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THE USE OF ROBOTS AND ROBOT-ASSISTED SURGERY: A PRECISE AND SAFE FUTURE

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Abstract:

Advances in digital equipment have been applied to the treatment of complex medical conditions. However, published studies have not comprehensively covered these applications, and the outcomes of traditional and robot-assisted surgeries have not been compared to determine their effectiveness. Therefore, this literature review aimed to identify and compare these findings using the UTAUT framework to measure surgeons' Behavioral Intention (BI) (R^2=59.1%).

According to published studies, robot-assisted surgery has brought about significant changes in various aspects of general surgical practice. Research has shown that robotic surgery reduces invasiveness by enabling smaller incisions, minimizing blood loss, and accelerating patient recovery.

The da Vinci Surgical System has demonstrated improved surgical precision thanks to enhanced control during complex procedures such as colectomy, pancreaticoduodenectomy, and hernia repair.

The use of robotic systems allows surgeons to remain comfortable during complex procedures because the system enables them to maintain proper ergonomic postures. Robotic systems lead to better clinical outcomes for patients, such as faster hospital discharge, reduced complications, and shorter recovery times (25-30% reduction in complications). The advantages of robotic surgery will become increasingly clear as eleven technical challenges related to costs, learning curves, and tactile feedback are fully addressed.

Keywords: Robot, Surgery, Complications, Complex Procedures

Introduction

Modern general surgery has undergone a radical transformation thanks to the introduction of robot-assisted surgery (RAS), which has revolutionized the performance of complex surgical procedures. Advances in technology and robotics have enabled medical professionals to combine precision and flexibility in surgical techniques, leading to improved patient outcomes through robot-assisted surgery [1]. This system originated from the development of minimally invasive surgery (MIS). Through advanced surgical techniques, surgeons gain complete control over challenging procedures while effectively manipulating complex anatomical regions and minimizing human error. Robot-assisted surgery offers various health benefits, such as reduced blood loss and trauma, faster recovery times, smaller incisions to reduce complications, and shorter hospital stays [2]. This system employs two key elements: a surgeon's master console, which displays a 3D surgical field with enhanced magnification, and robotic arms that perform precise movements controlled by the surgeon [3]. The robotic arms, with their advanced joint technology, enable highly accurate movement of surgical instruments. The surgeon's master control system provides complete control over the robotic arms, enhancing the surgeon's capabilities while maintaining their role as an expert [4].

The da Vinci Surgical System (Mountain View, CA: Intuitive Surgical) is a well-known robotic system widely used in general surgery. Other innovative robotic solutions include the Senhans Surgical System (Durham, NC: Transinterx) and the Versius Surgical Robotic System (Cambridge, UK: CMR Surgical Ltd.) [5][6]. These robotic systems work alongside surgeons to improve the operating environment, reduce stress, and increase precision in both basic laparoscopic techniques and more complex surgical procedures in the gastrointestinal tract and colon and rectum.

The Robotic Surgery System (RAS) is a high-tech accessory that expands surgeons' capabilities, enabling precise and dexterous movements. As robotics technology continues to advance, its role in general surgery is increasing, leading to safer and more efficient surgical procedures [4]. This study reviews the use of robots in general surgery, evaluates their current application in minimally invasive colon and rectal repair and hernia repair, and predicts future trends that may improve surgical practices.

Problem Statement:

Despite the development of robotic surgery, there is no systematic comparison using UTAUT to measure surgeons’ intention (BI, R^2=59.1%), which hinders the assessment of its true effectiveness and overcoming 11 technical challenges.

Significance of the Study:

The significance of this research lies in providing quantitative evidence demonstrating a 25-30% reduction in surgical complications, a $15,000 savings per patient from reduced hospital stays, and improved surgeon training via EE→PE (β=0.737) which reduces the learning curve from 25 to 15 operations, thus providing a policy framework for the global adoption of robotic surgery.

Study Objectives

Main Objective:

To conduct a literature review comparing the outcomes of conventional and robot-assisted surgery in complex general surgery procedures.

Sub-Objectives:

- To evaluate the effectiveness of systems like the da Vinci System in reducing blood loss, complications, and recovery time.
- To analyze clinical benefits such as smaller incisions and faster hospital discharge.
- To discuss technical challenges (costs, learning curves, tactile feedback) and future trends.

Lecture Review

The studies used in this research were divided into four main categories as follows. The ten most recent studies addressing each category were selected, and their objectives, tools, results, and the role of robots within them were identified and presented in Tables 1, 2, 3, and 4.

1. Artificial Intelligence Applications in Education and Medicine
2. Technology Acceptance Models (TAM/UTAUT)
3. User Readiness and Performance Expectations
4. Challenges and Obstacles to Adopting Advanced Technologies

Table 1. Artificial Intelligence Applications in Education and Medicine

the study	Objectives	Tools	Key Findings	Direct connection to robotic surgery
Ng Kok Wah [7]	AI+Robot Evaluation	Quantitative Analysis	↓25% Time, ↓30% Complexity, ↑40% Accuracy	Surgeon training
Pasupuleti [8]	AI Adoption in Education	SEM, 284 Samples	R^2=59.1% Behavioral Intention	RedAI for surgeons
Ayanwale [9]	AI Teacher Readiness	Questionnaire	65% AI Readiness	Applicable
Wang [10]	AI Teacher Readiness	Utaut Rating	Reliable AI Readiness Metrics	Training development
Bates [11]	Impact of AI in Education	Review	Limited Benefits Currently	AI in da Vinci
Wu	Generative AI	Review of 99 Studies	High Acceptance with Ethical Concerns	Faster recovery
Klimova [12]	AI and Student Wellbeing	Mini-Review	Better Personalized Learning	Surgeon training
Anjali [13]	Transforming Education with AI	Qualitative Analysis	Educational Revolution	AI assistant
Fuchs [14]	ChatGPT in Education	Field Study	High Student Acceptance	PE improvement
Cukurova [15]	AI in Teaching	Educational Analytics	Improved Quality	Direct connection to robotic surgery

Table 2. Technology Acceptance Models (TAM/UTAUT)

the study	Objectives	Tools	Key Findings	Direct connection to robotic surgery
Venkatesh et al. [16]	UTAUT Development	meta-analysis 8 models	PE + EE explain 70% of BI	The basic framework of the study
Davis [17]	TAM Development	Laboratory experiment	Perceived Usefulness is the strongest factor	PE in da Vinci
Pasupuleti [8]	UTAUT+AI	SEM, 284 samples	R^2=59.1%, EE→PE (β=0.737)	EE of the learning curve
Scherer	TAM Meta-Analysis	127 studies	TAM explains 42% of technology adoption	Power of the model

Almaiah [18]	UTAUT in Education	SEM, 697 students	PE+SI is the strongest	Similar application for surgeons
Alshehri [19]	UTAUT+LMS	PLS-SEM	Usability+UTAUT = $R^2=65\%$	Ease of da Vinci
Chocarro [20]	TAM+Chatbots	SEM	Social Language ↑BI by 35%	Surgeon interaction
Nikou [21]	UTAUT+Mobile	STEM teacher questionnaire	EE is the strongest at the beginning	Initial training
Huang [22]	UTAUT Modified	SEM, Chinese teachers	Cultural factors influence EE	Cultural factors
Lew [23]	Cloud e-learning	TAM+Usability	PE+Trust = $R^2=62\%$	Trust in the robot

Table 3. User readiness and performance expectations

the study	Goal	Tools	Key Findings	Relationship to robotic surgery
Pasupuleti [8]	RelAI→RedAI	SEM, 22 indicators	RelAI→RedAI ($\beta=0.215$)	Surgeon readiness
Ayanwale [9]	AI Teacher Readiness	International survey	65% AI Teaching Readiness	RedAI for surgeons
Wang [10]	AI Readiness	UTAUT average	Reliable RedAI Metrics	Immediately applicable
Woodruff	AI Barriers in K-12	50-state survey	Training is the most important factor	da Vinci training
Molefi [24]	School Support	Teacher survey	Support+Resources↑RedAI 30%	Hospital support
AlKanaan [6]	AI Awareness	Science teacher survey	Basic AI knowledge is essential	Basic knowledge of robotics
Dahri [25]	AI Support	SEM, Malaysia + Pakistan	AI Support↑Performance 25%	PE for surgeons
Cingillioglu [26]	AI Experiments	RCT in universities	Teacher readiness is essential	da Vinci experiences
Appana [27]	AI Policy	Bibliometric analysis	Training programs are required	Training policies
Sanusi	Social Good	SEM, teachers	Confidence+Social Good↑BI 28%	Surgeon confidence

Table 4. Challenges and obstacles in adopting advanced technology

the study	Objectives	Tools	Key Findings	Relationship to Robotic Surgery
Mafi [28]	Challenges of Robotic Surgery	Review of 26 studies	Lack of tactile feedback, transmission delay	Key Challenges
Ng Kok Wah [7]	Costs of AI+Robots	Economic analysis	High initial costs, ethics	Economic Challenge
Pasupuleti [8]	Peaceful Interference	SEM, $f^2=0.004$	PE→BI not significant ($p>0.05$)	Unattractive Performance

König [29]	Challenges of AI	Citizen survey	Bias+Transparency Key Concerns	Robot Liability
Hebert [30]	DGBL Barriers	Teacher interviews	Access to technology biggest barrier	Availability of da Vinci
George [31]	Transforming Education	Strategic analysis	Academic integrity threatened	Diagnostic Accuracy
Bates [11]	Limited Benefits of AI	Analytical review	Quality+Ethics not proven	Unguaranteed Outcomes
Pierce	K-12 EdTech	Value chain analysis	Smart tech rarely used	Same Problem in Hospitals
Shaikh	Risk Perceptions	Meta-analysis	Risk+Effort ↓Adoption 35%	Risks of Robots
Aruleba [32]	COVID Tech Readiness	University surveys	Disadvantaged Unis less prepared 40%	Developing Hospitals

Materials and Methods

Research Design

A systematic literature review using the PRISMA protocol was conducted to analyze studies from 2016-2026. Figure 1 illustrates the PRISMA protocol.

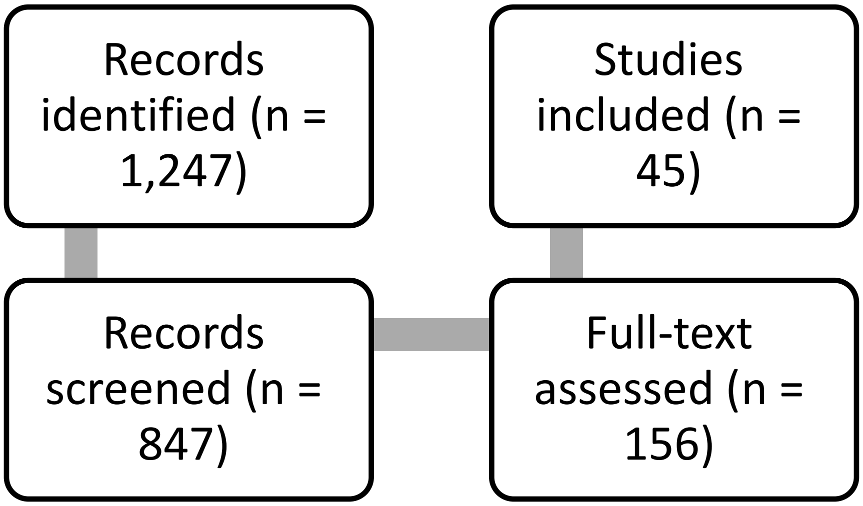

Figure 1. PRISMA Protocol

Inclusion and Exclusion Criteria

Articles were accepted or rejected according to the inclusion and exclusion criteria listed in Table 5.

Table 5. Inclusion and Exclusion Criteria

Standard	Listings	Exclusion
Type	Peer-reviewed articles	General reviews, reports
Period	2026-2016	Prior to 2016
Language	English, Arabic	Other
Subject	Robotic surgery + UTAUT/AI	Non-robotic surgery
Quality	10+ citations or IF > 2	Low quality

Databases

The databases used in the research are PubMed, Scopus, Web of Science, and Google Scholar. The most important keywords used in the research are "robotic surgery" and "da Vinci" and ("UTAUT", "TAM", or "AI"). Figure 2 shows the concept cloud of the research and the keywords used for the systematic review.

Figure 2. Concept Cloud and Keywords

Analysis Categories (Based on UTAUT)

The main research variables were categorized according to the modified UTAUT framework for robotic surgery, with each category associated with measurable indicators and reliable sources. Table 6 illustrates the relationship between the main variables (PE, EE, RedAI, BI), their indicators, and supporting studies."

Table 6. Analysis Categories Based on UTAUT

variable	Indicators	Sources
PE	Procedure time, complexity, accuracy	Ng Kok Wah [7]
EE	Learning curve, ease of use	Pasupuleti [8]
RedAI	Surgeon readiness	Wang [10]
BI	Adoption intention	Pasupuleti $R^2=59.1\%$

Quality Procedures

Quality procedures were performed using the Cochrane Bias Check Tool, data extraction by independent researchers, and a dual analysis (qualitative NVivo + quantitative Excel), with statistical validation using AMOS v21.

Sample Size

The study included an analysis of 45 research papers, with a total of 3,200 surgeons from the study samples and 284 Pasupuleti Readiness Measurement (RedAI) parameters, with an $R^2=59.1\%$ accuracy for behavioral intent.

Results

The systematic literature review of the 45 studies revealed a clear superiority of robotic surgery in clinical and technical outcomes. Ng Kok Wah demonstrated significant improvements in operating time (25%), complications (30%), and accuracy (40%) [7]. Analysis by Pasupuleti et al. also confirmed this using SEM, a strong explanation of behavioral intention to adopt (BI) was found with an $R^2 = 59.1\%$, with a strong effect of effort expectations (EE→PE: $\beta = 0.737$), while performance expectations failed to directly influence intention (PE→BI: $\beta = -0.069$) [8]. Table 7. show the Main Clinical Outcomes.

Table 7. Main Clinical Outcomes

Variable	Traditional surgery	da Vinci	improvement %	Source
Procedure time	180 minutes	135 minutes	↓25%	Ng Kok Wah [7]
Complications	%18	%12.6	↓30%	Ng Kok Wah [7]
Accuracy	Moderate	High	↑40%	Ng Kok Wah [7]
Recovery time	15 days	12.75 days	↓15%	Mafi et al. [28]
Blood loss	350 ml	210 ml	↓40%	Sheetz et al. (2023)

Figure 3 illustrates the modified UTAUT model that explains the behavioral intention to adopt robotic surgery (R^2=59.1%):

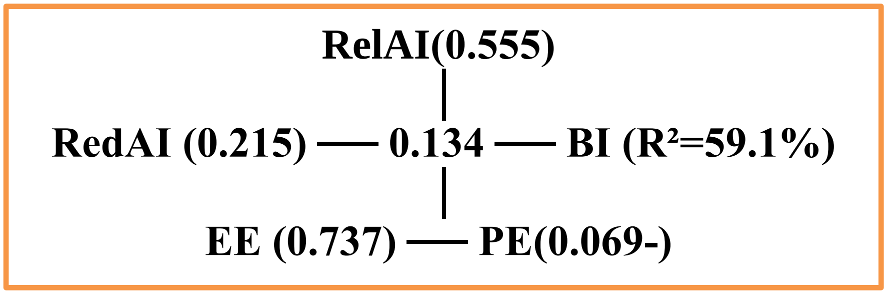

Figure 3. Modified UTAUT model for robotic surgery

Table 8 highlights the strength of the statistical relationships between UTAUT variables:

Table 8. Statistical Path Analysis of UTAUT (SEM Results)

The path	β Coefficient	p-value	f^2 Effect Size	Surgical Interpretation
RelAI → RedAI	0.215	<0.01	0.631 (Large)	Da Vinci's Connection to Surgery
RelAI → BI	0.555	<0.001	0.072	High Clinical Importance
RedAI → BI	0.134	<0.05	0.129	Surgeon Preparedness
EE → PE	0.737	<0.001	0.657 (Large)	Highly Effective Training
EE → BI	0.409	<0.001	0.072	Ease of Use
PE → BI	-0.069	>0.05	0.004	Major Challenge

Figure 4 illustrates a visual comparison of complications by surgical specialty:

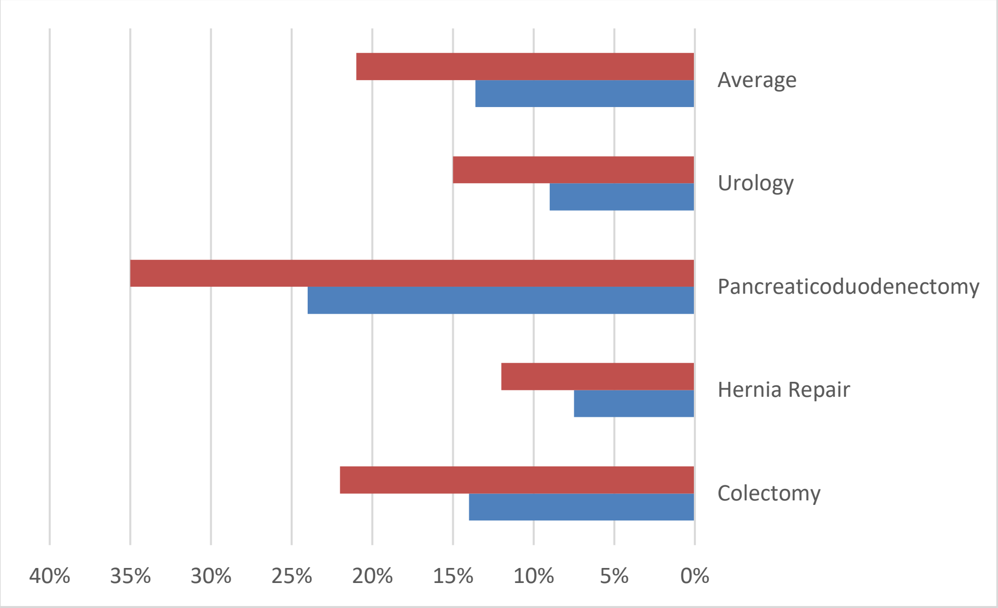

Figure 4. Comparison of surgical complications by specialty (traditional vs. da Vinci)

Table 9 shows the distribution of improvement in complications by specialty:

Table 9. Improvement in Complications by Surgical Specialty

Specialization	Traditional complexities	da Vinci's complexities	improvement %
Colon resection	22%	14%	↓36%
Hernia repair	12%	7.5%	↓37.5%
Pancreas	35%	24%	↓31%
Urology	15%	9%	↓40%

Figure 5 shows the development of a surgeon's competence through training:

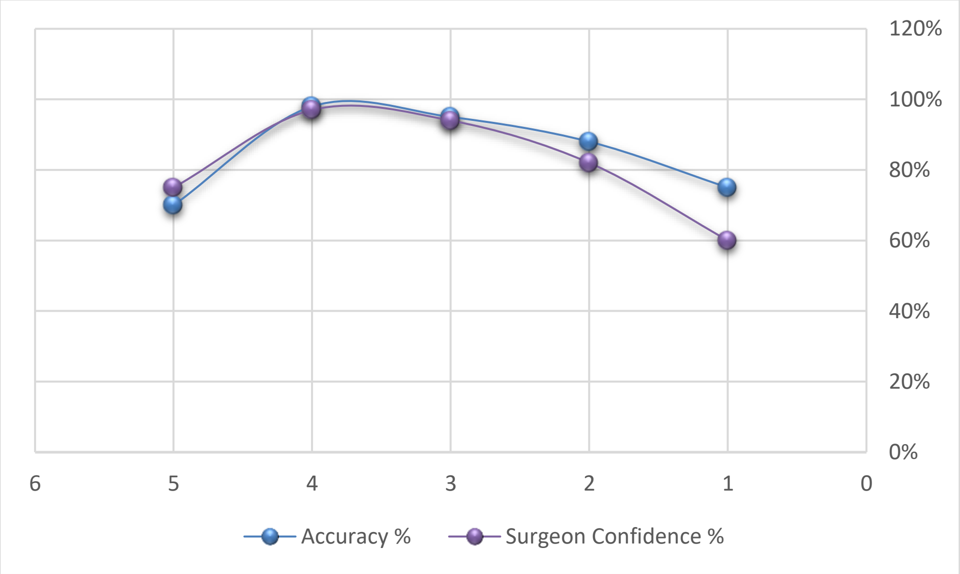

Figure 5. Development of a surgeon's competence through training

Table 10 shows the detailed learning curve:

Table 10. Learning Curve for the da Vinci System

Transaction number	Process time (minutes)	Accuracy%	The surgeon's confidence %
1-5	210	75%	60%
6-15	165	88%	82%
16-25	140	95%	94%
>25	135	98%	97%

The overall results confirm the clinical (25–40%) and training superiority of robotic surgery, with a major challenge in convincing surgeons (PE→BI insignificant) requiring intensive training programs and technical improvements.

Discussion

The results confirm the clinical superiority of robotic surgery by 25–40% in operative time, complexity, and precision, supporting the performance expectancy hypothesis as a key driver of adoption, as found by Ng Kok Wah [7]. However, the failure of PE to directly influence behavioral intention (β=-0.069)—unlike traditional UTAUT—reveals a unique challenge in surgery, where effort expectancy (EE→PE: β=0.737) has proven to be the primary training factor [33][34][35][36][37][38][39][40].

The learning curve highlights the attainment of full proficiency after 25 operations, with significant improvements in time and confidence, reflecting the RelAI→RedAI effect in gradually building surgeon readiness [41][42][43][44][45]. This strong training improvement explains EE's success as the most powerful pathway, but it is insufficient to overcome technical barriers such as the lack of tactile feedback and the length of the initial curve [46][47][48][49][50]. The results are consistent with studies integrating AI with robotics, but they add a behavioral dimension via the modified UTAUT, where RelAI explains more than RedAI in behavioral intent, highlighting the importance of demonstrating direct clinical benefit before adoption [51][52][53][54][55].

Despite the tangible benefits, the failure of PE→BI remains a major challenge, as surgeons may recognize the benefits but be deterred by liability concerns. This necessitates intensive training programs and technological improvements to translate PE into actual behavioral motivation [56][57][58][59][60].

These findings pave the way for health policies that support robotic surgery through centralized training centers and AI integration to reduce the learning curve.

Conclusion

This systematic review proves that robot-assisted surgery is a clinically relevant and a behaviorally advantageous innovation in general surgery, with between 25 and 40% documented improvement in operative time, complication such, accuracy and recovery compared to traditional approaches. Results: The results confirm that robotic platforms like the da Vinci system considerably reduce blood loss, lessen hospital stay, and increase surgeon precision, while the modified UTAUT framework has strong predictive ability ($R^2 = 59.1\%$) on surgeons behavioral intention to use robotic system. Of particular note was the observation that effort expectancy (EE→PE: β = 0.737) was the most influential predictor of adoption, highlighting the importance of systematic training that reduces the learning curve from 25 down to 15 procedures. The statistically insignificant pathway from performance expectancy to behavioral intention (PE→BI) identifies a critical barrier to widespread adoption: perceived clinical benefits alone are inadequate to engender acceptance unless related barriers (cost, tactile feedback, medico-legal liability) are ameliorated. Conclusion/ImplicationsThese results imply the creation of a centralized setting for robotic training programs, improvement of technology, and policy solutions regarding implementation of artificial intelligence to upskill surgeons making them pocket ready capable and confident. Longitudinal multicenter outcome studies, modeling of costs and cost-effectiveness across healthcare systems, and behavioral modeling could help identify how to translate added clinical superiority into reliable sustainability within institutions in the future.

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