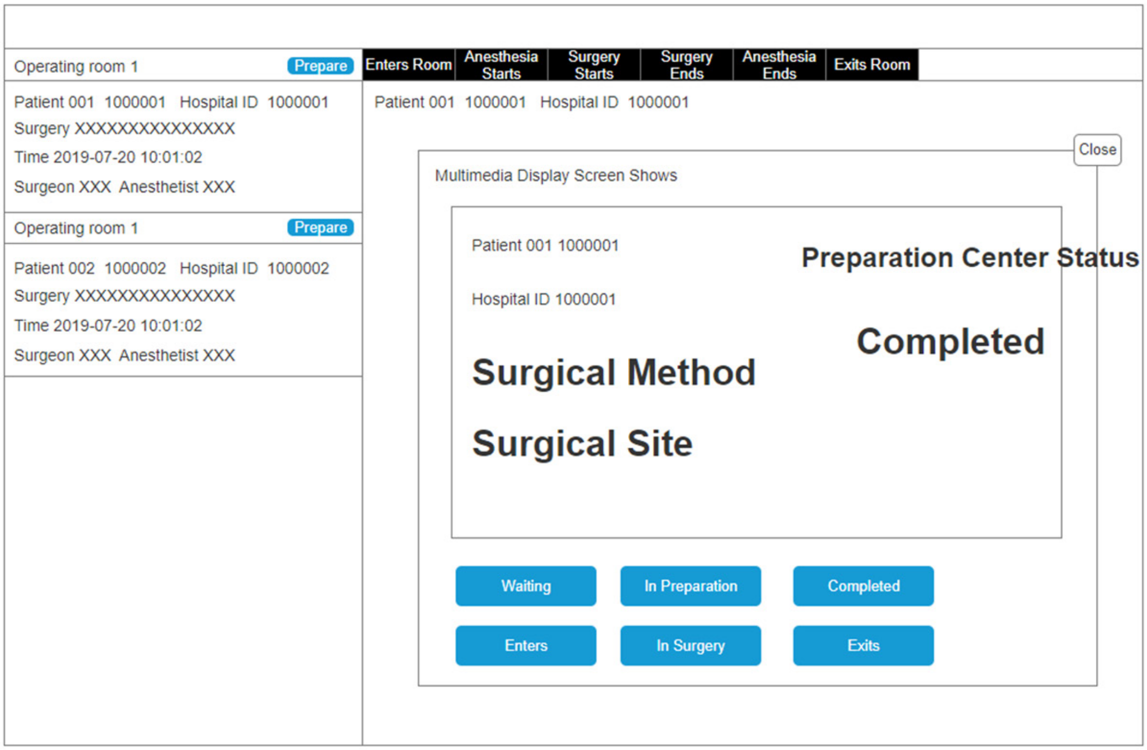

Figure 4. Multimedia display screen and anesthesia terminal before patient entering the operating room.

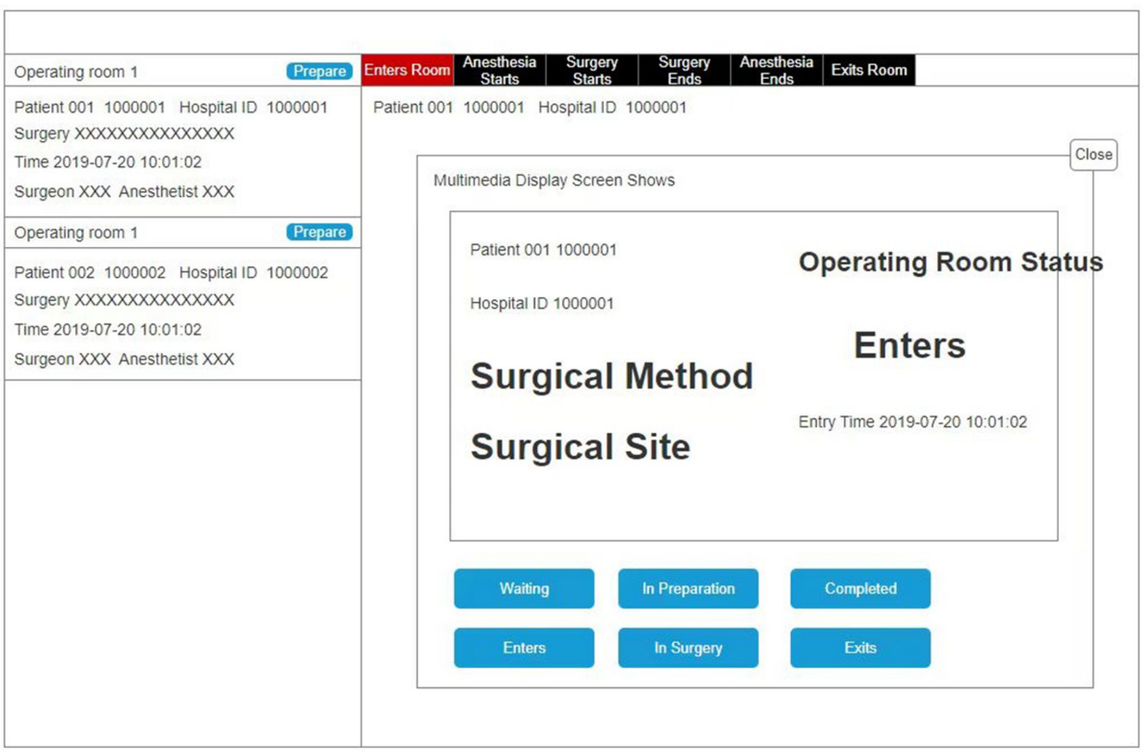

Figure 5. Multimedia display screen and anesthesia terminal before patient entering the operating room.

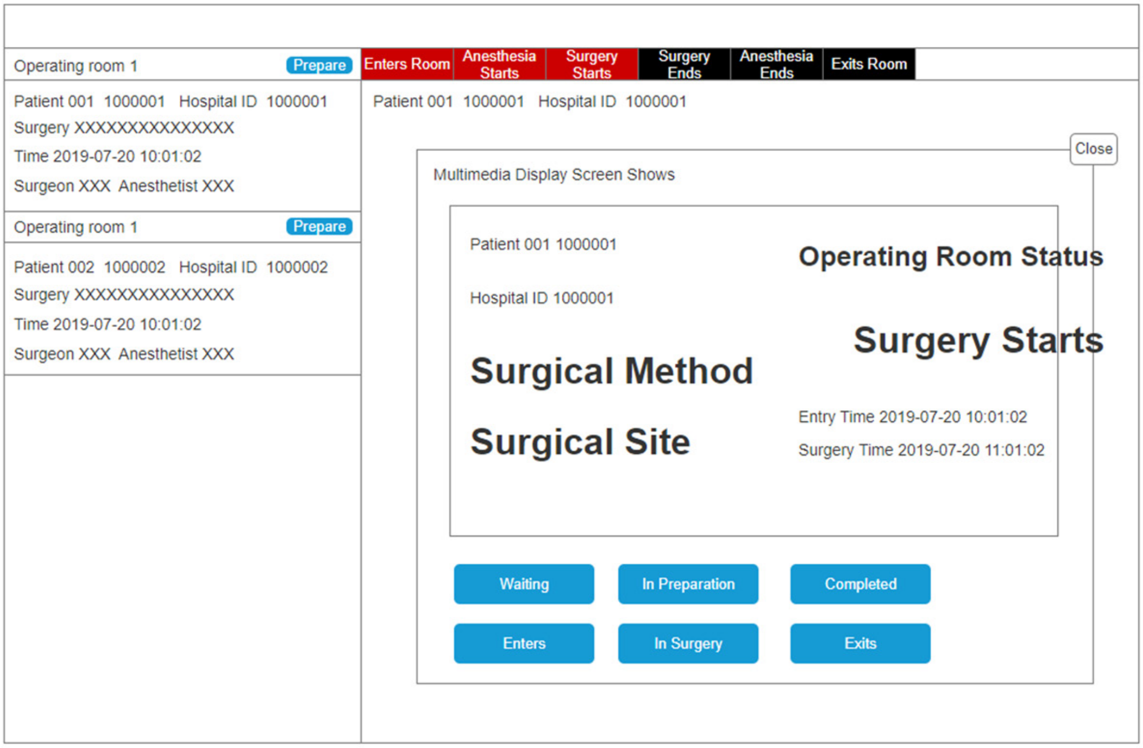

Figure 6. Multimedia display screen and anesthesia terminal after patient entering the operating room.

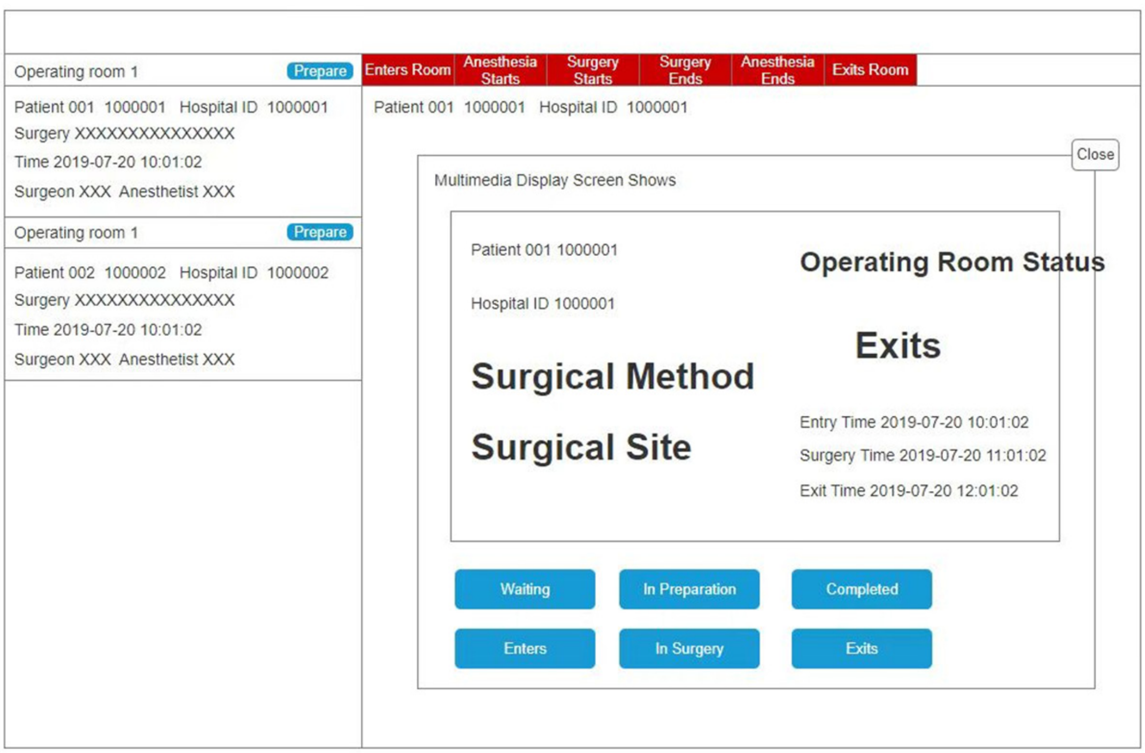

Figure 7. The multimedia display screen and anesthesia terminal after patient exiting the operating room.

Table 1. Comparison of baseline data

Group	Experimental group (n=71)	Control group (n=141)	χ^2/t	P
Gender			0.008	0.779
Male	69	136		
Female	2	5		
Age (year)	4.6±1.5	4.5±1.3	0.526	0.600
Disease type			0.495	0.584
Hydrocele	32	80		
Indirect hernia	4	12		
Prepuce	21	10		
Cryptorchism	9	8		
Urethral diseases	2	-		
Others	3	31		

Note: t: data from t-test; χ^2: data from chi-square test.

Table 2. Comparison of intraoperative data

Group	Blood loss (ml)	Comfort scores 24 h after surgery
Experimental group (n=71)	2.14±0.77	1.4±0.8
Control group (n=141)	2.38±0.30	1.5±0.9
t	0.669	0.648
P	0.504	0.773

Note: t: data from t-test.

groups was evaluated. Execution rate (%) = number of complete executions/number of cases in the group × 100. Standardization rate (%) = number of standardized cases/number of cases in the group × 100.

The comfort level of patients was assessed using the Bruggrmann Comfort Scale with five levels: 0 points for continuous pain in patients; 1 point for no pain at rest but significant pain during deep breathing or coughing; 2 points for no pain at rest and minor pain during deep breathing or coughing; 3 points for no pain during deep breathing; and 4 points for no pain during both deep breathing and coughing [10].

Participant satisfaction rate

According to relevant literature [12-15], the satisfaction of surgical team members (including surgeons, anesthesiologists, and nursing staff) was evaluated from four dimensions: efficiency of the verification process within the surgical workflow, implementation of safety measures, effectiveness of team communication and collaboration, and the effect of AI interventions on the verification process. The scoring system rates each dimension out of a maximum of 100 points, categorizing satisfaction levels into four tiers: dissatisfied (below 60 points), somewhat satisfied (60-69 points), satisfied (70-84 points), and very satisfied (85-100 points). Satisfaction Rate (%) = the number of satisfied and very satisfied cases/the total cases * 100.

Data statistics

All data were analyzed using SPSS 22.0 statistical analysis software. The measurement data were expressed as mean ± standard deviation ($\bar{x}$ ± sd), and comparisons between groups used independent sample t-tests. The count data were expressed as n, and comparisons of rates between groups were made using the Chi-square test. $P<0.05$ was considered statistically significant.

Results

Comparison of baseline data between the two groups

There were no statistically significant differences between the two groups in terms of age, and disease type (all $P>0.05$, **Table 1**).

Comparison of intraoperative data between the two groups

No statistically significant differences were found between the two groups in terms of intraoperative blood loss and comfort scores 24 hours' post-operation (all $P>0.05$, **Table 2**).

Comparison of surgical safety checklist execution and standardization rates between the two groups

There was no statistical significance between the two groups in pre-anesthesia check rates, while differences at the other two observation

Table 3. Comparison of the implementation rate and completeness rate

Group	Experimental group (n=71)	Control group (n=141)	χ²	P
Check before anesthesia			1.532	0.216
Yes	71	138		
No	0	3		
Check before surgery starts			6.290	0.012
Yes	61	99		
No	10	42		
Check before leaving the operating room			11.134	0.000
Yes	65	106		
No	6	35		

Note: χ^2: data from chi-square test.

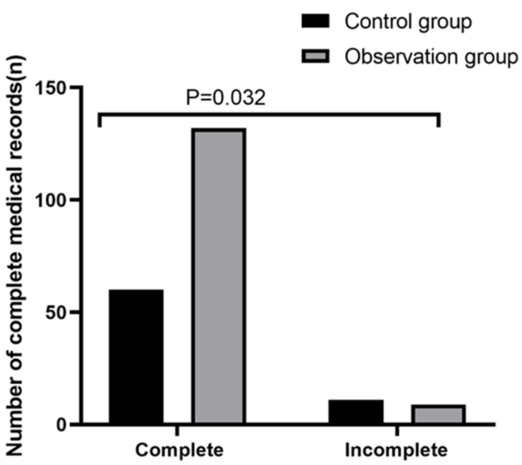

Figure 8. Comparison of the number of complete medical records between the two groups.

points, pre-surgery and before leaving the operating room, were significant (all P<0.05). Additionally, the completion rate of medical documentation in the observation group was higher than that in the control group (P=0.042). See **Table 3** and **Figure 8**.

Comparison of patient and surgical participant satisfaction between the two groups

The total satisfaction rate was higher in the observation group than that in the control group among anesthesiologists, surgeons, and nursing staff between the two groups (all P<0.05, **Table 4**).

Discussion

Currently, scholars have provided detailed interpretations of the "Surgical Safety Checklist", clarifying issues in clinical application such as the division of roles in information verification, preoperative patient preparation checks, surgical item checks, anesthesia methods, and achieving good results [16, 17]. Furthermore, since the implementation of the "Surgical Safety Checklist", relevant medical regulatory authorities have found that it can significantly reduce surgical site errors and accelerate patient recovery after surgery [18, 19]. Simultaneously, research has confirmed that strict adherence to standard operating procedures by surgeons, anesthesiologists, and circulating nurses plays a crucial role in preventing clinical errors [20]. Various measures have been implemented in different healthcare facilities. For example, the use of elastic wristbands to facilitate the verification of patient information during surgery, and covering with sterilized drapes of different colors is a reminder before surgery begins [21]. Those hospitals at the forefront of information technology have adopted digital monitoring, PDAs, and other electronic devices for management [22]. These initiatives aim to establish verification systems and processes that suit the specific conditions of each hospital, yet the field remains in a stage of continuous exploration and development.

This study investigated the effectiveness of implementing an AI-based system to assist with the execution of the "Surgical Safety Checklist" in urology and general surgeries. Compared to traditional paper-based verification methods, the use of an AI-based system significantly improved the efficiency of surgical safety checks and the completeness of the

Table 4. Comparison of surgery participant satisfaction between two patient groups

Group	Efficiency of verification methods	Implementation of safety measures	Communication and collaboration	Intervention of AI-based management in 'Surgical Triple-Checking', and the level of satisfaction/expectation with verification implementation
Experimental group (n=30)	18/30	22/30	21/30	22/30
Control group (n=40)	33/40	37/40	38/40	39/40
χ^2	4.389	4.755	8.090	8.940
P	0.361	0.029	0.004	0.003

Note: χ^2: data from chi-square test.

checklist, while effectively reducing the risk of patients entering the wrong operating room. Research from Hu et al. has shown that after applying AI, the completeness of the Surgical Safety Checklist increased by 13.08%, slightly higher than the increase observed in this study (9.72%). This difference that may be related to the small sample size in this study. In terms of execution efficiency and reducing the incidence of patients entering the wrong surgery room, findings in this study are consistent with existing research [23-25]. The mechanism might be as follows: The AI-based system integrates AI technology with multimedia electronic information, combining AI information processing with manual operations, which effectively overcomes the low execution efficiency issues of traditional paper-based methods. The application of intelligent information provides immediate and effective verification prompts and participation, ensuring the effective execution of the Surgical Safety Checklist. Each key step is monitored and reminded by electronic information, addressing issues such as low execution rates and missing pieces of the workflow, and avoiding risks like incorrect surgery sites, as well as patient identity confusion, and delays in filling out records. In this way, the AI-based system gradually achieves its goal of enhancing medical safety, seamlessly advancing the construction of a safe medical environment. Moreover, the AI-based system can also monitor the work efficiency and quality of relevant personnel through backend data, providing decision support for management, thereby further enhancing the clinical execution of the Surgical Safety Checklist and ensuring a safe medical environment.

Furthermore, this study utilized a self-designed satisfaction survey to evaluate the satisfaction levels of surgical participants, including nursing staff, surgeons, and anesthesiologists. The results indicated that the AI-based system significantly enhanced the satisfaction of all parties involved. It has been confirmed that after the adoption of AI technology, participants in surgery experienced a significant improvement in satisfaction and expectation levels regarding work efficiency in checks, execution of safety measures, communication and collaboration, and AI-managed intervention in the "Surgical Tripartite Check" similar to the findings of this study [26, 27]. This may be attributed to the AI-based system's effective promotion of the efficient and safe execution of clinical safety checks, which reduced the workload of medical staff, sped up the surgical process, and lowered the potential for errors in medical records. Moreover, from a management and quality control perspective, on the one hand, it enhanced the supervision of the execution effectiveness of the roles involved in the surgery. On the other hand, through high-quality safety checks, it further increased the rigor of the surgical process and the completeness of all tasks, achieving intelligent safety management in the perioperative period.

Since this is a single-center study with a small sample size, it necessitates future research with larger sample sizes to further validate the practical effects of the AI-based system in clinical settings. Additionally, how to broaden the application of the AI-based system becomes a crucial premise for verifying its actual effectiveness.

In summary, the AI-based system not only enhances the execution and standardization rates of surgical safety checks but also reduces the risk of patients entering the wrong operating room, and increases the satisfaction levels among all surgical participants. Therefore, it is highly recommended for clinical application.

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Disclosure of conflict of interest

None.

Address correspondence to: Dongfang Weng, Operating Room, Hangzhou Children's Hospital, No. 201 Wenhui Road, Gongshu District, Hangzhou 310000, Zhejiang, China. Tel: +86-18069802800; E-mail: hzchranran@163.com

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