Narrative Review

Safety, economic implications, and health system integration of robotic cholecystectomy in African Surgical Centers: A structured narrative synthesis with policy perspectives

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Abstract

Robotic platforms represent an advanced extension of minimally invasive surgery. Although widely adopted in high-income settings, their role in African surgical systems remains limited and unevenly documented. The aim of this study was to synthesize evidence on the clinical performance, economic implications, and implementation of robotic cholecystectomy in African contexts. A structured literature search was conducted in PubMed/MEDLINE, Scopus, African Journals Online, and Google Scholar for studies published between January 2015 and February 2026. Eligible sources included clinical, economic, implementation, and policy-focused reports relevant to African or comparable low- and middle-income settings. Given heterogeneity in study design and limited procedure-specific data, findings were synthesized narratively. Available evidence indicates that robotic cholecystectomy, when performed in adequately equipped tertiary centers, achieves perioperative outcomes similar to conventional laparoscopy. However, most studies are observational, single-center, and limited to short-term follow-up (30 to 90 days). Economic analyses consistently report substantially higher costs, including capital investment of approximately USD 1.5–2.5 million, annual maintenance exceeding USD 100,000, and increased per-procedure costs driven by disposable instruments and longer operative times. Implementation appears most feasible in institutions with multidisciplinary training structures and established technical support capacity. In conclusion, robotic cholecystectomy is technically feasible in selected African institutions, but its sustainability depends on rigorous health technology assessment, financial alignment, workforce readiness, and transparent governance. It should be considered a selectively adoptable innovation rather than a universally scalable solution, with implementation guided by system priorities to avoid compromising access to essential surgical care.

Keywords: Robotic cholecystectomy, robotic-assisted surgery, minimally invasive surgery, Africa, health technology assessment

Introduction

Surgical management of gallbladder disease has evolved substantially with the transition from open to laparoscopic cholecystectomy, establishing minimally invasive surgery as the standard of

Received: February 28, 2026 - Accepted: April 14, 2026 - Published online: April 15, 2026

care for symptomatic cholelithiasis [1]. Laparoscopy offers reduced postoperative pain, shorter hospital stays, and faster recovery. Robotic systems represent a further technological advancement, introducing articulated instruments, enhanced depth perception, and console-based ergonomics [2]. In high-resource settings, robotic surgery has expanded rapidly, particularly in urology and gynecology [3]. However, its incremental benefit in routine biliary surgery remains debated, with comparative studies demonstrating similar short-term safety outcomes to laparoscopy but with differing cost implications [4,5].

Across African surgical systems, adoption of robotic platforms has been gradual and geographically concentrated [6]. In South Africa, early implementation has occurred in institutions such as the University of Cape Town and Groote Schuur Hospital, where robotic systems have been integrated into established minimally invasive programs, particularly in urology and general surgery [7,8]. Comparable developments have been reported in North Africa, including at Ain Shams University in Egypt, where robotic-assisted procedures are gradually being integrated into routine surgical practice [9].

In West Africa, uptake remains limited, although selected institutions have begun to explore robotic platforms. Facilities such as Eko Hospital have introduced robotic systems within predominantly private or mixed funding models, reflecting the substantial financial and infrastructural requirements associated with this technology [10].

Collectively, these observations indicate that robotic surgery is technically feasible in selected African settings but remains closely linked to institutional resources. Consequently, adoption is concentrated in a limited number of tertiary academic and private referral centers rather than being widely distributed across national health systems [11]. Broader diffusion is constrained by financial limitations, infrastructure variability, workforce capacity, and competing health priorities [12]. At the same time, demographic transitions and the rising burden of non-communicable diseases are increasing demand for advanced surgical care, creating a policy challenge regarding the prioritization of high-cost technologies in resource-limited settings.

Health technology assessment (HTA) provides a structured framework to evaluate safety, cost-effectiveness, ethical considerations, and system readiness prior to the introduction of complex medical technologies [13]. While robotic surgery in low- and middle-income countries has been discussed in broader implementation contexts [14], focused synthesis of robotic cholecystectomy within African settings remains limited. The aim of this study was to synthesize current evidence on robotic cholecystectomy in African surgical systems, with particular emphasis on safety, economic implications, and health system integration. To our knowledge, no prior structured review has examined this topic through an integrated lens combining clinical outcomes, economic sustainability, and system-level considerations.

Methods

Study design and search strategy

This study was conducted as a structured narrative synthesis. Given the anticipated heterogeneity in study designs, outcome reporting, and economic evaluation methods, as well as the limited availability of procedure-specific data from African settings, a narrative approach was considered more appropriate than quantitative meta-analysis.

A comprehensive literature search was performed in PubMed/MEDLINE, Scopus, African Journals Online (AJOL), and Google Scholar for studies published between January 2015 and February 2026. Search terms combined controlled vocabulary and free-text keywords related to robotic cholecystectomy, robotic surgery in Africa and low- and middle-income countries, and health system and economic considerations. Search strategies were adapted to each database, and reference lists of included studies were screened to identify additional relevant sources.

Eligibility criteria

Studies were included if they reported clinical outcomes of robotic cholecystectomy, evaluated economic or procurement aspects, or addressed implementation and health system integration in African or comparable low- and middle-income country (LMIC) settings.

Studies were excluded if they focused solely on engineering or device design without clinical application, were editorials, opinion pieces, or commentaries lacking primary or analytical data, or were conference abstracts without accessible full texts.

Study selection

Titles and abstracts were screened for relevance, followed by full-text review of studies meeting the preliminary inclusion criteria. Given the limited number of procedure-specific African studies, evidence from broader LMIC and global literature on robotic surgery was included where directly relevant to contextual interpretation.

Data extraction

Data were extracted using a structured framework encompassing three domains: (1) clinical safety, including perioperative outcomes, complications, and learning curve considerations; (2) financial implications, including acquisition models, maintenance costs, cost differentials, and economic evaluation approaches; and (3) health system integration, including training pathways, infrastructure requirements, governance considerations, and biomedical engineering capacity.

Risk of bias and evidence appraisal

Given the predominance of observational and implementation-focused studies, formal risk-of-bias assessment using meta-analytic tools was not feasible. Instead, methodological quality was appraised narratively, with emphasis on clarity of outcome reporting, adequacy of follow-up, transparency of economic analyses, and contextual relevance.

Data synthesis

Given the substantial heterogeneity in study design, outcome reporting, and economic evaluation methods, quantitative synthesis was not appropriate. Instead, findings were synthesized using a structured narrative approach, allowing identification of patterns across studies without statistical pooling.

Data synthesis was conducted iteratively. Key information from each study was reviewed and organized into emerging thematic domains aligned with the review objectives, including clinical outcomes, financial implications, and health system integration. Related findings were grouped to capture broader patterns—for example, perioperative outcomes, complication profiles, and learning curves under clinical safety; capital investment, maintenance costs, and per-procedure expenditures under economic considerations; and training requirements, infrastructure, and technical support under system-level factors.

Themes were subsequently refined to ensure consistency and coherence across studies. Where discrepancies arose, original reports were re-examined to clarify context and interpretation. Differences in interpretation were resolved through discussion, with conclusions based on the most consistently supported evidence.

Characteristics of included studies

The structured search identified a heterogeneous body of literature addressing robotic cholecystectomy in African and comparable low- and middle-income settings. Most publications comprised observational studies, institutional case series, and implementation analyses, with few comparative cohort studies and no randomized controlled trials identified. Many reports presented descriptive outcomes without formal comparative statistical analysis [14,22].

The majority of studies originated from tertiary academic hospitals or private referral centers with established minimally invasive surgery programs. Evidence from district-level or rural institutions was not identified. Follow-up durations were generally short, typically limited to early postoperative outcomes within 30–90 days.

A clear predominance of single-center, non-collaborative studies was observed, with relatively few multicenter or collaborative investigations (**Figure 1**). This pattern highlights the limited extent of institutional collaboration and the absence of large-scale, multicenter datasets in the current literature.

Reporting depth varied across studies. Most focused on short-term perioperative outcomes, with limited long-term follow-up [14, 27]. Economic evaluations were primarily descriptive rather than model-based, and standardized complication classification systems were inconsistently applied [5,14,20]. Multicenter collaborations were uncommon, and cross-country pooled datasets were not identified.

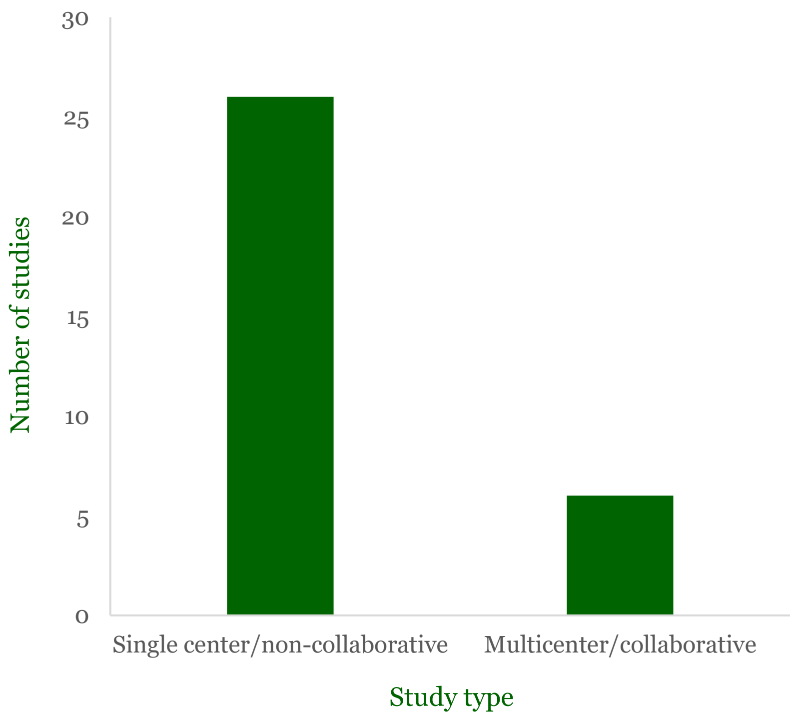

Figure 1. Distribution of included studies by collaboration type, showing a predominance of single-center (non-collaborative) studies compared to multicenter (collaborative) research.

Temporal and geographic distribution of publications

Publication activity has been concentrated over the past decade, with most studies emerging after 2018 (**Figure 2**). Earlier literature was largely derived from global or high-income settings, whereas procedure-specific reports from African contexts have become increasingly visible in recent years. This pattern suggests that robotic cholecystectomy in Africa remains an evolving and relatively early-stage field of documentation.

Geographic representation is uneven. Evidence from West and East Africa is limited and primarily based on single-institution reports rather than multicenter data [4,14]. No studies were identified from rural, district-level, or non-tertiary public hospitals. Robotic programs are predominantly located in institutions with established minimally invasive surgical services, with early adoption frequently occurring in private-sector or mixed public–private referral centers [6,14,22].

Clinical safety

In evaluating clinical safety, the included studies reported a range of perioperative parameters, including operative duration, intraoperative blood loss, need for transfusion, conversion to open surgery, intraoperative complications (e.g., bile duct injury), postoperative complications, length of hospital stay, readmission rates, and early postoperative mortality [14,27].

Available evidence indicates that robotic cholecystectomy achieves perioperative outcomes comparable to conventional laparoscopic approaches when fundamental anatomical safety principles are maintained [15,27]. International comparative analyses similarly report comparable rates of bile duct injury, conversion to open surgery, and short-term morbidity.

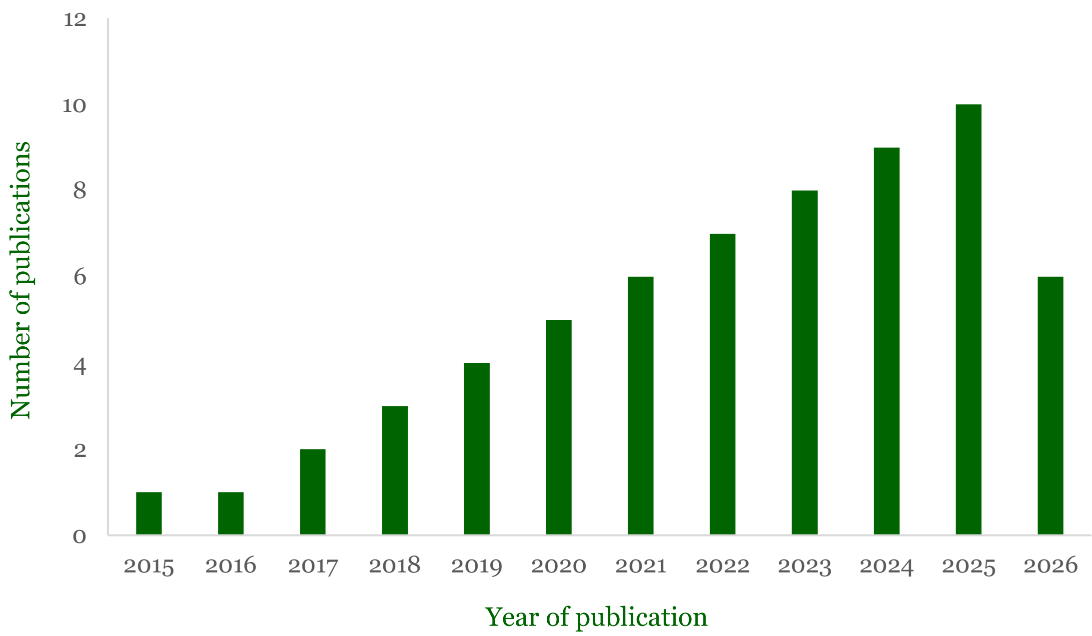

Figure 2. Temporal distribution of publications on robotic cholecystectomy in African and comparable low- and middle-income countries (LMIC) settings (2015–2026), demonstrating a progressive increase in reporting over the past decade.

Most studies reflect early institutional experience and generally report acceptable intraoperative and postoperative outcomes. Intraoperative complications—such as bleeding, bile duct injury, or conversion to open surgery—are infrequent, while postoperative events are typically limited to short-term complications, including surgical site infection, bile leak, and transient ileus.

These findings should be interpreted in the context of limited follow-up. In most studies, outcomes were assessed within 30 days, with only a few extending to 60–90 days. Consequently, evidence on long-term safety and durability remains limited, and sample sizes are generally modest [14,27]. No consistent signal of increased complication risk attributable to robotic instrumentation was identified.

Operative duration was frequently reported as longer than laparoscopic benchmarks during early adoption phases. However, several studies noted progressive reductions in operative time with increasing case volume, consistent with a learning curve effect. Reporting of operative efficiency metrics, however, was not standardized across studies.

Economic considerations

Robotic surgical systems require substantial capital investment. International acquisition costs are estimated at approximately USD 1.5–2.5 million, depending on system configuration [2,22]. Annual service contracts may exceed USD 100,000, with additional costs associated with disposable instruments and system maintenance [2,21]. Economic analyses consistently report higher direct per-procedure costs compared with laparoscopic cholecystectomy [5].

However, methodologies for cost estimation vary considerably across studies. Some analyses incorporate capital amortization and service contracts, whereas others focus primarily on consumables and operative time. Only a limited number of studies conducted within African health systems have undertaken formal cost–utility or budget impact analyses, and these often remain context-specific.

While some countries have begun to adopt elements of health technology assessment (HTA), these frameworks are still evolving and are not consistently applied to surgical innovations [13,26]. Consequently, many cost analyses rely on assumptions derived from high-income settings, which may not accurately reflect local practice [14]. Furthermore, purchasing power parity adjustments and country-specific financing structures are rarely incorporated into economic evaluations, limiting the generalizability of findings across African contexts.

Health system integration

Integration of robotic cholecystectomy into routine practice requires not only technological availability but also alignment with existing clinical capacity, infrastructure, and institutional processes. In African settings, early adoption has predominantly occurred in centers with established minimally invasive surgery programs and multidisciplinary coordination [6,14]. In South Africa, institutions such as the University of Cape Town and Groote Schuur Hospital have incorporated robotic platforms into existing surgical services. In these settings, robotic procedures are introduced alongside conventional laparoscopy, enabling gradual adoption while maintaining procedural safety [14].

A similar pattern is observed in North Africa, including centers affiliated with Ain Shams University in Egypt, where implementation has taken place within structured academic environments. Early adoption is typically limited to less complex procedures, with progressive expansion as institutional experience increases [14]. In West Africa, uptake remains more limited and is largely confined to private or mixed public–private settings. Institutions such as Eko Hospital illustrate how adoption is often driven at the institutional level, reflecting the substantial financial and technical requirements associated with robotic systems [14,22]. Across settings, several core requirements are consistently identified, including reliable electricity supply, appropriate operating theatre infrastructure, sterilization capacity, and access to technical support, particularly biomedical engineering. In addition, procurement guidance emphasizes the importance of long-term maintenance planning and system sustainability [21].

Collectively, these findings indicate that robotic cholecystectomy can be integrated into selected African centers; however, its adoption remains closely linked to local capacity. At present, implementation is concentrated in a limited number of well-resourced institutions, with broader scale-up constrained by infrastructure, workforce, and financial limitations [6,12].

Safety and technical considerations

Available evidence suggests that robotic cholecystectomy can be performed safely when established anatomical principles are maintained. In particular, attainment of the critical view of safety remains the key determinant in preventing bile duct injury [15]. Robotic systems offer enhanced visualization and articulated instrumentation, which may facilitate more precise dissection; however, evidence demonstrating clear superiority over conventional laparoscopy in routine cholecystectomy remains limited [5,27].

Importantly, international comparative analyses consistently indicate equivalence rather than superiority in safety outcomes. In the absence of randomized controlled trials from African settings, conclusions regarding local safety rely primarily on institutional case series and extrapolation from global data.

These findings suggest that while robotic cholecystectomy is technically feasible in selected tertiary environments, its clinical advantage over established laparoscopic approaches remains uncertain. Accordingly, claims of superiority should be interpreted with caution, and the lack of robust long-term outcome data underscores the need for continued evaluation.

Workforce development and training considerations

Robotic surgery introduces distinct ergonomic and technical demands compared with conventional laparoscopy. Console-based operation, instrument articulation, and docking coordination require structured skill acquisition, and global evidence demonstrates measurable learning curves across procedural domains [27]. In African contexts, workforce considerations are particularly important, as surgical training programs often operate under high service demands and limited subspecialty exposure [6]. Consequently, structured proctorship, simulation-based training, and competency-based credentialing are essential for safe adoption.

Simulation-based education has been shown to improve minimally invasive surgical performance [18]. However, robotic-specific training data from African settings remain limited. Moreover, access to simulation infrastructure—including validated training platforms, structured assessment tools, and protected training time—is inconsistent across institutions. While simulation offers a potential pathway to accelerate skill acquisition, its implementation must be contextualized within existing resource constraints.

Robotic integration also requires multidisciplinary training involving surgeons, anesthetic teams, scrub staff, and biomedical engineers. Team-based training models appear more sustainable than operator-centric approaches. However, variability in training capacity across regions, including differences in infrastructure and institutional resources, contributes to uneven exposure to advanced minimally invasive and robotic techniques.

In contrast to high-income settings, where robotic training is often embedded within formal fellowship programs, exposure in African contexts is frequently limited to post-specialization training through short-term proctorship or international observerships. This model may restrict standardized competency development and limit the equitable distribution of expertise.

Tele-mentoring has been proposed as a strategy to expand training capacity [19]. However, its implementation in African settings may be constrained by limitations in broadband connectivity, medico-legal frameworks, and real-time audiovisual infrastructure. While urban academic centers may be better positioned to adopt such models, peripheral institutions may face significant technical barriers.

Infrastructure stability and power reliability

Robotic surgical systems require uninterrupted power supply and climate-controlled operating environments. In many African settings, however, intermittent electricity remains a persistent systems-level challenge [6,12]. Although tertiary hospitals often maintain backup generators, transition delays and voltage fluctuations may still compromise equipment performance and reliability. Such infrastructure variability introduces operational risks not typically encountered in high-income settings. Accordingly, stable power systems, redundancy planning, and preventive maintenance protocols are essential prerequisites for safe and sustainable robotic integration. Without these safeguards, procedural continuity and patient safety may be adversely affected.

Biomedical engineering capacity

Sustainable implementation of robotic surgery requires timely access to trained biomedical engineers for preventive maintenance and technical troubleshooting. Across many Sub-Saharan health systems, however, biomedical engineering workforce capacity remains limited relative to the expansion of advanced medical device procurement [6]. Specialized servicing of robotic systems often depends on manufacturer-certified engineers, who may be regionally centralized or deployed across borders. This reliance on external technical support can prolong system downtime following a malfunction. In contrast, institutions that invest in local biomedical engineering capacity and structured maintenance planning may achieve greater operational resilience. Device lifecycle management frameworks emphasize the importance of developing in-house technical expertise alongside the acquisition of high-cost technologies [21], underscoring the need to align infrastructure investment with workforce capacity.

Equity and distribution within regional surgical networks

Advanced surgical technologies in Africa are predominantly concentrated in urban academic and private-sector institutions [6]. This distribution reflects broader patterns in specialist workforce density and the availability of tertiary-level infrastructure. Within multi-country training networks coordinated by regional surgical colleges, such concentration may lead to unequal exposure to advanced technologies across accredited centers. In the absence of deliberate governance and capacity-building strategies, robotic surgical capability may remain confined to a limited number of institutions, thereby restricting regional knowledge diffusion. Furthermore, available studies do not provide disaggregated analyses of access by rural versus urban populations, public versus private financing structures, or cross-border referral patterns. As a result, the equity implications of robotic surgery adoption in African settings remain largely inferential rather than empirically established.

Economic sustainability and health financing

The economic implications of robotic platform adoption extend beyond direct cost comparisons with laparoscopy. A more critical consideration is whether such investment delivers proportional system-level value within resource-constrained health financing environments. In many African settings, surgical expenditure competes with priorities such as primary care expansion, workforce development, and essential surgical capacity strengthening [12]. Under these conditions, capital-intensive technologies should be evaluated using structured health technology assessment (HTA) frameworks that incorporate budget impact, long-term maintenance costs, and opportunity cost considerations [13].

Current evidence is limited by the absence of purchasing power parity–adjusted analyses and country-specific cost–utility evaluations. Consequently, the long-term financial sustainability of robotic platforms remains uncertain. Platform utilization patterns also influence cost efficiency; while multi-specialty use may improve capital amortization, procedural volume alone does not ensure sustainability. Transparent procurement processes, reliable servicing agreements, and strong institutional governance are critical determinants of long-term operational viability. Collectively, these findings indicate that robotic adoption represents not only a technological decision but also a system-level financing strategy requiring careful and context-sensitive evaluation.

Systems integration and infrastructure

Integration of robotic surgery extends beyond financial procurement to encompass infrastructure readiness and system capacity. Reliable electricity supply, adaptable operating theatre environments, sterilization logistics, and biomedical engineering support are essential prerequisites for operational stability [21]. Guidance from the World Health Organization (WHO) emphasizes the importance of device lifecycle management and preventive maintenance in sustaining high-cost medical technologies [21]. Programs reliant on external servicing may experience operational interruptions, particularly where cross-border logistics are required. Consequently, institutional readiness must integrate infrastructure, workforce capacity, and governance processes. Facilities with established minimally invasive surgical ecosystems appear better positioned to incorporate robotic workflows efficiently.

The adoption of robotic cholecystectomy in African settings can therefore be conceptualized as a staged process involving infrastructure readiness, multidisciplinary workforce development, clinical governance, and continuous evaluation (**Figure 3**).

Equity and ethical governance

The adoption of high-cost surgical technologies in settings characterized by unequal access raises important distributive justice concerns [25]. Concentration of robotic platforms within urban academic and private-sector institutions may inadvertently exacerbate existing disparities. Notably, current evidence lacks granular data on payer distribution, rural–urban access, and public versus private outcome differentials. As a result, equity implications are largely inferred from broader health systems literature rather than procedure-specific analyses.

Ethical priority-setting frameworks emphasize transparency, accountability, and alignment with population health needs [25]. Policymakers must therefore balance technological innovation with equitable resource allocation. However, failure to adopt emerging technologies may also carry consequences, including constraints on academic development and specialist retention. The central challenge is not whether innovation should occur, but how it can be governed in a manner that promotes both equity and sustainability.

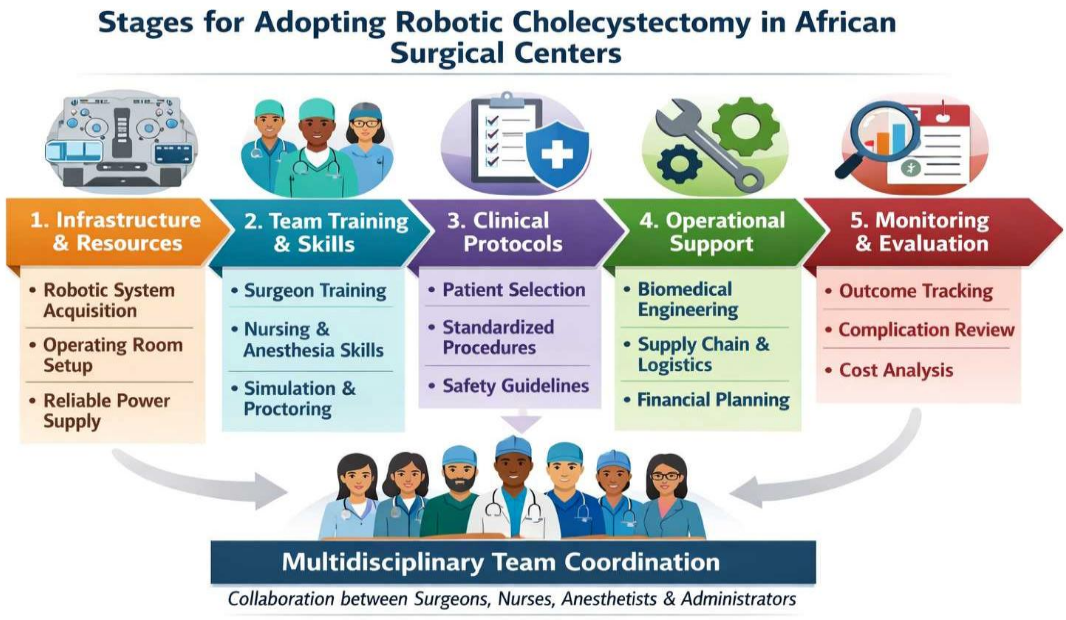

Figure 3. Framework for staged implementation of robotic cholecystectomy in African surgical systems, highlighting infrastructure, workforce, clinical governance, operational support, and evaluation components.

Innovation governance and future directions

Structured frameworks such as IDEAL provide a phased approach for the evaluation of surgical innovations [16]. Application of these models may support more systematic and responsible integration of robotic platforms. Hybrid effectiveness–implementation study designs offer a useful approach to concurrently assess clinical outcomes and health system impact [24]. In addition, the development of regional robotic surgery registries could facilitate longitudinal outcome monitoring, benchmarking, and cross-institutional learning. Without coordinated data collection and standardized reporting, future evaluation will remain fragmented and limit evidence-informed decision-making.

Conclusion

Robotic cholecystectomy is a technically feasible extension of minimally invasive surgery in selected African tertiary centers. When implemented in adequately resourced settings and guided by established biliary safety principles, short-term outcomes appear comparable to conventional laparoscopy. However, feasibility alone does not justify widespread adoption. Future integration should follow a structured pathway, including institutional readiness assessment, health technology evaluation, standardized training and credentialing, and transparent procurement processes. Models incorporating multi-specialty use, lifecycle maintenance, and local technical capacity development are more likely to achieve sustainability. At the regional level, establishment of collaborative robotic surgery registries would strengthen evidence generation through longitudinal outcome monitoring, economic evaluation, and equity assessment. Ultimately, adoption should be guided by demonstrated system-level value rather than technological availability alone. Prospective multicenter studies, context-specific economic analyses, and coordinated governance will be essential to support sustainable implementation.

Acknowledgements

None to declare.

Competing interests

All authors declare no conflicts of interest.

Funding

This study did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.

Underlying data

Derived data supporting the findings of this study are available from the corresponding author on request.

Declaration of artificial intelligence use

We hereby confirm that no artificial intelligence (AI) tools or methodologies were utilized at any stage of this study, including during data collection, analysis, visualization, or manuscript preparation. All work presented in this study was conducted manually by the authors without the assistance of AI-based tools or systems.

How to cite

Asafa OQ, Asafa AO, Oyeniran AO, *et al*. Safety, economic implications, and health system integration of robotic cholecystectomy in African Surgical Centers: A structured narrative synthesis with policy perspectives. Narra Rev 2026; 2 (1): e20 - http://doi.org/10.52225/narrarev.v2i1.20.

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