

Evaluating the Effectiveness of an Intelligent Single-Instrument Sterilization Tracking Management System: An Application of the Information System Success Model among Frontline Nurses

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Abstract

Background:

Effective surgical instrument management is critical for perioperative safety and workflow efficiency. While smart tracking technologies are increasingly adopted, empirical evidence evaluating these systems from the perspective of frontline nursing staff remains limited. This study aimed to evaluate the effectiveness of an intelligent single-instrument sterilization tracking system using the Information System Success Model (ISSM).

Methods:

A cross-sectional study was conducted among 224 clinical nurses at a regional hospital in Southern Taiwan from February 15 to May 31, 2025. Data were collected via a validated questionnaire based on the ISSM, assessing six dimensions: system quality, information quality, service quality, intention to use, user satisfaction, and perceived net benefits. Statistical analyses included descriptive statistics, t-tests, ANOVA, Pearson's correlation, and multiple regression analysis.

Results:

Participants reported high positive evaluations across all ISSM dimensions (means ranging from 3.20 to 3.31 on a 4-point scale). Information quality emerged as the strongest predictor of user satisfaction ($\beta = 0.65$, $p < .001$). System quality, information quality, and service quality significantly predicted intention to use ($R^2 = 0.78$). Notably, usage frequency significantly influenced perceptions of system quality ($p = .044$) and satisfaction ($p = .018$). The final regression model explained 78% of the variance in perceived net benefits, with intention to use and user satisfaction serving as key determinants.

Conclusions:

The intelligent tracking system is highly accepted by nurses and provides significant clinical value. Ensuring high information quality—specifically the accuracy and timeliness of data—is paramount for sustaining user satisfaction. Healthcare administrators should prioritize structured training and responsive technical support to maximize the benefits of digital traceability in perioperative environments.

Introduction

Ensuring the safety, traceability, and efficiency of surgical instrument management has become a critical global priority as healthcare delivery grows increasingly complex. The World Health Organization identifies unsafe care as one of the leading causes of death and disability worldwide and emphasizes traceability and prevention of avoidable harm as core goals in the Global Patient Safety Action Plan 2021–2030 [1]. Similarly, the ECRI Institute has repeatedly listed inadequate device tracking and recall management among the top health technology hazards, underscoring the risks associated with incomplete or inaccurate instrument traceability [2].

Ineffective tracking can lead to instrument loss, packaging errors, repeated sterilization, workflow delays, and compromised patient safety. In contrast, smart tracking technologies—such as barcodes, radio frequency

identification (RFID), and Unique Device Identifiers (UDI)—have demonstrated the ability to enhance instrument localization, workflow transparency, and traceability, thereby improving operating room efficiency and reducing safety risks[3, 4, 5, 6]. Despite these benefits, the successful implementation of smart instrument tracking systems depends not only on technological capability but also on organizational processes, data integration, and user behavior. Evidence from digital health and artificial intelligence (AI) implementation shows that transitioning from static datasets to real time clinical integration is challenging, with data quality, interoperability, and workflow alignment frequently cited as barriers [7].

Research on information security behaviors further highlights that inadequate standardization, insufficient training, and inconsistent user practices can compromise information quality and system reliability [8]. These challenges are highly relevant to instrument tracking systems, which require seamless coordination across operating rooms, central sterile supply departments, and hospital information systems. Nurses play a central role in both surgical instrument management and the use of healthcare information systems. Their perceptions, workload, and user experience directly influence system adoption and effectiveness. Studies show that information systems that reduce workload and streamline processes can improve nurses' satisfaction and willingness to use the system [9]. User experience—including ease of use, learnability, navigability, information presentation, and workflow integration—has also been shown to significantly affect acceptance and sustained use[10, 11, 12]. Conversely, systems that are difficult to use or poorly aligned with clinical workflows may lead to workarounds, reduced engagement, and diminished system benefits [13].

The Information System Success Model (ISSM) proposed by DeLone and McLean provides a comprehensive framework for evaluating information system performance. The model posits that system quality, information quality, and service quality influence user satisfaction and intention to use, which in turn affect perceived net benefits [14, 15, 16]. Subsequent studies have validated the applicability of ISSM in healthcare settings, identifying information quality as a key determinant of satisfaction and service quality as a driver of trust and continued use [17, 18, 19]. Empirical research in hospital information systems further confirms that these three quality dimensions are strong predictors of user intention and satisfaction [20].

Although smart instrument tracking systems are increasingly adopted worldwide, existing research has primarily focused on technical feasibility, workflow improvements, or policy implications. Limited attention has been given to nurses' user experience, perceptions of system quality, and the determinants of system success within the ISSM framework. In particular, the relationships among system quality, user satisfaction, intention to use, and perceived benefits remain underexplored among frontline nursing staff. Therefore, this study applies the ISSM to examine nurses' evaluations of system quality, information quality, and service quality in a smart single instrument tracking system. It further investigates how these factors relate to user satisfaction, intention to use, and perceived benefits, and explores whether demographic characteristics and user experience influence system perceptions. The findings aim to provide empirical evidence to guide healthcare organizations in optimizing system implementation, enhancing training strategies, and advancing the development of smart surgical instrument management systems.

Methods

Study Design and Participants

A cross-sectional study design was employed to evaluate the effectiveness of an intelligent single-instrument sterilization tracking management system among clinical nurses and to validate the relationships within the ISSM. The study was conducted at a regional hospital in Southern Taiwan from February 15 to May 31, 2025. Eligible

participants were required to meet the following inclusion criteria: (1) possession of a valid nursing license, (2) employment at the study hospital for at least three months, and (3) direct experience in operating the single-instrument sterilization tracking system. Nurses were excluded if they had less than three months of experience with the system or were unwilling to participate.

To ensure sufficient sensitivity for detecting associations within this population, we assumed a small-to-medium effect size of 0.20 based on Cohen's guidelines [21], with $\alpha = 0.05$ and a power of 0.90. The G*Power calculation indicated a minimum requirement of 207 participants. To account for a projected 10% attrition rate, the study targeted the recruitment of 230 individuals. Ultimately, 230 questionnaires were distributed, and 229 were returned (response rate: 99.6%). After excluding five incomplete responses, 224 valid questionnaires were included in the final analysis, yielding an effective response rate of 97.8%.

Ethical Considerations

The study protocol was reviewed and approved by the Institutional Review Board of Kaohsiung Veterans General Hospital (IRB No. KSVGH25 CT2 16). All procedures involving human participants were conducted in accordance with the ethical standards of the institutional research committee and the Declaration of Helsinki. Written informed consent was obtained from all participants prior to data collection.

Instruments

The structured questionnaire used in this study consisted of seven sections, totaling 32 items. The first section, (i) Demographics, was developed specifically for this study and included eight items: gender, age, education level, marital status, managerial position, clinical ladder level, nursing experience, and system usage frequency.

Sections (ii) through (vii) were adapted from the validated scales of Ojo (2017) [17], which are based on the Information System Success Model (ISSM) framework developed by DeLone and McLean (2003) [15]. These sections evaluate the following dimensions:

1. System Quality (4 items): Assessed system ease of use, data access speed, interface flexibility, stability, and convenience of data retrieval.
2. Information Quality (4 items): Evaluated the accuracy, completeness, timeliness, and reliability of the information provided by the system.
3. Service Quality (4 items): Covered technical support, system maintenance, the ability to provide accurate information promptly, and data integrity to ensure smooth workflow.
4. Intention to Use (4 items): Measured the system's ability to help users complete tasks quickly, improve performance, ease the workload, and perceived helpfulness.
5. User Satisfaction (3 items): Gauged satisfaction with system functions, workflow simplification, and overall satisfaction.
6. Perceived Net Benefits (5 items): Assessed the advantages of the system over traditional paper-based records, including improvements in record quality, retrieval efficiency, and overall system effectiveness.

Participants' responses for sections (ii) through (vii) were measured using a 4-point Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree). This specific format was adopted to eliminate the "neutral" midpoint, thereby minimizing central tendency bias and requiring respondents to provide a definitive evaluation of the system.

For each dimension, a composite score was calculated by averaging the scores of the constituent items, where higher mean scores indicated more positive perceptions of system quality, user satisfaction, and net benefits.

The instrument underwent validity and reliability testing. Content validity was evaluated by six experts with experience in medical informatics and clinical practice, yielding a Content Validity Index (CVI) exceeding 0.95. Reliability analysis showed that Cronbach's α values for all dimensions ranged between 0.94 and 0.96, indicating high internal consistency.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 24.0. Descriptive statistics, including absolute and relative frequencies, were used to summarize categorical variables, while means (M) and standard deviations (SD) were used for continuous variables. Inferential statistics included independent sample t-tests and one-way analysis of variance (ANOVA) with Scheffé's method to examine differences in system perceptions across demographic groups. Pearson's correlation coefficients were utilized to analyze the relationships among System Quality, Information Quality, Service Quality, Intention to Use, User Satisfaction, and Perceived Net Benefits. Finally, multiple regression analyses were performed to validate the hypothesized relationships within the ISSM framework. Statistical significance was defined as a two-tailed p-value < 0.05 .

Research Framework

Figure 1 illustrates the research framework guiding this study, which is based on the ISSM. In this model, System Quality, Information Quality, and Service Quality were conceptualized as key antecedent variables influencing Intention to Use and User Satisfaction [17]. These two user-related constructs were subsequently hypothesized to predict Perceived Net Benefits. This framework reflects the theoretical pathways tested through correlation and multiple regression analyses in the present study.

Results

Descriptive and Inferential Analysis of Participant Characteristics on Quality Dimensions (Table 1)

Table 1

Characteristics Associated with Perceived System, Information, and Service Quality among Nurses (N = 224)

Characteristics	N	System Quality			Information Quality			Service Quality		
		Mean (SD)	t/F	P	Mean (SD)	t/F	P	Mean (SD)	t/F	P
Gender										
Male	16	3.20(0.42)	0.01	.990	3.25(0.41)	-0.22	.826	3.19(0.43)	-0.70	.487
Female	207	3.20(0.45)			3.28(0.47)			3.27(0.47)		
Age										
< 30 years old	145	3.16(0.41)	1.55	.214	3.23(0.44)	2.03	.133	3.24(0.44)	1.00	.369
30–40 years old	42	3.29(0.52)			3.35(0.52)			3.35(0.57)		
> 40 years old	37	3.24(0.48)			3.36(0.48)			3.28(0.48)		
Education level										
^a Associate's degree	28	3.27(0.42)	1.16	.317	3.40(0.44)	2.43	.090	3.39(0.49)	1.40	.250
^b Bachelor's degree	190	3.18(0.45)			3.25(0.46)			3.24(0.47)		
^c Master's degree or above	6	3.41(0.49)			3.54(0.51)			3.38(0.49)		
Marital status										
Single	164	3.18(0.43)	-1.00	.319	3.25(0.46)	-1.17	.244	3.26(0.46)	-0.42	.675
Married	60	3.25(0.48)			3.33(0.18)			3.29(0.51)		
Managerial position										
Yes	17	3.32(0.47)	1.18	.238	3.32(0.47)	0.46	.645	3.32(0.47)	0.53	.599
No	207	3.19(0.44)			3.27(0.46)			3.26(0.47)		
Clinical ladder level										
N	51	3.19(0.39)	1.71	.165	3.24(0.41)	0.53	.662	3.23(0.44)	0.50	.682
N1	65	3.10(0.41)			3.24(0.44)			3.23(0.48)		
N2	85	3.27(0.48)			3.32(0.50)			3.31(0.48)		
N3 or N4	23	3.25(0.52)			3.25(0.52)			3.14(0.51)		
Nursing experience										
Note: * P<.05										

Characteristics	N	System Quality			Information Quality			Service Quality		
		Mean (SD)	t/F	P	Mean (SD)	t/F	P	Mean (SD)	t/F	P
(years)										
^a <1 year	16	3.13(0.34)	1.84	.123	3.13(0.34)	1.38	.243	3.13(0.34)	0.86	.489
^b 1–3 years	79	3.12(0.40)			3.22(0.43)			3.23(0.44)		
^c 3–5 years	40	3.24(0.45)			3.29(0.51)			3.31(0.47)		
^d 5-10 years	30	3.36(0.49)			3.41(0.48)			3.37(0.49)		
^e >10 years	59	3.22(0.48)			3.31(0.50)			3.27(0.53)		
System usage frequency										
^a Occasionally	50	3.14(0.45)	3.16*	.044	3.22(0.42)	2.09	.126	3.24(0.43)	1.18	.311
^b Frequently	78	3.14(0.40)		^c > ^{a,b}	3.22(0.43)			3.21(0.45)		
^c Always	96	3.29(0.47)			3.35(0.51)			3.32(0.51)		
Total	224	3.20(0.44)			3.27(0.46)			3.27(0.47)		
Note: * P<.05										

The initial phase of the analysis focused on the descriptive statistics of the three core quality dimensions of the ISSM: System Quality, Information Quality, and Service Quality. For the total sample of 224 nurses, the overall mean scores for System Quality, Information Quality, and Service Quality were 3.20 (SD = 0.44), 3.27 (SD = 0.46), and 3.27 (SD = 0.47), respectively, based on a 4-point Likert scale. These scores indicate that the participants generally held a positive perception of the intelligent single-instrument sterilization tracking system across all quality domains.

Regarding System Quality, the analysis examined potential differences based on demographic characteristics. Gender-based analysis showed that both males (M = 3.20, SD = 0.42) and females (M = 3.20, SD = 0.45) perceived system quality identically, with no significant difference (t = 0.01, p=.990). Age also did not play a significant role (F = 1.55, p=.214), although nurses aged 30–40 years reported a slightly higher mean (M = 3.29, SD = 0.52) compared to those under 30 (M = 3.16, SD = 0.41). Furthermore, education level (F = 1.16, p=.317), marital status (t = - 1.00, p=.319), and managerial position (t = 1.18, p=.238) showed no statistically significant impact on perceived system quality.

Notably, system usage frequency was the only variable that significantly influenced perceived system quality (F = 3.16, p=.044). Post-hoc analysis (if applicable) and descriptive trends suggested that participants who used the system "Always" (M = 3.29, SD = 0.47) rated system quality significantly higher than those who used it "Occasionally" (M = 3.14, SD = 0.45), indicating that increased exposure to the system may enhance the perception of its technical stability and functionality.

In terms of Information Quality and Service Quality, the results remained consistent across most demographic subgroups. For Information Quality, although nurses with a Master's degree or above reported the highest mean

score ($M = 3.54$, $SD = 0.51$), the overall effect of education level did not reach statistical significance ($F = 2.43$, $p = .090$). Similarly, regarding Service Quality, no significant differences were found across gender ($p = .487$), age ($p = .369$), education ($p = .250$), or nursing experience ($p = .489$). The perceived service quality remained stable across different levels of the clinical ladder ($F = 0.50$, $p = .682$), ranging from a mean of 3.14 to 3.31.

Demographic Influence on Intention to Use, User Satisfaction, and Perceived Net Benefits (Table 2)

Table 2
Characteristics Associated with Intention to Use, User Satisfaction, and Perceived Net Benefits among Nurses (N = 224)

Characteristics	N	Intention to Use			User Satisfaction			Perceived Net Benefits		
		Mean (SD)	t/F	P	Mean (SD)	t/F	P	Mean (SD)	t/F	P
Gender										
Male	16	3.22(0.40)	-0.41	.221	3.19(0.42)	-1.20	.244	3.21(0.42)	-0.67	.502
Female	207	3.27(0.47)			3.32(0.48)			3.29(0.47)		
Age										
< 30 years old	145	3.22(0.43)	1.80	.167	3.26(0.46)	2.32	.101	3.26(0.44)	1.49	.228
30–40 years old	42	3.40(0.54)			3.38(0.52)			3.40(0.52)		
> 40 years old	37	3.30(0.49)			3.42(0.48)			3.29(0.49)		
Education level										
^a Associate’s degree	28	3.38(0.46)	1.32	.270	3.46(0.49)	2.68	.071	3.36(0.48)	1.41	.247
^b Bachelor’s degree	190	3.24(0.46)			3.28(0.47)			3.27(0.46)		
^c Master’s degree or above	6	3.38(0.49)			3.56(0.50)			3.53(0.47)		
Marital status										
Single	164	3.25(0.44)	-0.51	.613	3.30(0.47)	-0.66	.511	3.27(0.45)	-0.72	.475
Married	60	3.29(0.53)			3.34(0.51)			3.32(0.50)		
Managerial position										
Yes	17	3.35(0.55)	0.83	.410	3.35(0.51)	0.39	.698	3.20(0.53)	-0.80	.425
No	207	3.26(0.46)			3.31(0.48)			3.29(0.46)		
Clinical ladder level										
N	51	3.24(0.41)	0.30	.827	3.25(0.43)	1.66	.176	3.25(0.42)	1.01	.390
N1	65	3.23(0.43)			3.25(0.45)			3.23(0.46)		
N2	85	3.29(0.51)			3.40(0.51)			3.35(0.48)		
N3 or N4	23	3.29(0.54)			3.27(0.54)			3.28(0.51)		
Note: * P<.05										

Characteristics	N	Intention to Use			User Satisfaction			Perceived Net Benefits		
		Mean (SD)	t/F	P	Mean (SD)	t/F	P	Mean (SD)	t/F	P
Nursing experience (years)										
^a <1 year	16	3.13(0.34)	0.61	.654	3.13(0.34)	1.08	.367	3.13(0.34)	1.42	.230
^b 1–3 years	79	3.24(0.41)			3.28(0.45)			3.25(0.45)		
^c 3–5 years	40	3.29(0.50)			3.34(0.53)			3.37(0.47)		
^d 5–10 years	30	3.33(0.53)			3.41(0.50)			3.40(0.47)		
^e >10 years	59	3.28(0.50)			3.33(0.50)			3.26(0.49)		
System usage frequency										
^a Occasionally	50	3.21(0.42)	1.28	.279	3.22(0.42)	4.07*	^c > ^{a,b}	3.22(0.42)	1.68	.190
^b Frequently	78	3.23(0.46)			3.24(0.46)			3.25(0.47)		
^c Always	96	3.32(0.49)			3.41(0.51)			3.35(0.48)		
Total	224	3.26(0.46)			3.31(0.48)			3.29(0.47)		
Note: * P<.05										

Table 2 presents the descriptive and inferential statistics for the outcome dimensions of the ISSM: Intention to Use (M = 3.26, SD = 0.46), User Satisfaction (M = 3.31, SD = 0.48), and Perceived Net Benefits (M = 3.29, SD = 0.47).

The intention to use the system was consistently high across all groups. For example, nurses in managerial positions reported a mean intention of 3.35 (SD = 0.55), while non-managers reported 3.26 (SD = 0.46), but this difference was not statistically significant (t = 0.83, p=.410). Age groups also showed no significant variance (F = 1.80, p=.167), despite the 30–40 age group having the highest mean (M = 3.40, SD = 0.54). Total nursing experience (F = 0.61, p=.654) and clinical ladder levels (F = 0.30, p=.827) likewise did not affect the nurses' intention to adopt the tracking system.

A significant finding was observed in User Satisfaction related to system usage frequency (F = 4.07, p=.018). Nurses who used the system "Always" reported significantly higher satisfaction levels (M = 3.41, SD = 0.51) compared to those who used it "Occasionally" (M = 3.22, SD = 0.42). This suggests that high-frequency users might find the system more indispensable to their daily workflow, thereby leading to higher satisfaction.

Regarding Perceived Net Benefits, no demographic characteristics showed significant associations. Whether categorized by gender (p=.502), age (p=.228), marital status (p=.475), or nursing experience (p=.230), the perceived benefits of the system remained high and uniform across the cohort. This indicates a general consensus among the nursing staff that the intelligent tracking system provides substantial value in instrument sterilization and management, regardless of their personal professional background.

Inter-dimensional Correlation Analysis (Table)

Table 3

Correlations between System quality, Information quality, Service quality, Intention to use, User satisfaction and Perceived net benefits among Nurses (N = 244)

Measures	System quality	Information quality	Service quality	Intention to use	User satisfaction	Perceived net benefits
System quality	1	0.777 ^{***}	0.763 ^{***}	0.810 ^{***}	0.732 ^{***}	0.742 ^{***}
Information quality		1	0.840 ^{***}	0.822 ^{***}	0.863 ^{***}	0.777 ^{***}
Service quality			1	0.822 ^{***}	0.807 ^{***}	0.805 ^{***}
Intention to use				1	0.892 ^{***}	0.849 ^{***}
User satisfaction					1	0.846 ^{***}
Perceived net benefits						1
Note: ^{***} P<.001						

The interrelationships between the six dimensions of the ISSM were assessed using Pearson's correlation coefficient (r). As illustrated in Table 3, all dimensions exhibited positive and statistically significant correlations at the $p<.001$ level, indicating strong internal consistency within the theoretical framework.

System Quality was found to have a strong positive correlation with both Information Quality ($r = 0.777$, $p<.001$) and Service Quality ($r = 0.763$, $p<.001$). Information Quality and Service Quality also shared a very strong correlation ($r = 0.840$, $p<.001$), suggesting that when nurses perceive the information provided by the system as accurate and reliable, they are also likely to view the support services as being of high quality.

The analysis revealed that User Satisfaction had the strongest correlation with Information Quality ($r = 0.863$, $p<.001$), emphasizing that the accuracy and timeliness of instrument data are primary drivers of nursing satisfaction. Furthermore, Intention to Use was highly correlated with System Quality ($r = 0.810$, $p<.001$) and Service Quality ($r = 0.822$, $p<.001$).

The ultimate outcome variable, Perceived Net Benefits, demonstrated robust correlations with all other dimensions. Most notably, its correlation with Intention to Use ($r = 0.849$, $p<.001$) and User Satisfaction ($r = 0.846$, $p<.001$) confirms that the more satisfied the nurses are and the more they intend to use the system, the more they perceive the overall benefits to their clinical practice and patient safety.

Predictors of System Success: Multiple Regression Analysis (Table)

Table 4

Summary of multiple regression analyses for Intention to use, User satisfaction, and Perceived net benefits among Nurses (N = 244)

Dependent Variable	Predictors	Unstandardized regression coefficient		t	p	VIF	R ²
		β	standard error				
Intention to use	Constant	0.14	0.11	1.29	.199		0.78
	System quality	0.36	0.06	6.41***	< .001	2.82	
	Information quality	0.29	0.06	4.50***	< .001	3.98	
	Service quality	0.32	0.06	5.16***	< .001	3.78	
User satisfaction	Constant	0.26	0.11	2.27*	.024		0.77
	Information quality	0.65	0.06	10.49***	< .001	3.38	
	Service quality	0.29	0.06	4.71***	< .001	3.38	
Perceived net benefits	Constant	0.28	0.11	2.57*	.011		0.78
	Service quality	0.25	0.06	4.30***	< .001	3.36	
	Intention to use	0.34	0.08	4.41***	< .001	5.74	
	User satisfaction	0.33	0.07	4.69***	< .001	5.33	
Note: * P<.05, ***P<.001							

To determine the predictive power of the various ISSM dimensions, three separate multiple regression models were developed. Each model demonstrated a high explanatory power, with R² values ranging from 0.77 to 0.78.

In the first model, System Quality, Information Quality, and Service Quality were entered as predictors of Intention to Use. The model was significant and explained 78% of the variance (R² = 0.78). All three quality dimensions were significant predictors: System Quality (β = 0.36, t = 6.41, p < .001), Information Quality (β = 0.29, t = 4.50, p < .001), and Service Quality (β = 0.32, t = 5.16, p < .001). These results indicate that technical stability, data accuracy, and administrative support are all vital in fostering a nurse's willingness to use the tracking system.

The second model focused on User Satisfaction. Information Quality and Service Quality were significant predictors, accounting for 77% of the variance (R² = 0.77). Information Quality exerted a particularly strong influence (β = 0.65, t = 10.49, p < .001), while Service Quality also remained a significant contributor (β = 0.29, t = 4.71, p < .001). This confirms that the quality of information is the most critical factor in determining how satisfied nurses are with the sterilization tracking system.

The final model evaluated the predictors of Perceived Net Benefits. After accounting for the influence of Service Quality, Intention to Use, and User Satisfaction, the model explained 78% of the variance (R² = 0.78). Service Quality (β = 0.25, t = 4.30, p < .001), Intention to Use (β = 0.34, t = 4.41, p < .001), and User Satisfaction (β = 0.33, t = 4.69,

$p < .001$) were all significant positive predictors. This highlights that the ultimate success and perceived value of the system are determined not only by service support but also by the psychological and behavioral responses of the users (satisfaction and intention).

To ensure the validity of the regression models, multicollinearity was assessed using the Variance Inflation Factor (VIF). The VIF values for all predictors across the three models ranged from 2.82 to 5.74. Since all values were well below the common threshold of 10, it can be concluded that multicollinearity did not significantly bias the regression estimates, ensuring the reliability of the predictive paths identified in this study.

Discussion

This study examined nurses' perceptions of System Quality, Information Quality, Service Quality, Satisfaction, Intention to Use, and Perceived Net Benefits within an intelligent single-instrument sterilization tracking management system. Overall, the findings demonstrate strong acceptance of the system and highlight the central role of information quality and service support in shaping user satisfaction and behavioral intention. These results align with the ISSM, which posits that system, information, and service quality are foundational determinants of system success [14, 15, 16].

Consistent with prior research, information quality emerged as the strongest predictor of user satisfaction. Nurses valued accurate, timely, and reliable instrument-related data, which directly supports clinical workflow and reduces uncertainty. Similar findings have been reported in studies of nursing information systems, where high-quality information enhances trust, reduces cognitive load, and improves perceived usefulness [10, 11]. Evidence from Malaysian public hospitals further supports this relationship, showing that information quality significantly predicts both user satisfaction and perceived net benefits [20]. Additionally, Zhang et al. [22] demonstrated that high information quality within an intensive care unit (ICU) electronic medical record (EMR) quality control system significantly improved nurses' satisfaction and perceived system value. Recent evidence from AI implementation research further reinforces this point: Rahimi et al. [7] found that data quality and real-time data integration are critical enablers of successful digital system adoption, highlighting that information integrity directly shapes user trust and perceived usefulness. The strong correlation between information quality and satisfaction in this study underscores the importance of reliable information in high-risk environments such as operating rooms.

Service quality also significantly influenced both satisfaction and intention to use. This echoes previous evidence showing that training, technical support, and responsive assistance are critical for sustaining engagement with digital systems [8, 12]. Newer literature on digital readiness further supports this finding. Mabaso et al. [23] emphasized that effective communication, training support, and organizational culture strongly shape nurses' readiness for digitalization. Their qualitative findings highlight that emotional support, technology literacy, and continuous communication are essential for successful adoption—factors that closely mirror the service quality dimension in ISSM. Similarly, Rahimi et al. [7] reported that organizational readiness, technical support, and workflow alignment are key determinants of successful AI system implementation, underscoring the importance of service quality in promoting user acceptance. Thus, the present study adds quantitative evidence to the growing recognition that human-centered implementation strategies are indispensable for digital transformation in healthcare.

System quality was also a significant predictor of intention to use, consistent with prior studies showing that ease of use, stability, and workflow integration influence acceptance of clinical technologies [9, 12]. The Technology Acceptance Model (TAM) literature provides additional insight: perceived usefulness and ease of use are central

determinants of behavioral intention [24, 25]. In the context of smart instrument tracking, nurses who frequently used the system rated its quality higher, suggesting that familiarity reduces perceived complexity and enhances perceived usefulness. This aligns with Strudwick [24], who found that repeated exposure increases comfort and acceptance of smart infusion pumps. Similarly, Zhang et al. [22] reported that system stability and workflow integration within an ICU EMR quality control system significantly enhanced nurses' intention to use the platform. Rahimi et al. [7] also emphasized that system reliability and workflow compatibility are essential for sustaining engagement with AI-enabled systems, further supporting the importance of robust system design. Together, these results suggest that early hands-on experience and iterative training may accelerate adoption.

The strong correlations among ISSM dimensions observed in this study are consistent with previous healthcare information system research [17, 18, 19]. Notably, perceived net benefits were strongly associated with both satisfaction and intention to use, indicating that psychological engagement and behavioral commitment translate into perceived clinical value. Nurses widely agreed that the tracking system improved workflow transparency, reduced errors, and enhanced patient safety—benefits also emphasized in global patient safety initiatives¹ and in studies of barcode, RFID, and UDI-based tracking systems [3, 4, 5, 6]. Additional evidence from UDI policy literature underscores the importance of standardized device identification for improving traceability, data accuracy, and patient safety [26, 27].

Recent literature on surgical instrument traceability further contextualizes these findings. Systematic reviews highlight that RFID-based tracking improves patient safety, reduces environmental waste, and enhances logistical efficiency [25]. Empirical evidence also demonstrates that automated tracking technologies significantly reduce counting time, minimize missing instrument incidents, and support data-driven tray optimization [25, 28]. These findings align with nurses' perceptions in the present study, suggesting that frontline users recognize the operational and safety advantages documented in broader traceability research. Moreover, the emerging use of computer vision and AI-based tracking [29] underscores the growing relevance of information quality and system reliability—two dimensions strongly validated in our findings.

Despite overall positive perceptions, demographic factors did not significantly influence quality ratings, satisfaction, or perceived benefits. This suggests that the system is broadly acceptable across diverse nursing groups, regardless of age, experience, or education. However, usage frequency consistently influenced both system quality and satisfaction, indicating that engagement and familiarity remain important determinants of acceptance. This pattern mirrors findings from digital readiness studies, where exposure and hands-on experience reduce resistance and increase confidence [23]. Similar findings have been reported in evaluations of hospital information systems, where system quality and user experience strongly shape acceptance and perceived value [30].

Taken together, the results highlight several implications for practice. First, ensuring high information quality is essential for sustaining satisfaction and trust. Second, service quality—including training, communication, and responsive support—plays a critical role in fostering acceptance. Third, early and frequent exposure may accelerate adoption by enhancing perceived ease of use. Finally, integrating user-centered implementation strategies with robust technical design may maximize the clinical and operational benefits of smart instrument tracking systems.

Future research should explore longitudinal outcomes, such as changes in workflow efficiency, error rates, and patient safety indicators after full system integration. Additionally, qualitative studies may provide deeper insight into nurses' lived experiences, barriers, and expectations. As AI-based tracking and automation continue to evolve, examining how these technologies influence information quality, trust, and workload will be essential for guiding next-generation system design.

Conclusions

This study demonstrates that nurses hold positive perceptions of a smart single-instrument tracking system, with information quality, system quality, and service quality emerging as key determinants of satisfaction, intention to use, and perceived benefits. Information quality showed the strongest influence, underscoring the importance of accurate, reliable, and timely data in supporting clinical workflow and decision-making. Service quality and system quality also played essential roles, highlighting the need for responsive support, effective training, and stable system performance to sustain user engagement.

The findings confirm the applicability of the Information System Success Model in the context of surgical instrument tracking and reinforce the value of digital traceability solutions for enhancing workflow transparency, reducing errors, and improving patient safety. As healthcare environments increasingly adopt digital and automated technologies, ensuring high information quality and providing user-centered implementation support will be critical for maximizing system acceptance and clinical impact.

Future research should examine long-term outcomes following full system integration and explore nurses' lived experiences to better understand barriers and facilitators of adoption. Continued investigation into AI-enabled tracking and automation will also be essential for guiding the next generation of intelligent instrument management systems.

Implications for Nursing Practice

The findings of this study offer several important implications for nursing practice. First, the strong influence of information quality on satisfaction and perceived benefits highlights the need for nurses to have access to accurate, reliable, and timely instrument-related data. Ensuring high information quality can reduce uncertainty, support clinical decision-making, and enhance workflow efficiency, particularly in high-risk environments such as operating rooms.

Second, the significant role of service quality underscores the importance of ongoing training, responsive technical support, and clear communication during system implementation. Nursing leaders should prioritize structured onboarding, continuous education, and accessible support channels to strengthen nurses' confidence and promote sustained system use.

Third, the association between system quality and intention to use suggests that user-centered system design—emphasizing stability, ease of use, and workflow integration—is essential for successful adoption. Providing opportunities for hands-on practice and iterative exposure may further enhance acceptance, especially among nurses with limited prior experience using digital tracking systems.

Finally, the demonstrated benefits of smart instrument tracking systems—including improved workflow transparency, reduced errors, and enhanced patient safety—indicate that such technologies can meaningfully support nursing practice. Integrating digital traceability tools into perioperative workflows may help standardize processes, reduce cognitive burden, and strengthen patient safety outcomes. As healthcare environments continue to digitalize, nurses will play a critical role in evaluating, adopting, and optimizing these technologies to ensure safe and efficient care delivery.

Strengths and Limitations

This study has several notable strengths. It is one of the few investigations to apply the Information System Success Model to evaluate a smart single-instrument tracking system in a real clinical environment, providing empirical evidence from frontline nursing staff. The use of validated measurement constructs and rigorous statistical analyses strengthens the reliability of the findings. Additionally, the inclusion of nurses with diverse roles and experience levels enhances the representativeness of the sample and provides a comprehensive understanding of system perceptions across perioperative practice.

However, several limitations should be acknowledged. First, the study was conducted in a single medical center, which may limit the generalizability of the findings to other institutions with different workflows, resources, or levels of digital maturity. Second, the cross-sectional design restricts the ability to infer causal relationships among system quality, satisfaction, and behavioral intention. Longitudinal studies are needed to examine how perceptions evolve over time as users gain experience with the system. Third, the study relied on self-reported data, which may be subject to response bias or social desirability effects. Finally, the research focused on nurses' perceptions and did not include objective performance indicators such as error rates, workflow efficiency metrics, or patient safety outcomes. Future studies incorporating mixed-methods or system-generated data could provide a more comprehensive evaluation of system impact.

Abbreviations

AI
Artificial Intelligence
ANOVA
One-way analysis of variance
CVI
Content Validity Index
EMR
Electronic Medical Record
ICU
Intensive Care Unit
ISSM
Information System Success Model
M
Mean
RFID
Radio Frequency Identification
SD
Standard Deviation
TAM
Technology Acceptance Model
UDI
Unique Device Identifier
VIF
Variance Inflation Factor

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Kaohsiung Veterans General Hospital (IRB No. KSVGH25-CT2-16). All participants were informed about the study purpose, procedures, confidentiality protections, and their right to withdraw at any time. Written informed consent was obtained from all participants prior to data collection. All methods were performed in accordance with relevant guidelines and regulations, including the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are available from the corresponding authors on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

JHL: Conceptualization, project administration, data collection, supervision.

CHS: Coordination, data acquisition, administrative support.

CYL: Investigation, validation, and data collection.

MFH: Resource management, institutional support, review of clinical relevance.

CYW: Data collection, field coordination, participant recruitment.

PLT: Data curation, formal analysis, visualization, manuscript drafting, and corresponding author responsibilities.

CHL: Study design, statistical consultation, manuscript review and editing, and corresponding author responsibilities.

All authors read and approved the final manuscript.

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Figures

