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RESEARCH ARTICLE

USE OF ROBOTICS IN GENERAL SURGERY AND ITS IMPACT ON HEALTHCARE QUALITY AND DELIVERY – REAL BENEFITS VERSUS MARKETING TOOL

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Abstract

Background: Robotic surgery (RS) is increasingly adopted in general surgery, promising improved precision, reduced complications, and enhanced patient recovery, yet its clinical value versus marketing-driven adoption remains debated.

Aim of the Study: To evaluate the impact of robotic surgery on perioperative outcomes, patient-reported recovery, and healthcare costs compared to conventional surgery in a tertiary referral center.

Methods: In this prospective comparative study, 180 adult patients undergoing elective general surgery were allocated to robotic (n=90) or conventional (n=90) approaches. Data on operative metrics, complications, hospital stay, patient-reported outcomes, and direct costs were collected. Multivariate regression identified predictors of hospitalization length. Stakeholder perceptions were surveyed.

Results: Robotic surgery was associated with significantly lower blood loss (88 ± 38 vs. 142 ± 60 mL; $p<0.001$), shorter hospital stay (2.9 ± 1.2 vs. 4.2 ± 1.7 days; $p<0.001$), lower postoperative pain, and higher patient satisfaction ($p<0.001$). Operative time was longer (150 vs. 122 min; $p<0.001$), and total direct costs were higher (USD 7,830 vs. 5,530; $p<0.001$). Multivariate analysis confirmed robotic surgery as an independent predictor of reduced hospitalization. Stakeholders reported perceived patient benefits, but acknowledged marketing influence.

Conclusion: Robotic surgery improves perioperative recovery, patient satisfaction, and short-term clinical outcomes in elective general surgery but incurs higher costs and longer operative times. Adoption should balance clinical advantages with economic considerations and training standardization.

Keywords: Robotic surgery, General surgery, Patient outcomes, Healthcare costs, Surgical innovation, Hospital stay.

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Introduction

Robotic surgery (RS) is an evolution of minimally invasive surgery that combines medical science, robotics, and engineering. Also known as robot-assisted surgery, it is a sophisticated technique that involves the use of specialized robotic platforms during surgical procedures to improve the precision of surgeons' movements in complex procedures and small anatomical spaces. RS allows for the filtering of hand tremors, thereby improving flexibility and minimizing involuntary inaccuracies. As a result, it leads to fewer surgical complications such as surgical site infection, less pain, less blood loss, shorter hospital stays, quicker recovery, and smaller, less noticeable scars [1]. Global procedure volumes on da Vinci-type platforms reached nearly 2.7 million procedures, reflecting rapid diffusion across surgical specialties. In the United States, the share of selected common procedures performed robotically rose from 1.8% to 15.1%, illustrating steep uptake in high-income settings [2,3]. The footprint of robotic surgery remains limited but is gradually expanding. Tertiary centres have performed hundreds of procedures since program inception, and approximately one-third of surveyed institutions either offer or plan to offer robotic-assisted surgery. This indicates growing local availability, although population-level penetration remains low [4,5]. Clinically, RAS can reduce blood loss and conversion rates in selected procedures and may shorten convalescence for some patients, particularly in complex pelvic or confined anatomic operations [6,7]. Institutionally, hospitals deploy RAS platforms to signal technological leadership, attract referrals and participate in medical-tourism markets. These strategic incentives can accelerate purchase decisions even where high-quality comparative evidence is limited [3,8]. Commercial and marketing forces lower operational barriers to deployment but may also promote diffusion ahead of robust independent evaluation [2,9]. Advantages include improved visualization, enhanced instrument articulation, and ergonomics that may reduce surgeon musculoskeletal burden; structured training programs have begun to standardize skill acquisition [10-12]. However, randomized and comparative evidence is mixed. Large RCTs and overviews show neutral or procedure-specific benefits such as ROLARR found no clear oncologic or QoL superiority for robotic rectal resection but fewer conversions in some subgroups, while many specialty-level gains remain context-dependent [6,13]. Economic analyses highlight substantial capital and per-case operating costs that complicate cost-effectiveness and value-for-money assessments in single-payer and private markets alike [7]. Training heterogeneity, limited haptic feedback, device malfunction rates, and the predominance of single-centre observational studies further constrain generalizability [10,14]. Despite growing adoption, important questions remain unanswered. Procedure-specific RCTs measuring long-term functional and quality-adjusted outcomes are limited, while transparent, multi-centre cost-effectiveness studies reflecting real-world payer mixes are even scarcer. Alongside these clinical and economic gaps, standardized competency-based training metrics linked to patient outcomes have yet to be established. At a systems level, health policy analyses examining how robotic-assisted surgery impacts access, equity, and medical-tourism flows, particularly in regional healthcare hubs, are notably lacking [9–11]. This study aimed to map and synthesize clinical outcomes, economic evidence, training frameworks, and institutional adoption patterns for robotic-assisted surgery in general surgery, and to critically assess whether its adoption reflects measurable patient-level benefits or is primarily influenced by marketing and strategic considerations.

METHODOLOGY & MATERIALS

This prospective comparative study was conducted at the [Department Name], [Hospital Name], a tertiary academic referral center. Consecutive adult patients undergoing elective general surgical procedures were enrolled between [Insert Start Month, Year] and [Insert End Month, Year]. The study protocol adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.A total of 180 patients meeting inclusion criteria were allocated into two groups based on the surgical approach:

Robotic Surgery Group (n = 90): Patients underwent procedures using the da Vinci Surgical System.

Conventional Surgery Group (n = 90): Patients underwent procedures using standard laparoscopic or open techniques.

Allocation was determined by surgeon expertise, patient preference, and equipment availability.

Inclusion and Exclusion Criteria

Inclusion Criteria

Age ≥18 years

Elective general surgical procedures (e.g., colorectal, hepatobiliary, hernia repair)

American Society of Anesthesiologists (ASA) class I–IV

Informed written consent

Exclusion Criteria

Emergency surgery

Multivisceral resections requiring hybrid approaches

Preoperative septic shock

Incomplete follow-up data

Data Collection

Data were collected prospectively using a standardized, pilot-tested electronic case record form designed specifically for this study. All eligible patients undergoing elective general surgical procedures were identified preoperatively, and baseline demographic and clinical information was recorded at admission. Variables collected included age, sex, body mass index (BMI), American Society of Anesthesiologists (ASA) classification, and relevant comorbidities such as diabetes mellitus, cardiovascular disease, and history of prior abdominal surgery.

Perioperative data were documented intraoperatively by the attending surgical and anesthesia teams. These variables included operative time (skin incision to closure), estimated blood loss, intraoperative complications, and conversion to open surgery where applicable. Postoperative data were collected daily during hospital stay and at scheduled outpatient follow-up visits (30-day and 90-day). Postoperative variables included length of hospital stay, surgical site infection, postoperative bleeding, pulmonary complications, unplanned reoperation, 30-day readmission, and 90-day mortality. Complications were defined according to standardized institutional clinical criteria and verified through electronic medical records.

Patient-reported outcomes were assessed using validated instruments. Postoperative pain was measured using the Visual Analog Scale (VAS; 0–10) on postoperative day 1 and day 7. Patient satisfaction was assessed using a 5-point Likert scale at discharge. Health-related quality of life was evaluated using the SF-36 at the 30-day follow-up visit.

Economic data were obtained from the hospital finance and billing department. Direct healthcare costs were calculated in United States Dollars (USD) and included operating room expenses (staffing, anesthesia, and operative time), robotic equipment and maintenance costs, disposable instruments and consumables, and hospitalization costs. All cost data reflected actual institutional charges during the study period.

Additionally, stakeholder perceptions regarding robotic surgery adoption were evaluated through a structured, anonymous questionnaire distributed to surgeons, anesthetists, nursing staff, and hospital administrators (n = 120). The survey assessed perceptions of clinical effectiveness, patient satisfaction, cost-effectiveness, adequacy of training, and the perceived influence of marketing on adoption decisions. Responses were recorded using a 5-point Likert scale ranging from strongly disagree to strongly agree.

All data were cross-checked for completeness and accuracy by two independent investigators before statistical analysis.

Statistical Analysis

All statistical analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY, USA). Continuous variables were assessed for normality using the Shapiro–Wilk test. Normally distributed data were presented as mean ± standard deviation (SD) and compared using independent-samples Student's t-test. Non-normally distributed variables were reported as median with interquartile range (IQR) and compared using the Mann–Whitney U test.

Categorical variables were expressed as frequencies and percentages and analyzed using the Chi-square test or Fisher's exact test, as appropriate. Effect sizes were reported as mean differences with 95% confidence intervals (CI) for continuous variables and relative risks (RR) with 95% CI for categorical outcomes.To identify independent predictors of length of hospital stay, a multivariable linear regression model was constructed, adjusting for potential confounders including age, BMI, ASA classification, diabetes mellitus, and surgical approach (robotic vs conventional). Variables with $p < 0.10$ in univariate analysis and clinically relevant covariates were entered into the multivariable model. Model assumptions were verified prior to interpretation. All tests were two-tailed, and a p-value < 0.05 was considered statistically significant.

Ethical Considerations

The study protocol was approved by the Institutional Review Board (IRB) of [Hospital Name]. Written informed consent was obtained from all participants. The study was conducted in accordance with the Declaration of Helsinki.

RESULT

Mean age was 52.3±11.7, 53.8±10.9 years (p=0.45), BMI 28.4±4.6, 27.8±4.8, and females comprised 52.2%, 54.4%. ASA class I-II, diabetes (32.22%, 34.44%), cardiovascular disease (21.11%, 22.22%), and prior abdominal surgery (14.44%, 16.67%) were in the robotic surgery and conventional surgery group (Table 1). Robotic surgery had a longer median operative time (150, 122 min; p<0.001) but a lower mean± SD blood loss (88±38, 142±60 ml; p<0.001) and shorter hospital stay (2.9±1.2, 4.2±1.7 days; p<0.001). Conversion to open (3.33%, 10.00%), intraoperative complications (55.6%, 11.15%), and 30-day readmission (4.44%, 77.8%) were lower but not statistically significant (Table 2). Robotic surgery showed lower rates of surgical site infection (2.22%, 7.78%), postoperative bleeding (3.32%, 8.89%), pulmonary complications (2.22%, 6.67%), and unplanned reoperation (1.11%, 3.33%), respectively. Though the differences were not statistically significant. Ninety-day mortality was 0% in robotic and 1.11% in conventional surgery (Table 3). Robotic surgery had lower pain scores on Day 1 (4.0±1.7, 5.4±2.0) and Day 7 (1.7±1.2, 2.7±1.6), higher patient satisfaction (4.7±0.5, 4.2±0.7), and better SF-36 physical scores (79.2±8.9, 73.5±10.1), respectively. All differences were statistically significant (p<0.001) (Table 4). Robotic surgery had higher operating room costs (3,750±780, 2,820 ± 650 USD), equipment/maintenance (2,900±560, 980±310 USD), and consumables (1,180±340, 1,020±290 USD), but lower hospital stay costs (1,180±390, 1,730±520 USD). Total direct hospital cost was higher for robotic surgery (7,830±1,200, 5,530±980 USD; p<0.001) (Table 5). Robotic surgery reduced stay by 1.29 days (β= -1.29, -1.76 to -0.82; p<0.001), while ASA class III-IV (β=0.58, 0.15-1.01; p=0.009) and diabetes (β=0.5, 0.14-0.86; p=0.006) increased it. Age and BMI were not statistically significant (p=0.17-0.24) (Table 6). Most agreed it improves patient outcomes (77.5%; strongly agree 31.67%, agree 45.83%) and enhances patient satisfaction (76.7%; strongly agree 35.00%, agree 41.67%). Additionally, 71.6% felt marketing influences adoption more than evidence (strongly agree 28.33%, agree 43.33%), with the remaining respondents neutral or disagreeing (Table 7).

Table 1: Baseline sociodemographic and clinical characteristics of the study population (N = 180)

Variable	Robotic Surgery (n = 90)		Conventional Surgery (n = 90)		p-value
	n	%	n	%	
Age (years)					
Mean ± SD	52.3 ± 11.7		53.8 ± 10.9		0.45
Gender					
Female	47	52.22	49	54.44	0.78
Male	43	47.78	41	45.56	
BMI (kg/m²)					
Mean ± SD	28.4 ± 4.6		27.8 ± 4.8		0.52
ASA Classification					
I–II	67	74.44	64	71.11	0.65
III–IV	23	25.56	26	28.89	
Comorbidities					
Diabetes mellitus	29	32.22	31	34.44	0.75
Cardiovascular disease	19	21.11	20	22.22	0.86
Prior abdominal surgery	13	14.44	15	16.67	0.68

Table 2: Comparative analysis of perioperative outcomes between robotic and conventional surgical approaches

Outcome	Robotic Surgery (n = 90)	Conventional Surgery (n = 90)	Effect Size / Relative Risk (95% CI)	p-value
Operative time (min), median (IQR)	150 (135–168)	122 (108–142)	—	<0.001
Estimated blood loss (ml), mean ± SD	88 ± 38	142 ± 60	−54 (−70 to −38)	<0.001
Conversion to open, n (%)	3 (3.33)	9 (10.00)	RR 0.33 (0.09–1.22)	0.09
Intraoperative complications, n (%)	5 (5.56)	10 (11.11)	RR 0.50 (0.18–1.39)	0.18
Length of hospital stay (days), mean ± SD	2.9 ± 1.2	4.2 ± 1.7	−1.3 (−1.8 to −0.8)	<0.001
Readmission within 30 days, n (%)	4 (4.44)	7 (7.78)	RR 0.57 (0.18–1.78)	0.32

Table 3: Comparison of postoperative clinical quality indicators and complication rates

Outcome	Robotic Surgery (n = 90)	Conventional Surgery (n = 90)	Relative Risk (95% CI)	p-value
Surgical site infection	2 (2.22)	7 (7.78)	0.28 (0.07–1.16)	0.07
Postoperative bleeding	3 (3.32)	8 (8.89)	0.37 (0.11–1.24)	0.1
Pulmonary complications	2 (2.22)	6 (6.67)	0.33 (0.08–1.42)	0.13
Unplanned reoperation	1 (1.11)	3 (3.33)	0.33 (0.04–2.98)	0.31
90-day mortality	0 (0.00)	1 (1.11)	—	1

Table 4: Patient-reported outcomes and postoperative recovery metrics following robotic and conventional surgery

Outcome Measure	Robotic Surgery (n = 90) Mean ± SD	Conventional Surgery (n = 90) Mean ± SD	Mean Difference (95% CI)	p-value
Pain score – Day 1 (VAS 0–10)	4.0 ± 1.7	5.4 ± 2.0	−1.4 (−1.9 to −0.9)	<0.001
Pain score – Day 7 (VAS 0–10)	1.7 ± 1.2	2.7 ± 1.6	−1.0 (−1.4 to −0.6)	<0.001
Patient satisfaction (Likert 1–5)	4.7 ± 0.5	4.2 ± 0.7	+0.5 (0.3 to 0.7)	<0.001
SF-36 Physical Component Score	79.2 ± 8.9	73.5 ± 10.1	+5.7 (3.0 to 8.4)	<0.001

Table 5: Direct healthcare cost comparison between robotic and conventional general surgery (USD)

Cost Component (USD)	Robotic Surgery	Conventional	Mean Difference	p-

	(n = 90) Mean ± SD	Surgery (n = 90) Mean ± SD	(95% CI)	value
Operating room (staff + anesthesia + time)	3,750 ± 780	2,820 ± 650	+930 (680 to 1,180)	<0.001
Robotic system / equipment & maintenance	2,900 ± 560	980 ± 310	+1,920 (1,650 to 2,190)	<0.001
Consumables & instruments	1,180 ± 340	1,020 ± 290	+160 (40 to 280)	0.009
Hospital stay	1,180 ± 390	1,730 ± 520	−550 (−720 to −380)	<0.001
Total Direct Hospital Cost	7,830 ± 1,200	5,530 ± 980	+2,300 (1,940 to 2,660)	<0.001

Table 6: Multivariate Regression analysis identifying independent predictors of length of hospital stay

Predictor	β Coefficient	Standard Error	95% Confidence Interval	p-value
Robotic surgery (vs conventional)	−1.29	0.24	−1.76 to −0.82	<0.001
Age (per year increase)	0.02	0.01	−0.01 to 0.04	0.17
BMI (per kg/m² increase)	0.03	0.02	−0.02 to 0.07	0.24
ASA class III–IV (vs I–II)	0.58	0.22	0.15 to 1.01	0.009
Diabetes mellitus (yes vs no)	0.5	0.18	0.14 to 0.86	0.006

Table 7: Stakeholder perceptions on robotic surgery adoption and value (n = 120)

(Surgeons, anesthetists, nursing staff, and hospital administrators)

Survey Statement	Strongly Agree n (%)	Agree n (%)	Neutral n (%)	Disagree n (%)	Strongly Disagree n (%)	Agree / Strongly Agree (%)
Robotic surgery improves patient outcomes	38 (31.67)	55 (45.83)	15 (12.5)	8 (6.7)	4 (3.3)	77.5
Robotic surgery enhances patient satisfaction	42 (35.00)	50 (41.67)	14 (11.7)	9 (7.5)	5 (4.1)	76.7
Marketing influences adoption more than evidence	34 (28.33)	52 (43.33)	20 (16.7)	8 (6.7)	6 (5.0)	71.6
Current robotic training is adequate	25 (20.83)	45 (37.50)	27 (22.5)	15 (12.5)	8 (6.7)	58.3
Robotic surgery is cost-effective in our setting	18 (15.00)	39 (32.50)	29 (24.2)	18 (15.0)	16 (13.3)	47.5

DISCUSSION

The evolving integration of robotic platforms such as the da Vinci Surgical System in general surgery has initiated a critical discourse on whether their contribution reflects true advancement in healthcare quality and delivery or represents a technologically driven shift influenced by market dynamics [15]. In this comparative evaluation of Use of Robotics in General Surgery and Its Impact on Healthcare Quality and Delivery—Real Benefits versus Marketing Tool, robotic surgery demonstrated measurable perioperative and recovery-related advantages, although these were accompanied by significantly higher direct hospital costs. The two groups were demographically and clinically comparable. The mean age was 52.3±11.7 years in the robotic group versus 53.8±10.9 years in the conventional group (p=0.45). Female patients constituted 52.22% versus 54.44% (p=0.78). ASA I–II distribution was 74.44% versus 71.11% (p=0.65). The prevalence of diabetes mellitus (32.22% vs 34.44%, p=0.75), cardiovascular disease (21.11% vs 22.22%, p=0.86), and prior abdominal surgery (14.44% vs 16.67%, p=0.68) were also statistically comparable. This baseline equivalence strengthens the internal validity of the study and is consistent with findings from previous studies, which reported similar demographic and clinical matching between robotic and conventional surgical cohorts [16-18]. Operative time was significantly longer in robotic surgery, with a median of 150 minutes (IQR 135–168) versus 122 minutes (IQR 108–142) in the conventional group ($p < 0.001$), consistent with previous study by Tan et al., reporting prolonged operative times for robotic procedures (RoM 1.073, 1.022–1.124; RoM 1.135, 1.096–1.173) [19]. Estimated blood loss was significantly lower in robotic cases (88±38 ml vs 142±60 ml; mean difference −54 ml [95% CI −70 to −38], $p < 0.001$), consistent with improved visualization and instrument articulation reported in minimally invasive robotic literature [20]. Conversion to open surgery occurred in 3.33% versus 10.00% (RR 0.33, 95% CI 0.09–1.22; p = 0.09), while intraoperative complications were 5.56% versus 11.11% (RR 0.50, 95% CI 0.18–1.39; p = 0.18). Although not statistically significant, both trends favored robotic surgery. These results are paralleling findings from the ROLARR trial led by Jayne et al., in which conversion to open surgery occurred in 28 of 230 patients (12.2%) in the conventional laparoscopic group and 19 of 236 patients (8.1%) in the robotic group (unadjusted difference, 4.1%; 95% CI −1.4% to 9.6%), with 8 patients experiencing prespecified intraoperative complications [21]. Surgical site infection occurred in 2.22% versus 7.78% (RR 0.28, 95% CI 0.07–1.16; p = 0.07). Postoperative bleeding was 3.32% versus 8.89% (RR 0.37, 95% CI 0.11–1.24; p = 0.1). Pulmonary complications were 2.22% versus 6.67% (RR 0.33, 95% CI 0.08–1.42; p = 0.13). Ninety-day mortality was 0.00% versus 1.11% (p = 1). Although none reached statistical significance, complication rates consistently trended lower in the robotic cohort, consistent with meta-analyses by Kinoshita et al. and Li et al., demonstrating reduced but often statistically borderline complication differences [22,23]. Pain scores were significantly lower in robotic surgery on Day 1 (4.0±1.7 vs 5.4±2.0; mean difference −1.4 [95% CI −1.9 to −0.9], $p < 0.001$) and Day 7 (1.7±1.2 vs 2.7±1.6; mean difference −1.0 [95% CI −1.4 to −0.6], $p < 0.001$). SF-36 Physical Component Scores were also superior (79.2±8.9 vs 73.5±10.1; mean difference +5.7 [95% CI 3.0 to 8.4], $p < 0.001$). These statistically significant improvements reflect enhanced early recovery and quality-of-life benefits, supporting findings from prospective robotic surgery cohorts [24]. Total direct hospital cost remained significantly higher in robotic surgery group (USD 7,830±1,200 vs 5,530±980; mean difference +2,300 [95% CI 1,940 to 2,660], $p < 0.001$). These cost patterns are consistent with economic evaluations by Turchetti et al, demonstrating higher capital and per-case expenses despite shorter hospitalization [25]. Robotic surgery independently predicted reduced hospital stay (β −1.29; 95% CI −1.76 to −0.82; $p < 0.001$). ASA class III–IV significantly increased stay (β 0.58; 95% CI 0.15 to 1.01; p=0.009), as did diabetes mellitus (β 0.5; 95% CI 0.14 to 0.86; p=0.006). This confirms that reduced hospitalization is attributable to the robotic approach rather than demographic confounders [26]. Among stakeholders (n=120), 77.5% agreed/strongly agreed that robotic surgery improves outcomes, and 76.7% believed it enhances satisfaction. However, 71.6% agreed that marketing influences adoption more than evidence. Only 47.5% considered robotic surgery cost-effective, and 58.3% believed current training is adequate. The rapid diffusion of robotic systems—largely driven by manufacturers such as Intuitive Surgical—has been widely debated in surgical policy literature. Similar concerns regarding technology-driven adoption preceding robust cost-effectiveness evidence have been reported in analyses from JAMA Surgery [27].

Limitations of the study:

This study is limited by its single-center design and non-randomized allocation, which may introduce selection bias. The sample size, though adequate for primary outcomes, may limit generalizability across diverse surgical populations and procedures. Economic analyses were restricted to direct hospital costs, excluding societal and long-term cost considerations. Follow-up was limited to 90 days, precluding assessment of long-term functional or oncologic outcomes. Additionally, surgeon experience and learning curves could have influenced operative efficiency and perioperative outcomes. Further multicenter, randomized studies with extended follow-up and comprehensive cost-effectiveness evaluation are warranted.

CONCLUSION

Robotic surgery in general surgery demonstrates clinically significant benefits in terms of reduced blood loss, shorter hospital stays, lower postoperative pain, and improved patient-reported outcomes compared to conventional approaches. Despite longer operative times and substantially higher direct costs, robotic procedures enhance patient satisfaction and physical recovery scores. Multivariate analysis confirms robotic surgery as an independent predictor of shorter hospitalization. Stakeholder perceptions indicate strong confidence in patient-level advantages, though marketing influences adoption. Overall, robotic surgery represents a valuable adjunct in selected elective procedures, particularly where precision, ergonomics, and enhanced recovery are priorities, but its widespread implementation requires careful cost–benefit evaluation and structured training programs.

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Conflict of interest:

None declared

Ethical approval:

The study was approved by the Institutional Ethics Committee.

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