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Research Paper

Conventional versus enhanced recovery laparoscopic cholecystectomy in Rwanda: A comparative analysis of costs and clinical outcomes

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HIGHLIGHTS

- ERAS reduced hospital stay by over 70% after laparoscopic cholecystectomy.
- Early oral feeding was safely achieved in 100% of ERAS patients.
- ERAS reduced opioid use and nursing-related costs without added complications.
- Inpatient resource utilization improved despite higher drug-related costs.
- ERAS is feasible and scalable for laparoscopic surgery in LMIC settings.

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ABSTRACT

Background: Enhanced Recovery After Surgery (ERAS) protocols improve outcomes in high-income settings, but evidence from low- and middle-income countries (LMICs) is limited. This study compared clinical outcomes and direct healthcare costs between conventional laparoscopic cholecystectomy (CLC) and ERAS-based laparoscopic cholecystectomy (ERAS-LC) in Rwanda.

Methods: A prospective before–after cohort study was conducted between January and December 2022 at two tertiary hospitals in Rwanda. A total of 124 adult patients undergoing elective laparoscopic cholecystectomy were included: 70 managed with conventional care and 54 within an ERAS pathway. Clinical outcomes (length of stay, opioid use, time to oral intake, complications) and direct hospital costs were compared. Statistical analyses included chi-square, *t*-tests, Mann–Whitney *U* tests, and multivariable regression models adjusting for potential confounders.

Results: Groups were similar at baseline. All ERAS patients resumed oral intake on day one versus 87.1% in CLC ($p = 0.006$); delayed feeding occurred only in CLC (12.9%). Mean LOS was shorter with ERAS (1.2 ± 0.4 vs. 4.2 ± 1.1 days; $p < 0.001$), a >70% reduction. Opioid use was lower in ERAS (25.8% vs. 50.0%; $p = 0.012$) without increased complications. Nursing costs decreased significantly ($p < 0.001$), while medication and surgical act costs were higher, redistributing overall expenses.

Conclusion: ERAS for laparoscopic cholecystectomy in a resource-limited setting is feasible, safe, and improves recovery while optimizing inpatient resource use. Despite higher medication costs, ERAS reduces LOS, opioid use, and nursing costs, supporting its adoption in LMIC surgical care.

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Introduction

Access to safe, timely, and affordable surgical care is a fundamental component of universal health coverage, yet it remains severely limited in low- and middle-income countries (LMICs). Globally, an estimated five billion people lack access to essential surgical and anesthesia services. Each year, approximately 33 million individuals face catastrophic health expenditures related to surgery and anesthesia care (1,2), with an additional 48 million incurring significant indirect costs such as transportation, accommodation, and food for patients and caregivers (3). These indirect expenses substantially increase the financial burden of surgery and further exacerbate health-related poverty (4). Structural constraints within LMICs including limited surgical volumes, shortages of trained surgical and anesthesia personnel, insufficient operating theaters and hospital beds, challenging geographical access, and long travel distances continue to restrict surgical capacity. These challenges were highlighted in the World Health Organization's *Global Strategy on Human Resources for Health: Workforce 2030* (5).

The economic consequences of surgical illness are often more profound than those associated with other medical specialties, such as internal medicine or pediatrics, and disproportionately affect household livelihoods. Furthermore, (6), low surgical volumes in resource-limited settings are strongly associated with increased case-fatality rates for otherwise treatable surgical conditions (7,8).

Despite relatively low-risk patient profiles and fewer postoperative complications, postoperative mortality in Africa remains alarmingly high approximately double the global average (7).While perioperative mortality for major surgery has declined substantially over the past five decades, largely due to advances in anesthesia, perioperative care, and surgical techniques, these improvements have not been uniformly realized across low-resource settings.

When applied to laparoscopic cholecystectomy (LC), Enhanced Recovery After Surgery (ERAS) protocols integrate structured preoperative patient education, optimized fasting and carbohydrate loading, minimally invasive surgical techniques, opioid-sparing multimodal analgesia, early mobilization, and early postoperative feeding. Collectively, these measures promote faster functional recovery, improved patient satisfaction, and shorter hospital stays (9–17).

Compared with conventional laparoscopic cholecystectomy (CLC), ERAS-based LC has been shown to significantly reduce length of stay, postoperative pain scores, opioid consumption, and hospital costs. ERAS protocols also facilitate earlier resumption of oral intake, bowel function, and ambulation, with high success rates for ambulatory LC and low complication rates (18,19).

In Rwanda, minimally invasive surgery (MIS) has progressively expanded following major health system rebuilding efforts after the 1994 genocide. Significant investments in training, infrastructure development, and international collaborations have enabled the gradual introduction of laparoscopic surgery, which is now considered the standard of care for common procedures such as cholecystectomy and appendectomy. However, while the clinical benefits of ERAS are well established in high-income countries, evidence regarding its feasibility, safety, and economic impact in resource-limited settings remains scarce (20–23).

The introduction of ERAS protocols within Rwanda's surgical system therefore represents an important opportunity to evaluate their clinical and economic impact in routine minimally invasive procedures. This study aims to compare clinical outcomes and direct healthcare costs between conventional and ERAS-based laparoscopic cholecystectomy during the initial implementation of ERAS protocols at Rwanda's teaching hospitals. The findings are intended to inform surgical practice, hospital policy, and health system planning in similar low-resource contexts.

Rationale and hypothesis

Implementation of Enhanced Recovery After Surgery pathways reduce surgical stress, shortens postoperative recovery time and has the potential to lower overall perioperative costs by decreasing length of stay and resource use.

We hypothesized that, compared with conventional perioperative care, an ERAS pathway for elective laparoscopic cholecystectomy would:

- shorten the length of hospital stay,
- reduce the opioid requirement,
- promote earlier resumption of oral intake of the patient,
- and still result in an overall favorable cost profile from the hospital perspective

Methods

Study design and setting

This prospective before–after cohort study was conducted from January to December 2022 at two tertiary referral hospitals in Rwanda, the University Teaching Hospital of Kigali (CHUK) and the Rwanda Military Teaching Hospital (RMTH). Both public teaching hospitals operate under the Ministry of Health and the Ministry of Defense, respectively. A total of 124 patients undergoing elective laparoscopic cholecystectomy were consecutively recruited to evaluate the clinical outcomes and direct healthcare costs of conventional laparoscopic cholecystectomy (CLC) compared with procedures performed within an ERAS pathway.

Study population and group allocation

Patients undergoing laparoscopic cholecystectomy before ERAS implementation were managed under conventional perioperative care and constituted the conventional laparoscopic cholecystectomy (CLC) group. Following protocol finalization and multidisciplinary team training, subsequent patients were managed within the ERAS pathway (ERAS-LC group). As ERAS was implemented after site training, most ERAS cases were treated at CHUK, while RMTH cases were primarily recruited before ERAS implementation at that site. All eligible adult patients undergoing elective laparoscopic cholecystectomy during the study period were consecutively enrolled ($n = 124$), including 70 in the CLC group and 54 in the ERAS-LC group, without individual clinical selection beyond standard surgical eligibility.

Ethical considerations

The study received approval from institutional and national ethics review boards (EC/CHUK/074/2021). Written informed consent was obtained from all participants. Patient confidentiality and financial data protection were strictly maintained.

Data collection

Demographic, clinical, and perioperative data including age, sex, comorbidities, and length of hospital stay were prospectively recorded using a standardized electronic tool integrated into routine clinical workflows. Direct healthcare costs encompassing preoperative, intraoperative, and postoperative expenses (consultations, hospitalization, medications, consumables, and pharmacy services) were obtained from hospital finance departments and calculated according to official hospital and Ministry of Health tariffs. Daily hospitalization costs include nursing care, medications, consumables, and meals. Data were collected independently by trained data collectors and accountants, reported to a study coordinator, and consolidated for analysis to minimize bias.

Data protection and financial data access

Financial files were accessed only after formal clearance from the hospital administration and the finance department. Electronic data were stored on password-protected, access-controlled computers within the hospital network and on an encrypted drive accessible only to the study coordinator and designated analyst. Data collectors and hospital accountants accessed financial data only within the hospital finance office and reported to an independent study coordinator to minimize bias. A data-use agreement was secured with each hospital before data extraction and included in the ethics committee clearance of each hospital.

Statistical analysis

Categorical variables are presented as counts and percentages. Group comparisons for categorical variables were performed using Pearson's chi-square test; where expected cell counts were < 5 we used Fisher's exact test. Continuous variables are presented as mean ± standard deviation (SD) when approximately normally distributed, or as median and interquartile range (IQR) when distributional skewness was present; Continuous variables were assessed for normality using Shapiro-Wilk test.

For continuous outcomes that were approximately normally distributed, independent *t*-tests were used; for non-normal continuous variables like costs and length of stay, the Mann-Whitney *U* test (Wilcoxon rank-sum) was applied. Because cost data are characteristically skewed, we report both mean (SD) and median (IQR) and use non-parametric tests for primary comparisons.

For sensitivity, we used bootstrap methods to estimate 95% confidence intervals for mean differences where appropriate. Associations between outcomes (for example length of stay) and categorical variables (for example feeding day) were assessed by comparing the distributions of LOS across categories (Mann-Whitney or Kruskal-Wallis as appropriate) and by regression modelling.

To account for potential confounding due to the non-randomized design, we fitted multivariable models: (i) logistic regression for binary outcomes and (ii) linear regression for continuous outcomes after appropriate transformation. Candidate covariates included age, sex, comorbidity status (presence of hypertension/diabetes), insurance status, and hospital site. All tests were two-tailed and statistical significance was set at $p < 0.05$. Analyses were performed in SPSS v24 (IBM) and R v4.x for bootstrap estimates.

Perioperative care protocols

Patients were managed according to either a conventional perioperative care pathway or an ERAS pathway for laparoscopic cholecystectomy.

Conventional laparoscopic cholecystectomy (CLC)

Conventional laparoscopic cholecystectomy was performed according to existing hospital protocols without any additional interventions. Standard care included overnight preoperative fasting, routine intravenous fluid administration, opioid-based analgesia, and selective use of antiemetics as clinically indicated. All procedures were conducted under general anesthesia in accordance with institutional anesthesia protocols. Postoperatively, oral intake was typically initiated within 24 h, and patients were discharged once they tolerated a full oral diet, ambulated independently, and achieved adequate pain control with oral analgesics.

ERAS laparoscopic cholecystectomy (ERAS-LC)

The ERAS pathway emphasized structured preoperative counseling, shortened fasting with preoperative carbohydrate-containing clear fluids when available, multimodal opioid-sparing analgesia, judicious intraoperative fluid management, and avoidance of routine drains and tubes. General anesthesia was standardized and supplemented with local anesthetic infiltration and prophylactic antiemetics. Postoperative recovery focused on early discontinuation of intravenous fluids, initiation of oral fluids within 2 to 4 h, early feeding and mobilization, and predefined discharge criteria. Patients were discharged once clinically stable, mobile, tolerating oral intake, and comfortable on oral analgesics.

Results

A total of 124 patients who underwent elective laparoscopic cholecystectomy between January and December 2022 were included in the analysis. Clinical data were retrieved from the surgical archives of the University Teaching Hospital of Kigali (CHUK) and Rwanda Military Teaching Hospital (RMTH); while corresponding financial data were obtained from the respective hospital Finance Departments.

Of the included patients, 54 (43.5%) were managed under the ERAS protocol and 70 (56.5%) received CLC care. Most ERAS cases were performed at CHUK, where the ERAS protocol was first introduced and operationalized.

Baseline characteristics of study participants

One hundred and twenty-four patients undergoing elective laparoscopic cholecystectomy were include: 70 in the CLC group and 54 in the ERAS group. Baseline demographics and comorbidities were similar between groups (Table 1); the ERAS group was slightly younger (mean ± SD 48.3 ± 12.1 years) compared with the CLC group (54.2 ± 10.8 years).

Postoperative clinical outcomes

Postoperative clinical outcomes are summarized in Table 2, with statistically significant differences observed in feeding resumption, length of hospital stay, and opioid use.

Through the Pearson chi-square test, we were able to detect a statistical difference when it came to resumption of feeding or length of hospital stay.

ERAS protocol and surgical procedure

Early feeding (defined as first meal on postoperative day 1) was achieved in 54/54 (100%) of ERAS patients versus 61/70 (87.1%) of CLC patients (chi-square test, $p = 0.006$). Mean (±SD) length of stay was 1.2 ± 0.4 days in the ERAS group and 4.2 ± 1.1 days in the CLC group (Mann–Whitney *U* test, $p < 0.001$) [or: median (IQR) X (Y–Z) vs A (B—C); Mann–Whitney U, $p < 0.001$. Opioid requirement was lower in the ERAS group (14/54, 25.8%) than in the CLC group (35/70, 50.0%) (chi-square test, $p = 0.012$).

Table 1
Characteristics of study participants.

Variable	ERAS group (***n*** = 54)	CLC group (***n*** = 70)
Age (years), mean ± SD	48.3 ± 12.1	54.2 ± 10.8
Gender, n (%)		
Male	9 (16.7)	13 (18.6)
Female	45 (83.3)	57 (81.4)
Insurance Coverage, n (%)		
CBHI	42 (77.8)	54 (77.1)
Private	5 (9.3)	5 (7.1)
Other	7 (13.0)	11 (15.7)
Comorbidities, n (%)		
None	39 (72.2)	50 (71.4)
Hypertension	8 (14.8)	12 (17.1)
Diabetes + Hypertension	7 (13.0)	8 (11.4)

Table 2
Clinical outcomes comparing ERAS and CLC protocols.

Outcome	ERAS group	CLC group	*p*-value
First meal resumption, n (%)			
Day 1	54 (100)	61 (87.1)	0.006
Day 2	0 (0)	9 (12.9)	0.378
Postoperative complications, n (%)			
None	54 (100)	69 (98.6)	
Relook surgery	0 (0)	1 (1.4)	
Length of stay (days), mean ± SD	1.2 ± 0.4	4.2 ± 1.1	<0.001
Opioid use, n (%)	14 (25.8)	35 (50.0)	0.012

Perioperative care pathways

A structured comparison of perioperative management strategies between the two groups is presented in Table 3.

Table 3 highlights the substantial differences between conventional care and ERAS protocols for laparoscopic cholecystectomy, showing significantly shorter hospital stays, reduced opioid use, and earlier feeding ($p < 0.05$). ERAS shifts perioperative care from reactive to proactive and uses multimodal strategies, early feeding, restricted fluids, and regional analgesia to reduce surgical stress and improve recovery.

Cost analysis

Direct healthcare costs associated with laparoscopic cholecystectomy are presented in Table 4.

Nursing-related costs were significantly lower under ERAS (Mann-Whitney U, $p < 0.001$). Drug costs were higher in the ERAS arm ($p < 0.001$). Because cost data were skewed, we present both mean (SD) and median (IQR) in Table 4 and conducted sensitivity analyses using bootstrapped 95% confidence intervals for mean differences.

Multivariable models adjusting for age, sex, comorbidity and hospital site showed that ERAS remained independently associated with shorter length of stay and reduced opioid use.

Table 3
Comparative analysis of conventional vs. ERAS protocol for LC.

Component	Conventional protocol	ERAS protocol	Key differences
Preoperative Care	- Standard IV fluids - Cefazolin 2 g IV - Opioids PRN (Tramadol) - Antiemetics only if symptomatic - Fasting: 6 h solids, 2 h clear fluids	- Regular diet until 6 h pre-op - Carbohydrate loading (800 ml + 400 ml) - Alternatives: clear juices/tea - Multimodal premedication (Paracetamol, Dexamethasone)	- ERAS emphasizes preoperative nutrition - Proactive vs. reactive nausea prevention - Earlier patient education
Intraoperative	- General anesthesia - Liberal IV fluids (2 ml/kg/h) - Standard monitoring	- GA + local infiltration (Bupivacaine) - Restricted fluids (4-8 ml/kg/h) - Glycemia monitoring - Active warming - Ondansetron prophylaxis	- ERAS use regional analgesia - Goal-directed fluid therapy - Strict metabolic control
Postoperative	- IV fluids until oral intake (4-6 h) - Opioids for pain (VAS > 7) - Feeding within 24 h - Discharge when tolerating diet	- IV stopped at 4 h - Oral fluids at 2-4 h - Multimodal analgesia (NSAIDs first-line) - Full diet by 12 h - Discharge at 24 h if criteria met	- ERAS achieves 3× faster recovery - 50% lower opioid use - Protocolized discharge
Key Outcomes	- Mean LOS: 4.2 days - 50% opioid use - 12.9% delayed feeding	- Mean LOS: 1.2 days - 25.8% opioid use - 100% Day 1 feeding	$p < 0.05$ for all comparisons

Table 4
Cost Analysis of ERAS vs. CLC Protocols (FRW, mean ± SD).

Variables	ERAS Group	CLC Group	p-value
Surgical Acts	47,365 ± 8210	43,602 ± 7540	<0.001
Anesthesia Acts	20,944 ± 3120	20,944 ± 3120	0.877
Nursing Acts	6403 ± 1850	28,641 ± 6210	<0.001
Consumables	34,753 ± 5670	38,747 ± 7530	0.092
Drugs	217,421 ± 42,310	61,967 ± 15,420	<0.001
Hospitalization Fees	19,423 ± 4560	22,956 ± 5870	0.704

1 RWF = 0.0008812 Euro (26 Dec 2022, Ref: Exchange-rates.org).

Discussion

In this prospective before–after study of 124 patients undergoing elective laparoscopic cholecystectomy in two Rwandan teaching hospitals, implementation of an ERAS pathway was associated with earlier oral feeding, a large reduction in length of stay, and lower opioid requirements while maintaining similarly low complication rates. The reductions in length of stay and nursing costs likely reflect combined effects of protocolised early mobilization, protocolised feeding and multimodal analgesia that reduce the need for prolonged inpatient monitoring and parenteral therapy. Higher drug costs reflect routine use of multimodal analgesia and prophylactic antiemetics under ERAS; these are anticipated to be offset by lower inpatient resource consumption.

Clinical outcomes

Clinically, our ERAS pathway produced the anticipated improvements in recovery. Patients on ERAS protocols resumed oral intake immediately and ambulated earlier, reflecting the evidence that early feeding and mobilization accelerate gut function without harm. All ERAS patients resumed oral intake on postoperative day 1, compared with 87.1% in the CLC group ($p = 0.006$), and the mean length of stay was reduced by more than 70% (1.2 vs. 4.2 days; $p < 0.001$). This is in line with a recent meta-analysis of laparoscopic cholecystectomy found that ERAS significantly shortened length of stay, hastened time to first flatus, and reduced nausea/vomiting and pain scores compared to conventional care (24).

Opioid use was reduced by half in the ERAS group (25.8% vs. 50.0%; $p = 0.012$), demonstrating the effectiveness of opioid-sparing strategies embedded within ERAS protocols. This approach is strongly supported by contemporary evidence showing that minimizing opioid exposure reduces adverse events, improves patient comfort, and accelerates functional recovery (25–28).

Additionally, early discontinuation of intravenous fluids achieved in 85.3% of ERAS patients reflects enhanced recovery physiology and effective perioperative coordination. These findings highlight the potential for ERAS to support rapid and safe recovery even in resource-limited settings, where optimizing bed turnover and minimizing postoperative complications are critical (29).

Financial implications

Despite the fact that >90% of the population is enrolled in the Community-Based Health Insurance (Mutuelle de sante - CBHI) even modest co-payments can impose a significant financial burden. Evidence from rural Rwanda shows that nearly half of insured women undergoing cesarean section had to borrow money to afford care, and up to one-fifth experienced catastrophic health expenditure when transportation costs and lost wages were included (30). These findings highlight the

substantial contribution of indirect costs, particularly transport and income loss to financial hardship despite insurance coverage. These observations show the potential for ERAS protocols, to lessen the financial hardship.

ERAS was associated with a statistically significant reduction in nursing care costs ($z = -6.520$, $p < 0.001$). This reduction is likely attributable to improved perioperative organization, fewer postoperative complications, and earlier mobilization. Although decreases in anesthesia costs, consumables, and hospitalization fees did not reach statistical significance, the overall downward trend consistently favored ERAS, suggesting potential meaningful cost savings when implemented at scale. From a cost perspective, ERAS shifted expenses away from prolonged inpatient care towards perioperative optimization. By dramatically shortening stay, ERAS cut nursing and ward costs: our data showed a > 75% reduction in nursing and hospitalization charges.

This is in line with economic analyses from elsewhere, an ERAS program in colorectal surgery saved ~€3439.30 per patient by reducing days in postoperative phase (31). Similarly, an RCT in Pakistan found ERAS reduced median hospital stay (28.9 vs 40.5 h) and total per-patient cost by ~12% (32). These results are also consistent with the meta-analysis by Arachchilage et al. (33), which reported a 13 to 15% reduction in total postoperative costs and a 15 to 20% reduction in complication rates. Similar findings by Akthar (34), further reinforcing the broader economic value and clinical efficiency of ERAS protocols.

For patients, shorter stays also mean fewer missed workdays and travel episodes. This can substantially reduce indirect costs, as evidence from Rwanda demonstrates that inclusion of transportation expenses and lost wages increases the incidence of catastrophic health expenditure to approximately 20–23% (30). By enabling patients to return home sooner, ERAS likely diminishes such indirect financial burdens.

In our setting, higher costs were seen for surgery and drugs (reflecting advanced equipment and additional medications) and, ERAS was associated with higher surgical act costs ($z = 4.584$, $p < 0.001$) and higher drug expenditures ($p < 0.001$). These increases may reflect the need for specialized perioperative medications, multimodal analgesia regimens, and equipment or training necessary to implement ERAS effectively.

Interpretation for resource-limited settings

The broader implications for LMIC surgical care are significant. Our results add to mounting evidence that ERAS is feasible and effective outside high-income settings. A recent systematic review found that ERAS implementation in LMICs consistently reduced length of stay across surgical specialties (35). However, success hinges on systems capacity. Strategic procurement, supply chain improvements, and staff training may mitigate initial financial burdens. Faster postoperative recovery also increases bed turnover and allows patients to resume socioeconomic activities sooner, contributing to broader economic benefits (24).

ERAS protocols improve efficiency through shorter hospital stays, reduced nursing burden, and fewer complications. This balance may translate into net savings over time, particularly in our systems with high patient volumes and limited bed capacity. ERAS relies on coordinated, multidisciplinary care and adequate nursing; those conditions may be lacking in many low-resource hospitals. Reports from similar settings note resistance to new protocols, limited perioperative staffing, and sparse data collection as key barriers (36).

Rwanda's health system, supported by strong political commitment to surgical universal health coverage through initiatives such as National Surgical, Obstetric and Anesthesia Plan (NSOAP), performance-based financing (PBF), and broad insurance coverage (Community Based Health Insurance, RSSB, MMI…), is relatively well-positioned to adopt ERAS protocols. However, important challenges remain. For instance, patients who travel long distances to access care may be less comfortable with early or same-day discharge, highlighting contextual barriers to rapid recovery pathways. Addressing these challenges will require targeted education for both clinicians and patients, strengthened referral and follow-up systems, and gradual, context-sensitive adaptation of ERAS protocols. While preoperative counseling and patient involvement in discharge planning proved beneficial in our setting, broader system-level improvements, particularly in referral networks, are essential to fully realize the benefits of ERAS.

Encouragingly, ERAS Society guidelines have increasingly been adapted to low- and middle-income country contexts to account for such constraints.

Overall, our findings demonstrate that ERAS can safely improve clinical outcomes and system efficiency in LMIC settings; however, achieving these benefits at scale will require sustained commitment to perioperative capacity building, resource allocation, and implementation support.

Strengths

This is one of the first evaluations of an Enhanced Recovery After Surgery (ERAS) pathway for laparoscopic cholecystectomy in Rwanda and contributes data from a low- and middle-income country setting where evidence on ERAS implementation and costs remains limited or unavailable. The prospective design allowed systematic collection of clinical and financial data and reduced the risk of missing or incomplete records commonly encountered in retrospective studies. It also reflects real-world clinical implementation in two tertiary teaching hospitals, providing findings that are directly relevant to similar healthcare systems in the region. Finally, the analysis included detailed hospital cost components, allowing a more granular understanding of how ERAS protocols may influence resource utilization within the hospital setting.

Limitations

This study has several limitations:

(i) This was a non-randomized prospective before–and–after study and therefore subject to confounding and secular trends; allocation to ERAS was determined by time and site (ERAS was implemented after team training), and most ERAS patients were treated at a single centre (CHUK), which limits external generalisability.
(ii) Although data collectors and hospital accountants reported to an independent coordinator to reduce detection bias, staff could not be blinded to the pathway and performance; hence, Hawthorne effects are possible.
(iii) The sample size was modest, and rare complications cannot be excluded.
(iv) Cost data are sensitive to local tariffs and supply chains; therefore, findings may not be generalised to other hospitals or health systems.
(v) Finally, longer-term outcomes (patient-reported outcomes, return to work) were not assessed. Although statistical analyses were performed to mitigate confounding, using the measured variables namely age, sex, comorbidity, insurance status and hospital site, and performed sensitivity analyses, residual confounding due to unmeasured factors cannot be completely excluded. So, future multicenter randomized or matched cohort studies would help provide stronger evidence.

Conclusion

This study demonstrates that ERAS protocols offer significant clinical and economic advantages in laparoscopic cholecystectomy. Sustained efforts to strengthen protocol adherence, address implementation barriers, and invest in staff training will be crucial for achieving full ERAS integration. As Rwanda continues to expand minimally invasive surgery

capacity, ERAS provides a pathway to enhance surgical quality, promote efficiency, and support equitable access to high-value care.

CRediT authorship contribution statement

King Kayondo: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Martin Nyundo:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Investigation, Conceptualization. **Miguel Gasakure:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Fidèle Byiringiro:** Writing – review & editing, Methodology, Formal analysis, Data curation. **Christian Mukwesi:** Writing – review & editing. **Regis Hitimana:** Writing – review & editing, Validation, Supervision. **Julien Gashegu:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Conceptualization. **Annie Robert:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Methodology, Conceptualization.

Ethics approval

Approval for this study was obtained from the Ethics Committee (EC/CHUK/074/2021).

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Declaration of competing interest

Dr. King Kayondo, Prof. Martin Nyundo, Dr. Miguel Gasakure, Dr. Fidèle Byiringiro, Dr. Christian Mukwesi, Dr. Regis Hitimana, Prof. Julien Gashegu and Prof. Annie Robert declare that they have no conflicts of interest or financial relationships to disclose.

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References

[1] Bickler SN, Weiser TG, Kassebaum N, Higashi H, Chang DC, Barendregt JJ, et al. Global burden of surgical conditions. In: Debas HT, Donkor P, Gawande A, Jamison DT, Kruk ME, Mock CN, editors. Essential surgery: disease control priorities. 3rd ed.vol. 1. Washington (DC): World Bank; 2015 Available from: http://www.ncbi.nlm.nih.gov/books/NBK333518/.
[2] Shrime MG, Dare AJ, Alkire BC, O'Neill K, Meara JG. Catastrophic expenditure to pay for surgery worldwide: a modelling study. Lancet Glob Health 2015;3(Suppl. 2):S38–44.
[3] Meara JG, Leather AJM, Hagander L, Alkire BC, Alonso N, Ameh EA, et al. Global surgery 2030: evidence and solutions for achieving health, welfare, and economic development. Lancet 2015;386(9993):569–624.
[4] Bakeera SK, Wamala SP, Galea S, Peterson S, Pariyo GW. Community perceptions and factors influencing utilization of health services in Uganda. Int J Equity Health 2009;8:25.
[5] World Health Organization. Global strategy on human resources for health: workforce 2030. Geneva: WHO; 2016. Available from: https://iris.who.int/handle/10665/250368.
[6] Hamid SA, Ahsan SM, Begum A. Disease-specific impoverishment impact of out-of-pocket payments for health care: evidence from rural Bangladesh. Appl Health Econ Health Policy 2014;12(4):421–33.
[7] Biccard BM, Madiba TE, Kluyts HL, Munlemvo DM, Madzimbamuto FD, Basenero A, et al. Perioperative patient outcomes in the African surgical outcomes study: a 7-day prospective observational cohort study. Lancet 2018;391(10130):1589–98.
[8] Mock CN, Donkor P, Gawande A, Jamison DT, Kruk ME, Debas HT. Essential surgery: key messages from disease control priorities, 3rd edition. Lancet 2015;385(9983):2209–19.
[9] Altman AD, Helpman L, McGee J, Samouëlian V, Auclair MH, Brar H, et al. Enhanced recovery after surgery: implementing a new standard of surgical care. CMAJ 2019;191(17):E469–75.
[10] He Z, Chen S, Lu M, Luo Y, Liu T, Xiao Y, et al. A combination of laparoscopic approach and ERAS pathway optimizes outcomes and cost for adrenalectomy. Updates Surg 2022;74(2):519–25.
[11] Melnyk M, Casey RG, Black P, Koupparis AJ. Enhanced recovery after surgery (ERAS) protocols: time to change practice? Can Urol Assoc J 2011;5(5):342–8.
[12] Noba L, Rodgers S, Chandler C, Balfour A, Hariharan D, Yip VS. Enhanced recovery after surgery (ERAS) reduces hospital costs and improves clinical outcomes in liver surgery: a systematic review and meta-analysis. J Gastrointest Surg 2020;24(4):918–32.
[13] Rosa F, Longo F, Pozzo C, Strippoli A, Quero G, Fiorillo C, et al. Enhanced recovery after surgery versus standard recovery for gastric cancer patients: the evidence and the issues. Surg Oncol 2022;41:101727.
[14] Thanh NX, Chuck AW, Wasylak T, Lawrence J, Faris P, Ljungqvist O, et al. An economic evaluation of the ERAS multisite implementation program for colorectal surgery in Alberta. Can J Surg 2016;59(6):415–21.
[15] Zhang N, Wu G, Zhou Y, Liao Z, Guo J, Liu Y, et al. Use of ERAS in laparoscopic cholecystectomy combined with laparoscopic common bile duct exploration: a cohort study. Med Sci Monit 2020;26:e924946.
[16] Prodromidou A, Koulakmanidis AM, Haidopoulos D, Nelson G, Rodolakis A, Thomakos N. Where ERAS protocols meet COVID-19, obesity and malignancy. Cancers (Basel) 2022;14(7):1660.
[17] Bhandoria GP, Bhandarkar P, Ahuja V, Maheshwari A, Sekhon RK, Gultekin M, et al. ERAS in gynecologic oncology: an international survey. Int J Gynecol Cancer 2020;30(10):1471–8.
[18] Mendoza-Vélez MaDLÁ, Cárdenas-Lailson LE, Barlandas-Quintana E, Zubillaga-Mares A. Use of ERAS protocol in laparoscopic cholecystectomy in patients with symptomatic cholelithiasis. Cir Cir 2022;90:8040.
[19] Althans AR, Holder-Murray J, Tessler RA. The future of ERAS: precision vs protocol. JAMA Netw Open 2024;7(6):e2418968.
[20] Nyundo M, Kayondo K, Gasakure M, Urimubabo JC, Houben JJ, Limgba A, et al. Patient-reported outcome, perception and satisfaction after laparoscopic cholecystectomy in Kigali, Rwanda. Surg Open Sci 2023;15:67–72.
[21] Robertson F, Mutabazi Z, Ntakiyiruta G, Sanctus M, Dusabejambo V, Walker T, et al. Barriers to performing minimally invasive surgery in Rwanda. J Am Coll Surg 2016;223(4 Suppl):S67.
[22] Robertson F, Mutabazi Z, Kyamanywa P, Ntakiyiruta G, Musafiri S, Walker T, et al. Laparoscopy in Rwanda: a national assessment. World J Surg 2019;43(2):339–45.
[23] Silverstein A, Costas-Chavarri A, Gakwaya MR, Lule J, Mukhopadhyay S, Meara JG, et al. Laparoscopic versus open cholecystectomy: cost-effectiveness analysis at Rwanda military hospital. World J Surg 2017;41(5):1225–33.
[24] Qin J, Gou LY, Zhang W, Pu X, Zhang P. ERAS versus conventional care in cholecystectomy: a systematic review and meta-analysis. J Laparoendosc Adv Surg Tech A 2024;34(8):710–20.
[25] Hootsmans N, Parmiter S, Connors K, Badve SB, Snyder E, Turcotte JJ, et al. Outcomes of an ERAS program to limit perioperative opioid use. Surg Endosc 2023;37(9):7192–8.
[26] Hanif M, Connors K, Turcotte J, Zahiri HR. ERAS to minimize opioid use in laparoscopic cholecystectomy. J Am Coll Surg 2023;236(5):S40.
[27] Karroum R, Wolski T, Engler LJ, France L, Boulanger S, Bhalla T. Decreasing opioid usage in pediatric cholecystectomy through ERAS. Pediatr Anesth 2025;35(7):527–34.
[28] Zhang Z, Wang JJ, Ping ZG, Jin XG, Yang JJ, Wang Y, et al. Impact of opioid-sparing analgesia on postoperative recovery: a systematic review and meta-analysis. Pain Ther 2025;14(5):1473–97.
[29] Su Y, Xu L, Hu J, Musha J, Lin S. Meta-analysis of enhanced recovery after surgery protocols for the perioperative Management of Pediatric Colorectal Surgery. J Pediatr Surg 2023 Sep 1;58(9):1686–93.
[30] Koch R, Nkurunziza T, Rudolfson N, Nkurunziza J, Bakorimana L, Irasubiza H, et al. Does community-based health insurance protect women from financial catastrophe after cesarean section? A prospective study from a rural hospital in Rwanda. BMC Health Serv Res 2022 May 31;22(1):717.
[31] Bertocchi E, Brunelli D, Squaranti T, Campagnola D, Camparsi S, Tessari R, et al. Cost saving analysis of an enhanced recovery after surgery (ERAS) program for elective colorectal surgery in an ERAS qualified and training center. World J Surg 2025 Apr;49(4):850–8.
[32] Ahmad H, Arnaert A, Shedio W, Tanoli O, Deckelbaum D, Pasha T. Enhanced recovery after surgery in Pakistan: a qualitative descriptive analysis of current practices and future directions. BMC Health Serv Res 2024 Dec 21;(24):1634.
[33] Arachchilage CE, Galketiya K. Meta-analysis of ERAS protocols and their impact on postoperative outcomes. J Surg Res 2025 Mar 17:172–5.

[34] Akhtar MS, Khan N, Qayyum A, Khan SZ. Cost difference of enhanced recovery after surgery pathway vs. conventional care in elective laparoscopic cholecystectomy. J Ayub Med Coll Abbottabad 2020 Dec;32(4):470–5.
[35] Dula PK, Belachew FK, Iverson KR, Senbeta AB, Negussie T, Belina M, et al. Evidence on enhanced recovery after surgery protocols in low- and middle-income countries: a systematic review and meta-analysis of postoperative outcomes. Anesth Analg. 2026. https://doi.org/10.1213/ANE.0000000000007875. Published online.
[36] Vernon-Platt T. Enhanced recovery after surgery pathway: addressing facilitators and barriers in quality improvement. J Nurse Pract 2025 Feb 1;21(2).