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EDITOR-IN CHIEF

What if the future of surgery is not defined by what we can do, but by what we can avoid?

For more than a century, medicine celebrated its ability to intervene to cut, repair, replace, and rescue. Today, however, some of the most important advances are emerging from a different philosophy: achieving better outcomes through fewer complications, less pain, lower opioid exposure, and smarter systems of care.

This Special Issue explores that paradigm shift. From opioid-sparing anaesthesia and perioperative pain management to surgical safety checklists, artificial intelligence, ethical competence, governance frameworks, and healthcare systems improvement, the articles gathered here share a common thread: excellence is no longer measured solely by technical success. It is measured by the quality, safety, and humanity of the entire patient journey.

The operating room is often described as a theatre. Yet the greatest performances are not those with the most dramatic interventions; they are those in which risk is anticipated, suffering is minimized, and harm never occurs.

Science advances through answers. Progress advances through better questions.

As you engage with this issue, I invite you to reflect on a question that will shape the next decade of perioperative care: How do we make surgery not only possible but wiser?

The future belongs to those willing to challenge tradition, rethink assumptions, and redesign care around the patient rather than the procedure.

Welcome to Volume 2, Issue 2 | Special Issue 2026..

With appreciation,

Dr. Asjed Sanaullah
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The Operating Room Global Journal (TORGJ)

Dr. Asjed Sanaullah
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Theme: "Perioperative Pain, Anaesthesia & Opioid-Sparing Strategies"

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Perception and Involvement of Operating Room Professionals in the Use of the Surgical Safety Checklist: A Cross-Sectional Study in Cameroon

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ABSTRACT

Background: The WHO Surgical Safety Checklist (SSC) is a simple, low-cost tool that has been shown to save lives in operating rooms around the world. Yet knowing about a checklist and actually using it well during a stressful surgery are two very different things. In Cameroon, as in many resource-limited settings, the gap between what teams know in theory and what they do in practice remains a real challenge.

Methods: Between March and June 2025, we conducted a cross-sectional study in the operating theatres of two referral hospitals in Yaoundé. Forty-one surgical team members completed a structured questionnaire. In parallel, a trained observer silently watched 25 actual surgical procedures to document exactly how and how fully the checklist was being used in real time.

Results: The great majority of participants (85%) could accurately describe the checklist, and every single one agreed that it improves patient safety. Yet nearly half (46%) found it burdensome, and almost three-quarters (73%) struggled to use it during emergencies. When we watched actual surgeries, the picture became clearer: roughly 60% of checklists were executed incompletely or only on paper. Adherence was best during the Sign-In phase (78%), dropped noticeably during Time-Out (52%), and fell furthest during Sign-Out (41%).

Conclusion: Surgical teams in Yaoundé understand the value of the WHO checklist. What is missing is not awareness but consistent, meaningful practice. Closing this gap will require visible leadership from senior clinicians, hands-on team training especially for emergency scenarios and an effort to weave the checklist into the natural rhythm of daily surgical work rather than treating it as an added formality.

Keywords: *Cameroon; Operating Room; Patient Safety; Quality Improvement; Surgical Safety Checklist.*

INTRODUCTION

Every day, surgeons, anaesthetists, and nurses around the world perform hundreds of millions of procedures in the hope of healing their patients. Yet surgery, by its very nature, carries risk. Between 234 and 313 million major operations are performed globally each year [1, 2], and complications occur in as many as 16% of cases. Perioperative death rates range from 0.4% to 10% a burden that falls most heavily on low- and middle-income countries (LMICs) [1, 3]. What makes this figure particularly painful is that research consistently shows at least half of these adverse outcomes are preventable. Communication failures, human error, and organisational breakdowns in high-pressure operating rooms are frequently to blame [4, 5].

In Africa, the picture is even more stark: patients face roughly twice the risk of dying after surgery compared to the global average [6]. This is not simply a matter of surgical skill. It reflects deeper gaps in systems, resources, and safety culture. In

2008, the World Health Organization responded to this crisis with its "Safe Surgery Saves Lives" campaign. At its heart was a deceptively simple tool: the Surgical Safety Checklist (SSC). Modelled on the checklists pilots use before take-off, the 19-item SSC prompts teams to pause at three moments Sign-In (before anaesthesia), Time-Out (before the first incision), and Sign-Out (before the patient leaves the theatre) to confirm that nothing critical has been missed [7, 8].

The evidence for this tool is compelling. A landmark study in the New England Journal of Medicine showed that introducing the SSC cut postoperative complications from 11% to 7% and mortality from 1.5% to 0.8% across diverse hospitals worldwide [3]. Subsequent reviews have confirmed these gains: fewer infections, fewer unplanned returns to theatre, and lower in-hospital death rates [9, 10]. And beyond the numbers, the SSC does something harder to measure, it gives every member of the team regardless of seniority a legitimate voice in the room [11].

Despite all of this, high-fidelity implementation remains elusive. Researchers have labelled this the "implementation gap" the distance between what a tool can achieve in principle and what it actually achieves in daily practice [12]. In LMICs, this gap is driven by resource constraints, hierarchical cultures that discourage junior staff from speaking up, and insufficient institutional support [13, 14]. Studies across Africa have found inconsistent use, with barriers including a lack of surgeon ownership, inadequate training, and a widespread perception that the checklist is simply paperwork [15, 16].

Cameroon has made national-level efforts to address this, including a structured programme for SSC implementation described in the literature [17]. But national programmes depend ultimately on what happens in individual operating theatres, in the hands of individual teams, on any given day. There is currently little detailed, locally grounded evidence about how professionals in Cameroonian hospitals actually perceive and experience the checklist in their daily work. This study was designed to fill that gap. Working in two referral hospitals in Yaoundé, we set out to understand not just what teams know about the SSC, but what they think of it and whether that translates into how they actually use it.

METHODS

Study Design and Setting

This was a descriptive cross-sectional study conducted between March and June 2025 in the operating rooms of two referral hospitals in Yaoundé: the Military Hospital of Region 1, a major public facility, and Bethesda Hospital, a private faith-based institution. These two sites were deliberately chosen to capture a broader range of surgical contexts one representing the public sector, the other the private both performing a mix of elective and emergency procedures throughout the week.

Study Population and Sampling

We invited all healthcare professionals actively working in the operating rooms of both hospitals during the study period to participate. This included surgeons, physician anaesthetists, nurse anaesthetists, scrub nurses, and assistant operating room staff. We used convenience sampling anyone eligible and willing during data collection was included. To be eligible, participants needed to be a regular or rotating member of the surgical team and to give their informed consent. We excluded administrative staff and students on brief observation placements, as they are not directly involved in intraoperative care.

Data Collection

We used two complementary approaches. The first was a structured self-administered questionnaire; the second was direct, non-participant observation of real surgical cases. Together, these allowed us to compare what professionals reported believing and doing with what was actually happening in the theatre.

- **Questionnaire**

The questionnaire was developed based on a review of existing literature on SSC implementation and perception [15, 16] and was written in French, the working language of both hospitals. It covered four areas: sociodemographic and professional background (age, sex, role, years of experience); knowledge of the SSC (its definition, objectives, and three phases); perceptions of the checklist (attitudes toward its usefulness, its impact on teamwork, and its practical drawbacks); and barriers and facilitators in daily use. Before deployment, the questionnaire was piloted with five operating room professionals from a non-participating hospital to ensure clarity and relevance.

- **Direct Observation**

A single trained investigator observed 25 surgical procedures both elective and emergency cases without participating in the care. The observer had been trained on the WHO SSC using the official implementation manual [7, 17] before data collection began. For each case, a structured observation grid was used to document whether each checklist item was fully executed with active verbal confirmation, partially executed, or omitted entirely. While we cannot fully eliminate the possibility that being watched changed team behaviour, the observer maintained a discreet position in the theatre and did not interact with staff during procedures.

Data Analysis

Questionnaire and observation data were entered and analysed using Sphinx Plus V5 and Microsoft Excel 2016. We used descriptive statistics throughout, presenting categorical variables as frequencies and percentages. The self-reported findings were then triangulated with the observational data a step that proved especially revealing, as the two sources told rather different stories.

Ethical Considerations

The study received ethical approval from the institutional review boards of both participating hospitals. All participants received a clear explanation of the study's purpose before being asked to consent. For the observational component, consent was obtained from the head of surgery and the lead surgeon for each observed case. All data were anonymised and stored securely. Participation was entirely voluntary, with no incentives offered.

RESULTS

Sociodemographic and Professional Characteristics of Participants

Forty-one operating room professionals completed the questionnaire. The group was almost evenly split by sex: 21 men (51%) and 20 women (49%). In terms of professional role, nurse anaesthetists were the largest group (n=12, 29%), followed by operating room nurses (n=11, 27%), with surgeons and assistant operating room staff each accounting for 22% (n=9). Most participants had several years of experience working in surgical environments.

Table 1: Characteristics of respondents

Variable	n	%
Sex		
Male	21	51
Female	20	49
Professional Category		
Nurse Anesthetist	12	29
Operating Room Nurse	11	27
Surgeon	9	22
Assistant Operating Room Staff	9	22

What Professionals Know About the SSC

On paper, knowledge levels were high. Thirty-five participants (85%) could give a correct definition of the SSC, and every single one all 41 acknowledged that its primary objectives are to improve patient safety and reduce surgical errors. There was one notable gap, however: only 71% (n=29) could correctly identify and describe all three execution phases in the right sequence. That means roughly one in four team members was uncertain about the structure of the very tool they are expected to lead.

Table 2: Knowledge of the Surgical Safety Checklist

Knowledge Item	n	%
Correctly defined the SSC	35	85
Acknowledged the objectives of the SSC (improve safety, reduce errors)	41	100
Correctly identified all three execution phases	29	71

Perception of the Surgical Safety Checklist

Perception of the SSC was overwhelmingly positive in principle. All respondents (100%) agreed that the checklist improves patient safety and helps prevent surgical errors. A large majority (78%) also recognized its value in improving communication within the surgical team. However, this positive view was tempered by practical concerns. Nearly half of the participants (n=19, 46%) perceived the checklist as an additional administrative burden that added to their workload. Furthermore, a significant proportion (n=30, 73%) reported that using the checklist was difficult to apply correctly and consistently during emergency procedures, where time pressure is a major factor. Table 3 details these perceptions.

Table 3: Perception of the Surgical Safety Checklist

Perception Statement	Agree (%)
Improves patient safety	100
Prevents surgical errors	100
Improves team communication	78
Is considered an additional administrative burden	46
Is difficult to apply in emergencies	73

Professional Involvement and Observed Execution of the Checklist

This is where the study's most telling findings emerge. When we stepped into the operating rooms and watched, the picture shifted considerably from what questionnaire responses suggested. Across all 25 observed procedures, roughly 60% of checklists were poorly executed meaning items were skipped, completed without any real team engagement, or ticked off almost as a reflex rather than a genuine shared check. The quality of execution also varied markedly depending on which phase of the checklist was being performed.

The Sign-In phase, conducted before anaesthesia induction and typically carried out by the nurse and anaesthetist, was the most reliably completed, with 78% of its items correctly executed. It focuses on patient identity, consent, and anaesthesia safety checks tasks that are well rehearsed and do not require the whole team to stop. The Time-Out phase the critical pause that must happen just before the first incision, with the entire team present showed a sharp drop in compliance: only 52% of items were correctly executed. This is the moment that requires everyone in the room to pause, speak, and listen. In practice, it was frequently rushed, partially completed, or quietly skipped, especially during busy lists.

The Sign-Out phase, intended to close the procedure safely before the patient leaves the theatre, had the lowest compliance of all: just 41%. These observational findings are summarized in Table 4.

Table 4: Observed compliance with the WHO Surgical Safety Checklist by phase

Checklist Phase	Correctly Executed (%)
Sign-In (before anesthesia)	78
Time-Out (before incision)	52
Sign-Out (before leaving OR)	41

This study set out to understand the WHO Surgical Safety Checklist from the inside not just as a policy instrument, but as something that real people in real operating theatres in Yaoundé choose to use, half-use, or quietly set aside. By combining what professionals told us with what we actually observed, a nuanced and at times uncomfortable picture emerged.

Positive perception but limited translation into practice

The near-universal theoretical endorsement of the SSC among our participants is consistent with what studies from other parts of the world have found [11, 16]. Nobody in our study rejected the checklist's value. All 41 participants agreed it improves patient safety. By conventional measures of awareness, this could be declared a success.

And yet, when we watched those same teams work, roughly 60% of checklists were incomplete or superficial. This is one of the clearest illustrations we have seen in our local context of what the literature calls the "implementation gap" [12, 14] the persistent distance between knowing something matters and actually doing it consistently. In the rooms we observed, the checklist had often become a formality: boxes ticked, words said by rote, but without the shared attention and communication that give it meaning.

Variability in compliance across checklist phases

The progressive drop in compliance across the three phases from 78% at Sign-In to 41% at Sign-Out is not random. It maps directly onto what each phase demands of the team. Sign-In is a focused, bilateral interaction: a nurse and an anaesthetist confirming technical information before a third person has entered the room. It requires care but not collective disruption. Time-Out and Sign-Out are different. They require the entire team to stop simultaneously, speak openly, and in the case of Time-Out introduce themselves and discuss what could go wrong. These are the phases most dependent on psychological safety, on a team culture where junior staff feel entitled to speak, and on senior clinicians who actively lead rather than passively observe [8, 18].In the settings we observed, those conditions were inconsistently present. The Time-Out, in particular, was frequently rushed or incomplete especially during emergency cases or when operating lists were long. This is deeply concerning, because emergencies are precisely the moments when structured communication can prevent fatal errors [5].

Perceived barriers and contextual constraints

The 73% of participants who said the checklist is hard to use in emergencies are not making excuses. They are describing something real about operating rooms in resource-limited settings: understaffing, high case volumes, and constant pressure to move quickly [13, 15]. When the next patient is already waiting and the team is tired, a safety protocol that requires everyone to stop, speak, and listen can feel like a luxury rather than a necessity.

This perception that the checklist interrupts rather than supports the work is one of the most important barriers to address. It will not be resolved by posters on the wall or a single training session. It requires the checklist to be experienced, repeatedly, as something that fits the rhythm of surgical work rather than standing apart from it.

Team dynamics, hierarchy, and leadership engagement

The low compliance during Time-Out and Sign-Out phases also reflects a deeper structural reality in many African operating rooms: professional hierarchy. When the most senior surgeon in the room does not initiate or visibly endorse the checklist, the message that reaches junior staff is clear this is optional [15, 16].

Qualitative studies in sub-Saharan Africa have documented how difficult it is for nurses, in particular, to insist on checklist completion when surgeons have not themselves committed to it [16]. In our observational data, leadership during checklist execution was inconsistent across sites, with the phases requiring collective participation being the most frequently short-changed. Senior engagement is not a nice-to-have; it is the foundation on which everything else rests.

The Absence of Feedback Loops

One thread that runs through all of these findings is the absence of accountability. When checklist completion is not monitored, when omissions go unnoticed, and when no one reviews compliance data with the team, there is no mechanism to improve. The literature is consistent on this point: sustained gains in SSC use require institutional structures regular audits, feedback to teams, local champions who champion the tool not as a bureaucratic requirement but as a genuine safety practice [17, 19].

Without these structures, initial improvements tend to fade. What we observed in several of our cases checklist completion that looked more like a ritual than a real check is a well-documented endpoint of implementation without reinforcement, sometimes called the "tick-box" problem.

Placing These Findings in the Cameroonian Context

The national-level work on SSC implementation in Cameroon, notably the multi-component strategy described by White et al. [17], demonstrated that meaningful gains in checklist penetration are achievable through structured, supported programmes. Our findings do not contradict this. They complement it by showing what happens on the ground, in individual theatres, once that initial push has passed.

There is also a methodological point worth making. Self-reported data questionnaires like ours consistently overestimate actual compliance. Direct observation gives a more honest reading. The gap between what our participants said they did and what we watched them do underscores why mixed-method approaches are not merely a methodological preference but a practical necessity for anyone trying to understand SSC implementation realistically.

IMPLICATIONS FOR PRACTICE

Taken together, these findings point toward a set of concrete, context-sensitive actions. Team-based and simulation training focused specifically on emergency scenarios could help normalise checklist use under pressure. Explicit, visible leadership from senior surgeons who lead the Time-Out and Sign-Out with the same care they bring to the operation itself would change the cultural message. Regular, non-punitive feedback to teams about their checklist performance would close the accountability loop. And embedding the SSC into standard operating procedures making it part of how surgery works here, not an imported add-on would give it the relevance and staying power it currently lacks.

CONCLUSION

Operating room professionals in this study view the World Health Organization Surgical Safety Checklist as a valuable and essential tool for patient safety. However, this positive perception does not consistently translate into rigorous daily practice. In reality, its use remains uneven and is sometimes reduced to a mere formality, particularly during the critical Time-Out and Sign-Out phases. This gap is not coincidental. It reflects both structural and behavioral constraints: persistent time pressure in the operating room, entrenched hierarchical relationships that limit open communication, the perception of the checklist as an additional administrative burden, and a lack of strong institutional support. Bridging this gap requires more than simple awareness—it calls for a genuine change in practice. The checklist must be fully integrated into routine surgical workflows rather than treated as an optional add-on. Training approaches should move beyond theory and prioritize practical, simulation-based learning grounded in real operating room conditions. At the same time, teams must foster an environment of psychological safety, where every member, regardless of status, feels empowered to speak up.

DECLARATIONS

Authors' Contribution

All authors contributed equally to the conception and design of the study, data collection, analysis and interpretation of results, and the drafting and final approval of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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AI Use Declaration

Artificial intelligence tools were used solely for language editing and grammatical support during manuscript preparation. No AI tools were used for data generation, data analysis, interpretation of results, or substantive content creation. The authors take full responsibility for the manuscript's content.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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A Multinational Audit of WHO Surgical Safety Checklist Adherence in Low-Resource Settings

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Declaration:

Authors' Contribution: All authors contributed substantially to the study conception, design, data collection, analysis, manuscript preparation, and final approval of the submitted version. Prof. Adebusola Adenike Owokole led the overall study supervision, ensured regulatory compliance, coordinated site documentation across participating institutions, and reviewed all stages of the study; Asst. Prof. Nurhusen Riskey Arefayne conceptualized the study; Dr. Nigussie Tefera Habiteyohannis coordinated project implementation and supported site-level engagement and data collection processes; Mr. Hailemariam Getachew Tesema and Dr. Kevin Miko Maestrado Buac contributed to the development and design of the audit tool; Dr. Alazar Menbere Haile conducted the statistical analysis, data interpretation, and visualization of findings; Asst. Prof. Demeke Yilkal Fentie developed

ABSTRACT

Background: The World Health Organization Surgical Safety Checklist (WHO SSC) is a widely implemented intervention to improve perioperative safety. However, the extent to which these findings can be extrapolated to the real-world context is uncertain, particularly in low and middle-income countries (LMICs). The objective of this study was to evaluate the adherence to checklists, identify any implementation gaps, and assess the association between checklist adherence and perceived adverse event prevention across a range of healthcare settings.

Methods: A prospective multicenter observational audit was conducted across seven countries within The Operating Room Global (TORG). The study incorporated both direct observation and retrospective review of surgical procedures. Ethical approval was obtained from The Operating Room Global Institutional Review Board (TORG-IRB), approval number TORG/IRB/002/2025 and local institutions. The analysis encompassed a total of 1,132 surgical procedures. The degree to which checklist adherence was demonstrated was evaluated at the overall, phase, and item levels. The primary outcome was a self-reported measure of perceived adverse event prevention, based on intraoperative team reporting, and does not represent objectively

the audit proposal and contributed to the conceptual framework of the study; Dr. Kübra Özpınar led the manuscript drafting, integration of sections, literature synthesis, and overall writing of the manuscript; Data collection across participating institutions was conducted by Dr. John Amani, Clement Okyere Sefa, Sayed Ahbab Hussain, Arshad Ali M. Bashir, Bedlu Tilahun Amtate, Getachew Mekete Deress, Dr. Mesfin Shimelash Abeje, Dr. Samuel Wodajo Mamo, Dr. Nigat Amsalu Addis, Amare Belete Getahun, Dr. Joshua Olaopin, Abdulkarim Abdulwahab, Firdausi Yusha'u Muhammad, and Ahmed Shuaibu Tsafi. These contributors were responsible for data collection, validation, and submission using the standardized audit tool.

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verified clinical outcomes. The associations were evaluated using bivariate analysis and multivariable logistic regression, with mixed-effects modelling to account for hospital-level clustering. A qualitative analysis was also conducted on the implementation barriers that were encountered.

Results: Perceived adverse event prevention was reported in 77.1% of cases. Perfect checklist adherence was observed in 4.1% of cases and was associated with higher odds of perceived adverse event prevention in multivariable analysis (odds ratio [OR]: 6.40; 95% confidence interval [CI]: 1.91-39.9; $p < 0.001$), although the wide confidence interval suggests limited precision. However, this association was attenuated and no longer statistically significant after accounting for hospital-level clustering (OR: 3.45; $p = 0.100$; ICC = 0.27), indicating substantial variability between hospitals. Adherence to the checklist varied across the phases of the study, with substantial gaps in key safety items such as infection risk assessment (72.9%) and DVT prophylaxis (66.8%). The discriminative ability of checklist adherence was modest (AUC = 0.646). The qualitative findings identified training deficits and resource limitations as the primary barriers.

Conclusions: While higher checklist adherence was associated with perceived adverse event prevention, this relationship appears to be strongly influenced by the institutional context. However, this association was not statistically significant after accounting for hospital-level clustering, suggesting that institutional and system-level factors may play a more critical role than adherence alone. Strengthening training, infrastructure, and workflow integration may support improved checklist implementation in low-resource settings. These findings should be interpreted considering the subjective nature of the outcome measure.

Keywords: *Low-Resource Countries; Patient Safety; Surgical Safety Checklist; Global Surgery; Quality Improvement; Perioperative Safety*

INTRODUCTION

The launch of the World Health Organization (WHO) Surgical Safety Checklist (SSC) in 2008 represented a major milestone in global efforts to improve patient safety and surgical outcomes. The SSC was developed with the objective of reducing preventable incidents and perioperative adverse events. Since then, it has been adopted extensively across a wide range of healthcare systems, encompassing both high-income and low- and middle-income countries (LMICs). In settings where resources are limited and where the structural and systemic challenges are more pronounced, the checklist offers a particularly valuable and pragmatic intervention. Beyond the improvement of clinical outcomes, its implementation has been linked to enhanced team communication, greater adherence to evidence-based practices such as timely antibiotic prophylaxis, and the strengthening of institutional safety culture. However, evidence from real-world settings suggests that the effectiveness of the checklist is highly variable and dependent on context, with inconsistent adherence limiting its impact in routine practice (Alsadoun et al., 2024; Allen Ingabire et al., 2025).

The challenge of establishing a connection between evidence-based interventions and their consistent application in routine clinical practice remains a pivotal issue in global health. This necessity is especially evident in LMICs, where limited resources, inadequate facilities, and systemic deficiencies lead to suboptimal surgical safety and patient outcomes compared to those observed in high-income settings. Notwithstanding the well-established impact of the WHO SSC, its integration into routine surgical workflows in these contexts remains inadequate. Importantly, checklist adoption does not necessarily translate into effective adherence, and this distinction remains a critical gap in current evidence (White et al., 2021).

The consistent adherence to the WHO SSC remains a significant challenge, particularly in LMICs. A number of factors limit the effective integration of the checklist into routine surgical practice, including workforce shortages, high clinical workload, and logistical constraints. In addition, communication failures within the operating room represent a critical but often underrecognized barrier. It has been reported that a substantial proportion of intraoperative interactions are affected by communication breakdowns, occurring at frequent intervals during surgical procedures. Such disruptions may contribute to adverse events and compromise patient safety, further amplifying the burden associated with surgical care. Despite general awareness of the checklist among healthcare professionals, its uptake remains suboptimal, suggesting that familiarity alone is insufficient to ensure effective implementation. This underscores the complex interplay between systemic limitations and behavioral factors in shaping checklist utilization (Khalid et al., 2023; Allen Ingabire et al., 2025).

Furthermore, discrepancies between self-reported and observed practices have been highlighted in previous studies, suggesting that reported adherence may overestimate actual checklist use in clinical settings. This highlights the importance of objective evaluation methods, such as direct observation and structured audits, to accurately assess real-world implementation. The present study addresses this gap by incorporating both direct observation and retrospective review, enabling a more comprehensive assessment of real-world checklist adherence.

Addressing this gap requires a deeper understanding of the contextual barriers affecting implementation and the development of targeted, context-sensitive strategies. To advance patient safety, it is imperative to fortify the evidence base surrounding the utilisation of checklists in LMICs and to translate proven interventions into meaningful improvements in surgical care (White et al., 2021).

Despite the growing body of literature on the WHO SSC, significant gaps remain in understanding its real-world implementation. Many existing studies are limited by single-center designs or reliance on self-reported data, which may not accurately reflect routine clinical practice. This limits the generalizability of findings, particularly in low-resource settings where contextual and system-level challenges are more pronounced. Addressing these challenges requires a multifaceted approach, including improving checklist accessibility within clinical workflows, strengthening ongoing team training, and fostering a culture of patient safety (Allen Ingabire et al., 2025).
This study aimed to evaluate real-world adherence to the WHO SSC across multiple healthcare settings in LMICs, identify implementation gaps, and assess the association between adherence and perceived adverse event prevention.

METHODS

Study Design and Setting

The objective of this study was to conduct a prospective, multicentre observational audit with the aim of evaluating real-world adherence to the WHO SSC. The audit was conducted across a number of healthcare institutions participating in an international collaborative network coordinated by The Operating Room Global (TORG).
The study included both direct observation and retrospective record review of surgical procedures.

Study Population

Inclusion Criteria: All anonymized records of adult patients (18+ years) undergoing surgery during the audit period, where WHO SSC documentation is available. Cesarean section records will be included as part of the obstetric surgical population. All such data will be anonymized and evaluated for additional risks under local IRB oversight. Participation of such cases will be contingent upon IRB clearance confirming ethical suitability for inclusion.
Exclusion Criteria: Records lacking completed SSC documentation, missing outcome variables, or procedures performed outside a designated operating theatre environment. The exclusion of cases without completed checklist documentation may introduce selection bias, as cases with poor adherence may be underrepresented.

Sample Size

The study aims for complete audit data across 44 institutions. Institutions are expected to audit a representative sample of their surgeries over 4 months, including general, obstetric (Cesarean), orthopedic, and other major specialties. While the audit aims to collect a full census of surgeries across the 4 months, this volume is expected to provide sufficient statistical power for subgroup analyses, including cesarean-specific data, and to detect meaningful variations in adherence rates across facilities. Cesarean section cases were analysed both as part of the overall cohort and as a predefined subgroup due to their high representation. This pragmatic sampling approach, based on consecutive case inclusion over a defined audit period, is

consistent with multicentre audit methodologies and is expected to provide sufficient statistical power to detect meaningful variations in checklist adherence and associated outcomes across institutions.

Data Collection and Management

Data was collected by trained institutional auditors using a digital or paper-based tool and submitted weekly to a secure, encrypted database. Only de-identified information was accepted. Each participating institution appointed a local lead and secured ethics approval or exemption which was submitted prior to the commencement of data collection A copy was retained centrally for audit purposes. All data collectors completed standardized, virtual training modules developed by TORG to ensure uniform interpretation of checklist items and protocol adherence across sites. In some participating institutions, data collection was conducted by multiple members of the surgical team using a shared institutional login. In such cases, contributions were attributed at the site level to ensure data completeness while maintaining anonymity. The proportion of cases collected via direct observation versus retrospective review was not formally stratified, and differences between these methods were not independently assessed.

Statistical analysis

Statistical analyses were conducted using RStudio version 2024.04.2 (R Core Team, 2024). Categorical variables are presented as frequencies and percentages. Checklist adherence was defined as the proportion of applicable checklist items completed per case and was analyzed as a continuous variable, reported as means with standard deviations. Perfect checklist adherence was defined a priori as completion of all applicable checklist items for a given case and was analyzed as a binary variable. All checklist items were treated equally in this definition, consistent with prior audit-based studies, although this binary classification may not capture the relative importance of individual items. Adherence was assessed overall and stratified by checklist phase, country, and surgical specialty. Phase-specific and item-specific adherence rates were calculated as the proportion of checklist items completed.

The primary outcome was a self-reported measure of perceived adverse event prevention, operationalized from the checklist item, "Were any adverse events prevented due to checklist use?", and analyzed as a binary variable. This measure reflects subjective intraoperative team assessment and does not represent objectively verified clinical outcomes. Bivariate associations between perfect checklist adherence and perceived adverse event prevention were assessed using Fisher's exact test. Differences in continuous adherence between groups, including trained and untrained staff, were assessed using the Wilcoxon rank-sum test.

Multivariable logistic regression was used to examine the association between perfect checklist adherence and perceived adverse event prevention, adjusting for facility type. Covariates were selected based on clinical relevance and prior literature. Multicollinearity among covariates was assessed using variance inflation factors. Adjusted odds ratios with 95% confidence intervals were reported. Model assumptions, including goodness-of-fit and residual diagnostics, were assessed to ensure model validity. Model discrimination was evaluated using the area under the receiver operating characteristic curve.

To account for clustering of cases within hospitals, a mixed-effects logistic regression model with a hospital random intercept was fitted. Hospital-level clustering was prioritized due to expected variability in institutional practices, while country-level clustering was not included due to limited sample sizes within some countries. Between-hospital variance, intraclass correlation coefficient, and marginal and conditional R^2 values were reported. Given the low frequency of perfect adherence events, Firth's penalized logistic regression was used as a sensitivity analysis to reduce small-sample bias. Statistical significance was set at a two-sided p-value of <0.05. This approach was selected to address potential sparse data bias due to the low frequency of perfect adherence events.

Qualitative responses to barriers to checklist implementation were analyzed using descriptive content analysis. Free-text responses were coded into recurring themes and summarized as proportions. This outcome reflects perceived prevention based on intraoperative team reporting and does not represent independently adjudicated clinical outcomes. Patient-level variables such as age, case complexity, and urgency of surgery were not available in the dataset and therefore could not be included in the analysis.

Ethical Considerations

Ethical approval for this study was obtained from The Operating Room Global Institutional Review Board (TORG-IRB; Approval No. TORG/IRB/002/2025). No direct patient interaction or personal identifiers will be involved. All data will be

anonymized at the source and handled per international data governance standards. Sites will seek local IRB approval; The Operating Room Global IRB (TORG-IRB) will offer umbrella ethics oversight. Data Use Agreements will be signed by each institution. A waiver of informed consent was granted due to the minimal-risk, non-interventional nature of the study and the exclusive use of fully anonymized data. Formal Data Use Agreements (DUAs) between TORG and each participating institution will be executed prior to data transfer to govern data use, storage, security, and compliance with international standards such as GDPR.

Any participating site may withdraw from the study at any time before uploading data to the central platform. Once anonymized data is submitted, withdrawal will not be feasible due to de-identification. Cesarean section records will be included as part of the obstetric surgical population. All such data will be anonymized and evaluated for additional risks under local IRB oversight. Participation of such cases will be contingent upon IRB clearance confirming ethical suitability for inclusion. A staff-facing information sheet explaining the project's objectives, voluntary participation, and privacy protocols will be prepared. The study will comply with all relevant data protection laws, including GDPR. Data Transfer Agreements will be implemented prior to the launch, outlining international standards for cross-border data security.

RESULTS

Study population and surgical characteristics

Key findings are presented using descriptive tables and graphical visualizations to illustrate variations in checklist adherence and associated factors across settings. Data were derived from a combination of direct intraoperative observation and retrospective documentation review using a standardized audit tool. A total of 1,132 surgical cases from seven countries were included, reflecting a diverse range of healthcare settings. The majority of cases were contributed by Ethiopia and Nigeria, followed by Pakistan and Tanzania, demonstrating the broad distribution of surgical activity across participating sites. The distribution of facility types across participating institutions is illustrated in Figure 1. Checklist adherence varied across countries, with generally high median adherence but notable variability in some settings (Figure 4). The baseline characteristics of the study population, including distribution across countries, facility types, and surgical specialties, are summarized in Table 1.

Table 1. Distribution of Study Participants by Country and Healthcare Facility

Country	Hospital	Facility type	n = 1132 [1]
Ethiopia			
	Debre Berhan Comprehensive Specialized Hospital	University Teaching Hospital	146 (12.9%)
	Debre Tabor Comprehensive Specialized Hospital	University Teaching Hospital	114 (10.1%)
	University of Gondar Comprehensive Specialized Hospital (UOG)	University Teaching Hospital	104 (9.2%)
	Injibara University Hospital	Public	7 (0.6%)
Nigeria			
	Aminu Kano Teaching Hospital	University Teaching Hospital	112 (9.9%)
	Babcock University Teaching Hospital	University Teaching Hospital	100 (8.8%)
	Federal Medical Centre Nguru	Public	56 (4.9%)
	University of Port Harcourt Teaching Hospital Choba.	University Teaching Hospital	2 (0.2%)
Pakistan			
	District Head Quarter Hospital, Parachinar	Public	104 (9.2%)
	Indus hospital QF NST SMPT network jubilee Town	University Teaching Hospital	101 (8.9%)
Tanzania			
	Global Maternity	Both Private and Public	165 (14.6%)
Ghana			
	FOCOS Orthopedic Hospital	Private/NGO	111 (9.8%)
Rwanda			
	Kabutare District Hospital	Public	9 (0.8%)
Burundi			
	University Teaching Hospital of Kamenge (CHUK), Rwanda	University Teaching Hospital	1 (0.1%)

[1] n (%)

Figure 1. Distribution of Facility Types Across Participating Institutions

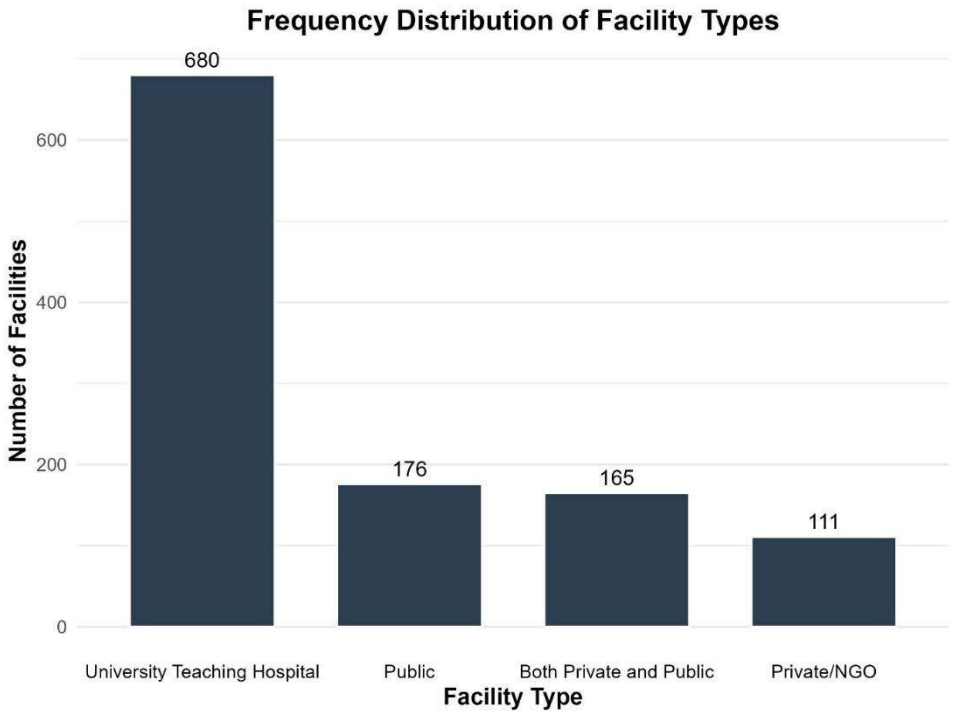
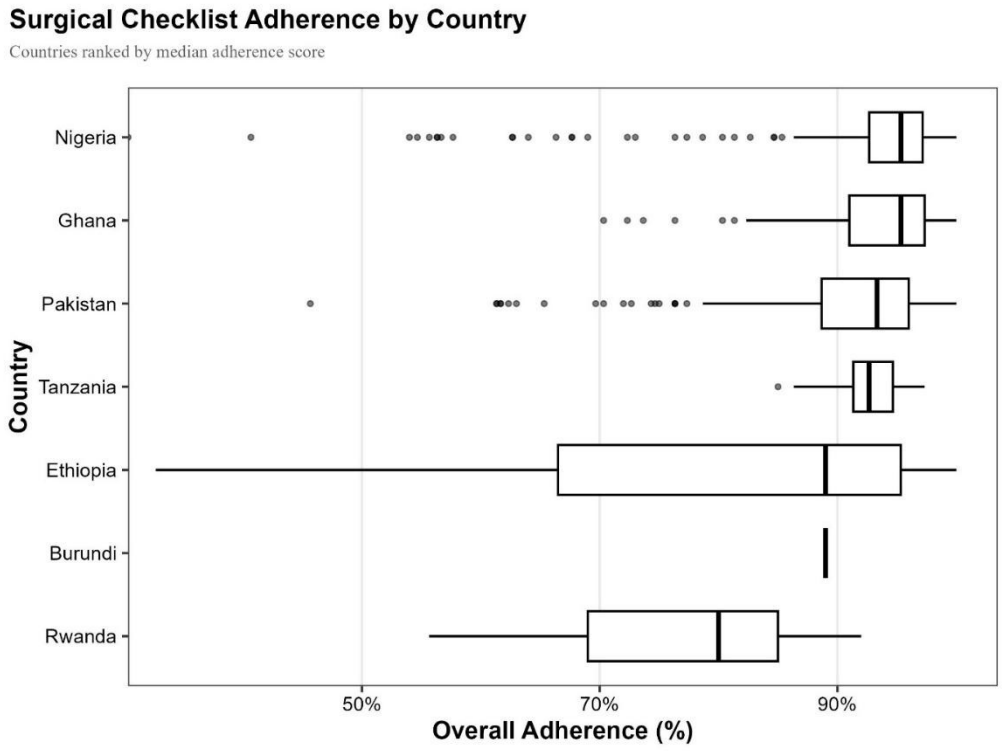
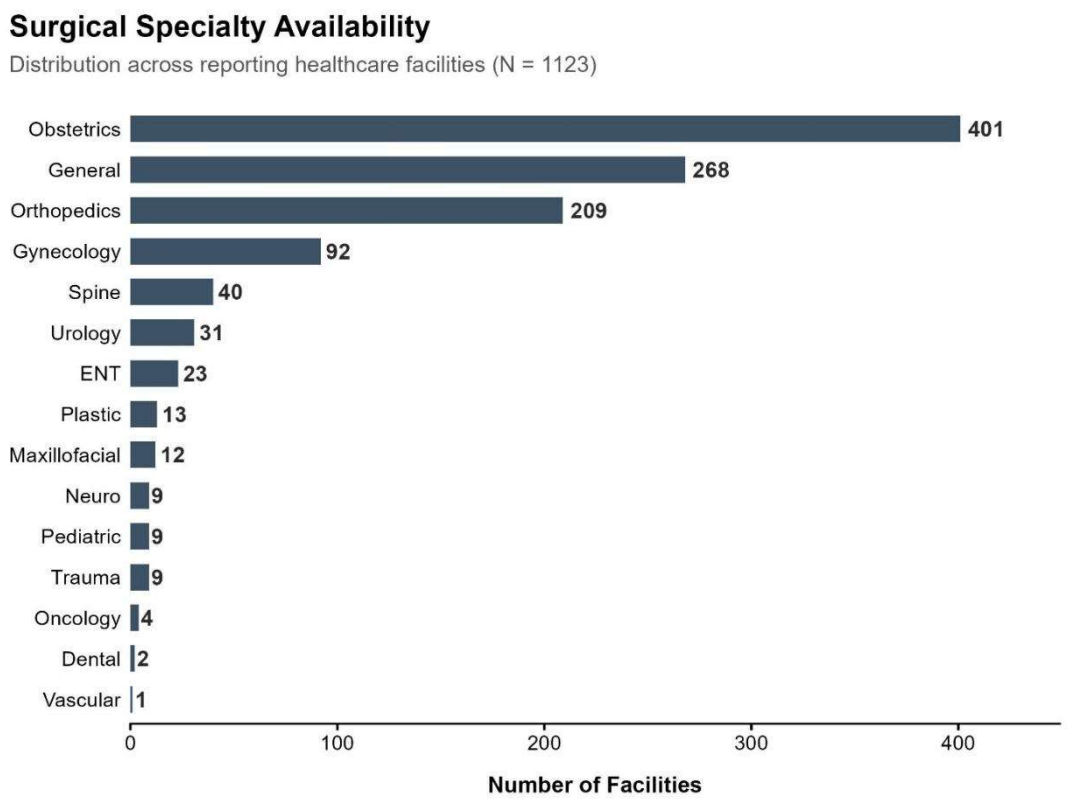


Figure 4. Variation in Checklist Adherence Across Countries



Most procedures were performed in university teaching hospitals, accounting for over half of all cases, with the remainder distributed across public and mixed public-private facilities (Figure 2). In terms of surgical specialties, obstetrics constituted the largest proportion of cases, followed by general surgery and orthopaedics, highlighting the varied clinical contexts in which the checklist was evaluated. The distribution of surgical specialties is shown in Figure 2.

Figure 2. Distribution of Surgical Specialties in the Study Cohort



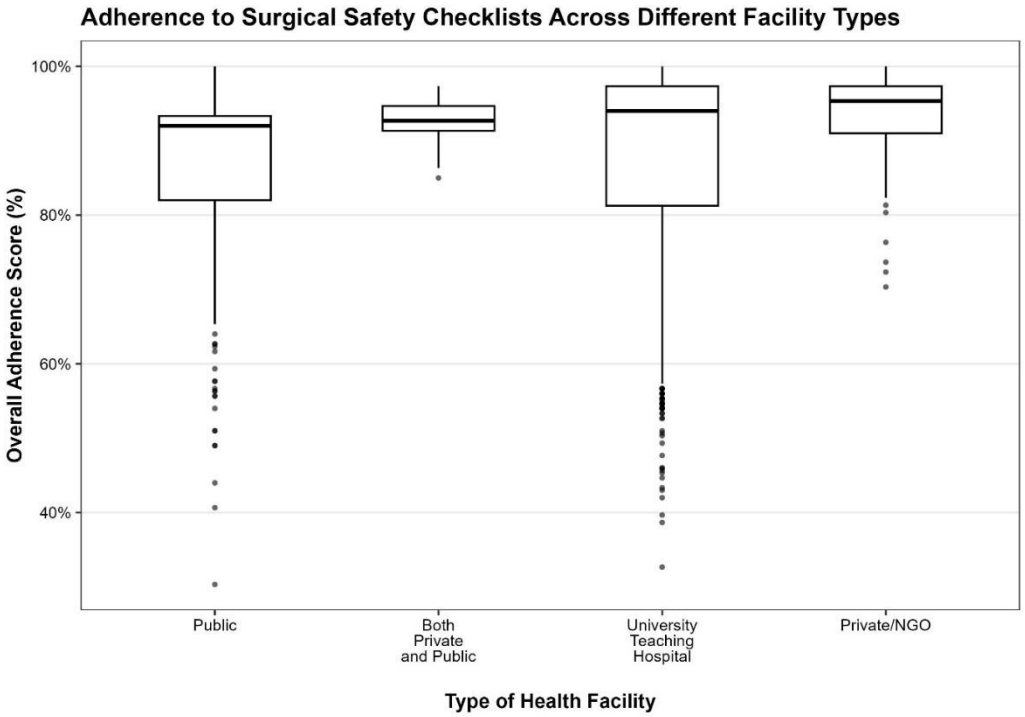
Adherence scores also differed across facility types, with university hospitals demonstrating slightly higher median adherence compared to other facility categories (Figure 3). Overall checklist adherence rates across participating institutions are presented in Table 2, demonstrating variation in adherence levels across settings.

Table 2. Surgical Safety Checklist Non-Adherence by Phase

Phase	Safety Item	Non-Adherence Rate (%)
Phase 0: Preop Briefing		
	Contingency Planning	14.2
	Safety Concerns Discussed	13.2
	Team Roles Defined	11.4
	Briefing Conducted	10.4
Phase 1: Sign-In		
	Infection Risks	72.9
	DVT Prophylaxis	66.8
	Airway Assessment	40.6
	Patient-Specific Specs	38.5
	Allergy Status	12.5
	Blood Loss Estimate	11.0
	Site Marking	8.1
	Antibiotic Prophylaxis	5.2
	Fasting Status	4.4
	Equipment Readiness	1.7
	Procedure Confirmation	1.3
	Anesthesia Machine Check	0.9
	Patient Identity	0.6
	Pulse Oximetry	0.4
	Informed Consent	0.2
Phase 2: Time-Out		
	Essential Imaging	43.5
	Team Introductions	11.2
	Critical Steps Review	4.2
	Sterility Indicators	2.3
	Pre-Incision Counts	2.3
	Final Site/Proc Check	1.5
Phase 3: Sign-Out		
	Recovery Concerns	2.7
	Post-Op Instructions	2.2
	Post-Op Counts	1.6
	Field Sterility Check	1.1
	Complete Documentation	0.9
	Post-Op Vital Signs	0.3
Phase 4: Postop Debriefing		
	Improvement Identified	24.6
	Debriefing Conducted	16.7
	Complications Review	16.4
	Follow-up Planning	7.8

[1]Percentage of cases where checklist items were omitted.
Color intensity reflects the degree of non-adherence.

Figure 3. Variation in Checklist Adherence by Facility Type



Item-Level Non-Adherence Across Checklist Phases

A detailed analysis of individual checklist components revealed substantial variability in non-adherence rates across different phases of the WHO SSC.

During the preoperative briefing phase, non-adherence rates ranged from 10.4% for completion of briefing to 14.2% for contingency planning, indicating relatively consistent execution of preparatory steps.

Conversely, the Sign-In phase exhibited the greatest variability, with the highest non-adherence rates observed. Infection risk assessment was the most frequently omitted item (72.9%), followed by deep vein thrombosis (DVT) prophylaxis (66.8%). Other critical safety checks, including airway assessment (40.6%) and patient-specific considerations (38.5%), also showed notable gaps. In contrast, essential safety steps such as patient identity verification (0.6%), pulse oximetry (0.4%), and informed consent (0.2%) were almost universally completed. Detailed item-level adherence rates, including high-risk omissions such as infection risk assessment and DVT prophylaxis, are presented in Table 4.

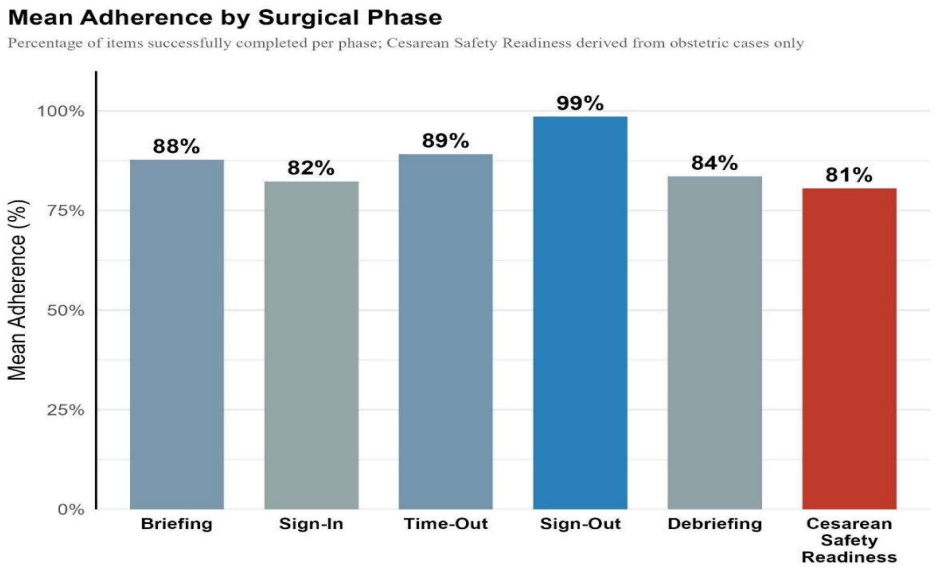
Table 4. Bivariate Analysis of Adverse Events Prevented

Predictors	Adverse Events Prevented			p-value[2]
	Overall N = 1,132[1]	No N = 259[1]	Yes N = 873[1]	
Perfect Adherence to Protocol				**<0.001**
Not-achieved	1,086 (96%)	257 (99%)	829 (95%)	
Achieved	46 (4.1%)	2 (0.8%)	44 (5.0%)	
Type of Health Facility				**<0.001**
Both Private and Public	165 (15%)	30 (12%)	135 (15%)	
Private/NGO	111 (9.8%)	50 (19%)	61 (7.0%)	
Public	176 (16%)	68 (26%)	108 (12%)	
University Teaching Hospital	680 (60%)	111 (43%)	569 (65%)	

[1]n (%)
[2]Fisher's exact test
Bold values indicate statistically significant results (P < .05)

Within the Time-Out phase, most checklist items demonstrated relatively high adherence, except for essential imaging review, which showed a non-adherence rate of 43.5%. Team introductions (11.2%) and critical step review (4.2%) demonstrated stronger adherence. The variation in adherence across the different phases of the checklist is summarized in Figure 5.

Figure 5. Mean Checklist Adherence Across Surgical Phases



The Sign-Out phase showed consistently high adherence, with non-adherence rates below 3% for most items, including recovery concerns (2.7%) and postoperative instructions (2.2%). Documentation completeness (0.9%) and postoperative vital sign recording (0.3%) were among the most consistently performed elements.

In the postoperative debriefing phase, non-adherence rates were comparatively higher. Identification of improvement points was omitted in 24.6% of cases, while debriefing conduct (16.7%) and complication review (16.4%) also demonstrated notable gaps. Follow-up planning was omitted in 7.8% of cases.

In the caesarean subgroup, adherence to key safety measures was generally high, including fetal heart rate assessment (87.4%), readiness of suction equipment (79%), and availability of a radiant warmer (75.3%) (Table 10). Phase-specific adherence rates across the WHO SSC are detailed in Table 3, highlighting variability across different stages of the surgical process.

Table 3. Summary of Surgical Safety Checklist Adherence by Specialty

Specialty	Procedures (n)	Item Completion, Mean (%)	Perfect Adherence, n (%)
Obstetrics	401	87.5%	15 (3.7%)
General Surgery	268	87.2%	8 (3.0%)
Orthopedics	209	87.9%	12 (5.7%)
Gynecology	92	92.2%	2 (2.2%)
Spine	40	94.2%	0 (0.0%)
Urology	31	87.8%	2 (6.5%)

Note: Data presentation is limited to specialties with n ≥ 30 to provide more stable descriptive estimates.

Factors Associated with Perceived Adverse Event Prevention

A total of 1,132 surgical procedures were analysed, and perceived adverse event prevention was reported in 77.1% of cases. Perfect checklist adherence was observed in 4.1% of cases.

In bivariate analysis, perfect checklist adherence and facility type were both significantly associated with the prevention of adverse events ($p < 0.001$ for both). Bivariate associations between checklist adherence and adverse event prevention are summarized in Table 5.

Table 5. Logistic Regression of Adverse Events Prevented

Predictors	OR[1]	95% CI[1]	p-value
Perfect Checklist Compliance	6.40	1.91, 39.9	**<0.001**
Facility Type			**<0.001**
Public	—	—	
Both Private and Public	2.87	1.76, 4.78	**<0.001**
Private/NGO	0.73	0.45, 1.19	0.2
University Teaching Hospital	3.09	2.14, 4.46	**<0.001**

[1]*OR = Odds Ratio, CI = Confidence Interval*
Bold values indicate statistically significant results (P < .05)

In multivariable logistic regression (Table 6), perfect checklist adherence was independently associated with higher odds of perceived adverse event prevention (OR: 6.40; 95% CI: 1.91-39.9; $p < 0.001$), although the wide confidence interval suggests limited precision. Results from multivariable logistic regression analysis are presented in Table 6, showing adjusted associations between checklist adherence and adverse event prevention.

Table 6. Firth Penalized Logistic Regression of Adverse Events Prevented

Predictors	OR[1]	95% CI[1]	p-value
Perfect Checklist Compliance	5.19	1.70, 25.7	**0.002**
Facility Type			
Public	—	—	
Both Private and Public	2.84	1.75, 4.72	**<0.001**
Private/NGO	0.73	0.45, 1.19	0.2
University Teaching Hospital	3.09	2.14, 4.45	**<0.001**

[1]OR = Odds Ratio, CI = Confidence Interval
Bold values indicate statistically significant results (P < .05)

Compared to public hospitals, both private-public facilities (OR: 2.87; 95% CI: 1.76-4.78; p < 0.001) and university teaching hospitals (OR: 3.09; 95% CI: 2.14-4.46; p < 0.001) demonstrated significantly higher odds of prevention, while private/NGO facilities were not significantly associated.

Findings were consistent in Firth penalized regression.
In mixed-effects analysis accounting for hospital-level clustering, importantly, this association was attenuated and no longer statistically significant (OR: 3.45; 95% CI: 0.79-15.15; p = 0.100). Substantial between-hospital variability was observed (ICC = 0.27), indicating a strong influence of institutional-level factors. The mixed-effects model accounting for hospital-level clustering is detailed in Table 7, demonstrating attenuation of the association between adherence and outcomes.

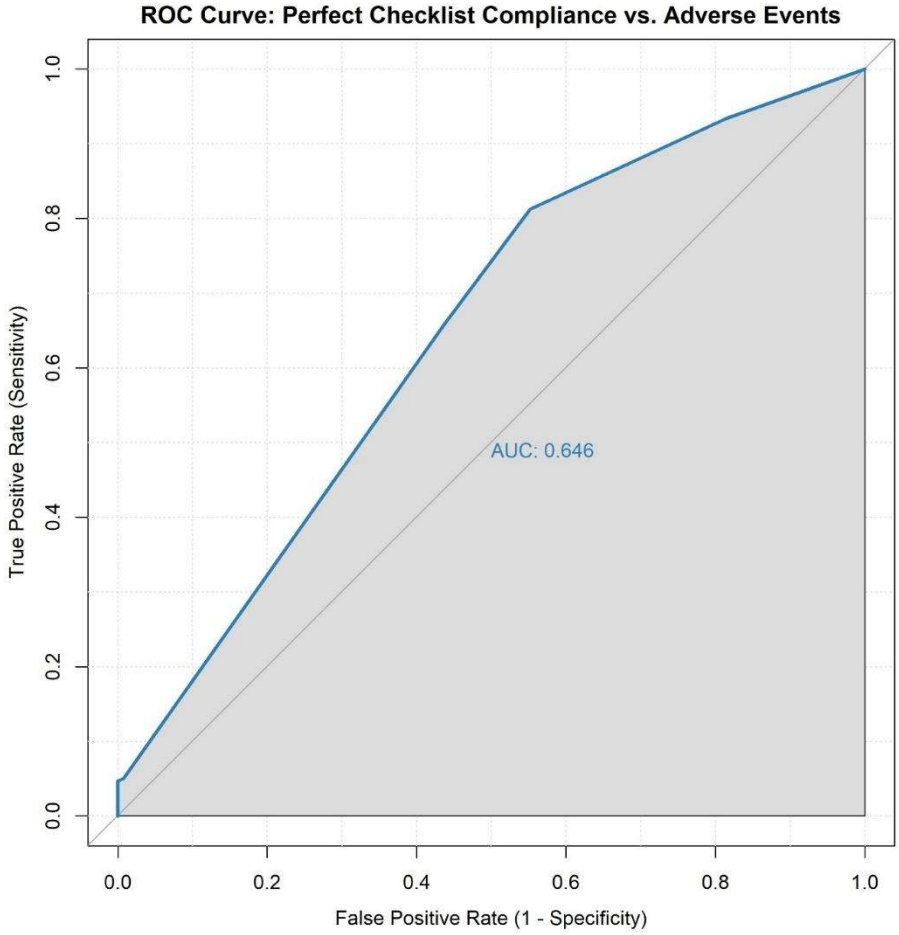
Table 7. Mixed-Effects Logistic Regression of Adverse Events Prevented

	Adverse Events Prevented		
Predictors	**OR[1]**	**95% CI[1]**	**p-value**
Intercept	4.56	2.35 - 8.85	**<0.001**
Perfect Checklist Compliance	3.45	0.79 - 15.15	0.100
Random Effects			
σ^2	3.29		
$\tau_{00\ hospital}$	1.23		
ICC	0.27		
$N_{\ hospital}$	14		

N = 1132; Marginal R2 = 0.013; Conditional R2 = 0.282
[1]OR = Odds Ratio, CI = Confidence Interval
Fixed effects shown. Model accounts for clustering by hospital (Random Intercept)
Bold values indicate statistically significant results (P < .05)

The discriminative ability of perfect checklist adherence to predict prevention of adverse events was modest (AUC = 0.646), as illustrated in Figure 7.

Figure 7. Receiver Operating Characteristic (ROC) Curve for Prediction of Adverse Event Prevention



In a subgroup analysis of caesarean deliveries, perfect checklist adherence was associated with a higher rate of adverse event prevention (100% vs. 76.6%; p = 0.046; Table 9). However, this finding is based on a small number of cases with perfect adherence (n = 14) and should be interpreted with caution.

Table 9. Effect of Checklist Adherence on Adverse Event Prevention (Cesarean Subgroup)

Checklist Adherence	Total (n)	Events Prevented (n)	Prevention Rate (%)
Not-achieved	334	256	76.6%
Achieved	14	14	100%

Fisher's Exact Test p-value: 0.046

Detailed subgroup analyses for cesarean deliveries and adherence to essential safety measures are presented in Table 9 and Table 10, respectively.

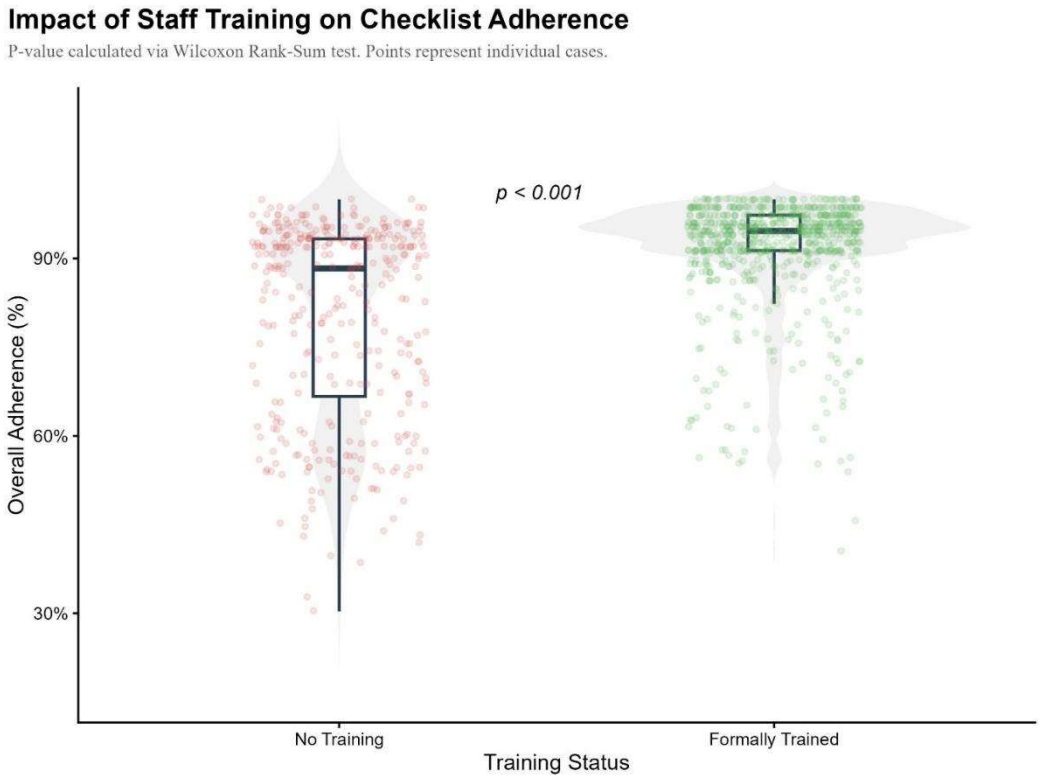
Table 10. Completion of Essential Cesarean Safety Measures

Cesarean Safety Item	Adherence (%)
FHR Check	87.4%
Radiant Warmer Ready	75.3%
Suction Machine Ready	79%

FHR: Fetal heart rate

As shown in Figure 6, checklist adherence was higher among trained staff, highlighting the importance of structured training in improving compliance.

Figure 6. Impact of Staff Training on Checklist Adherence



Additional analyses, including sensitivity and subgroup findings, are presented in Table 8.

Table 8. Summary of Qualitative Feedback

Qualitative Themes	*N = 1,132*[1]
Suggested Improvements to Enhance Compliance	
Training and awareness creation	331 (29%)
Resource and infrastructure support	34 (3.0%)
Checklist inclusion in the EMR	33 (2.9%)
Monitoring and supervision	27 (2.4%)
Better staffing and improved workload	24 (2.1%)
Improved checklist design and workflow	14 (1.2%)
Improved communication and teamwork	12 (1.1%)
Accountability	7 (0.6%)
Incentives and culture change	5 (0.4%)
None	645 (57%)

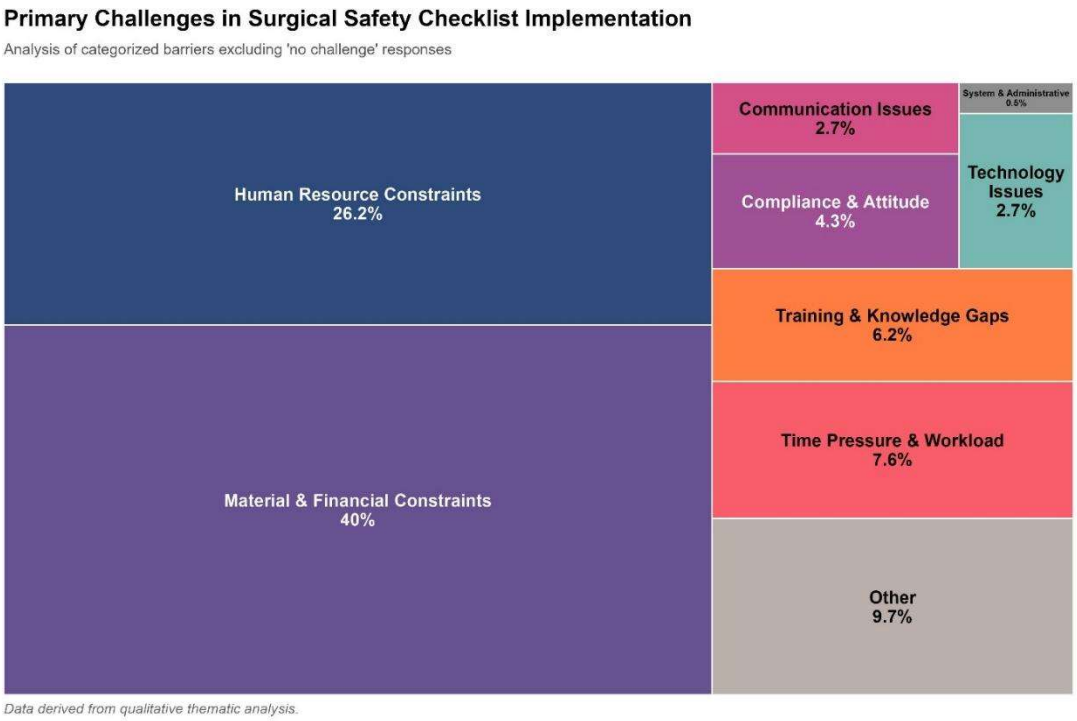
[1]n (%)

Qualitative Findings

Among participants who provided qualitative responses, 57% reported no suggested improvements. Among those who provided feedback, the most frequently reported theme was the need for training and awareness creation (29%). Other suggested improvements included resource and infrastructure support (3.0%), checklist integration into electronic medical records (2.9%), and enhanced monitoring and supervision (2.4%). Less frequently reported themes included staffing and workload improvements (2.1%), checklist design optimization (1.2%), improved communication and teamwork (1.1%), accountability (0.6%), and incentives or cultural change (0.4%).

The distribution of reported implementation challenges is summarized in Figure 8.

Figure 8. Reported Challenges in WHO SSC Implementation Across Sites



DISCUSSION

This In this multicenter study, overall adherence to the WHO SSC was relatively high; however, perfect adherence remained uncommon. While full adherence was previously associated with a markedly higher odds of perceived adverse event prevention in conventional regression models, this association was attenuated after accounting for hospital-level clustering. Importantly, this association was no longer statistically significant after accounting for clustering, which substantially affects interpretation of the findings. These findings suggest that while higher checklist adherence was associated with perceived improvements in safety outcomes, institutional and contextual factors play a substantial role. The variability in adherence observed across countries and facility types (Figures 3 and 4) further reinforces the influence of institutional factors on checklist effectiveness.

These findings are broadly consistent with previous studies, which have demonstrated the beneficial impact of the WHO SSC on surgical outcomes. The pioneering study by Haynes et al. reported a significant reduction in overall complication rates from 11.0% to 7.0% following the implementation of checklists, with even greater improvements observed in low-income settings (from 11.7% to 6.8%) (Haynes et al., 2009). Concurrently, Jain et al. documented a decline in surgical site infections (6.2% to 3.4%) and mortality (1.5% to 0.8%), with more pronounced benefits observed in low- and middle-income countries (Jain, Sharma ve Reddy, 2018). These findings are broadly consistent with prior studies; however, differences in study design, particularly the use of objective versus self-reported outcomes, limit direct comparability.

Furthermore, a meta-analysis by Bergs et al. reported substantial evidence supporting reductions in postoperative complications and mortality following checklist implementation (Bergs et al., 2014). The findings of this study serve to expand upon the existing body of evidence by demonstrating that, while adherence to checklists is associated with potential benefits, its impact may exhibit considerable variation across different institutions.

A significant contribution of current research is the demonstration that the relationship between checklist adherence and perceived adverse event prevention is influenced by hospital-level factors. While perfect adherence was found to be associated with a five- to six-fold increase in the odds of preventing adverse events, this effect was no longer statistically significant in mixed-effects models, with a substantial proportion of the variance explained by between-hospital differences. The observed intraclass correlation coefficient (ICC = 0.27) indicates considerable between-hospital variability, suggesting that institutional factors such as safety culture, workflow integration, and resource availability play a significant role in shaping checklist effectiveness These findings highlight the distinction between checklist adherence and broader system-level determinants of surgical safety, suggesting that institutional context may be more influential than adherence alone.

This observation is supported by previous literature highlighting challenges in integrating checklists into routine clinical workflows. Melekie et al. emphasised that, despite the widespread adoption of surgical checklists, concerns remain regarding their practical implementation and real-world effectiveness (Melekie & Getahun, 2015). The findings of this study provide empirical support for this concern by demonstrating variability in effectiveness across settings.

The qualitative findings further support the importance of system-level factors. These qualitative findings align with the observed between-hospital variability, suggesting that differences in training, resources, and institutional practices may explain the attenuation of the association in adjusted analyses. Despite most participants not reporting perceived barriers, those who did most frequently identified deficiencies in training and awareness. This aligns with previous reports emphasising the importance of structured training programmes and local leadership in facilitating successful checklist implementation (Jain, Sharma & Reddy, 2018). Moreover, earlier research has emphasised the significance of regular audits, the implementation of feedback mechanisms, and the adaptation to specific contexts in enhancing adherence and sustainability (Jain, Sharma & Reddy, 2018).

The findings of this study indicate that the barriers to effective checklist use are not primarily related to the checklist itself, but rather to limitations in implementation strategies, resource availability, and organisational support. These insights underscore the necessity for customised, context-sensitive methodologies to enhance checklist integration, particularly within the context of LMICs.

Taken together, the results of this study suggest that the promotion of checklist use alone may be insufficient to achieve optimal improvements in surgical safety. Instead, greater emphasis should be placed on the enhancement of institutional capacity, encompassing training, communication, and system-level integration. Adapting the checklist to local workflows and ensuring ongoing monitoring through audits may support improved adherence and potential effectiveness. Despite these limitations, this study provides one of the largest real-world, multi-country evaluations of WHO SSC implementation in low-resource settings, offering valuable insights for policy and practice.

STUDY LIMITATIONS

This study has several important limitations. First, the primary outcome was based on self-reported perceived adverse event prevention, which may be subject to reporting bias and does not reflect objectively measured clinical outcomes, and may be influenced by subjective intraoperative team assessment. Second, variability in documentation practices across institutions may have influenced adherence estimates. In addition, the exclusion of cases without completed checklist documentation may introduce selection bias, as cases with lower adherence may be underrepresented. Third, in some sites, data collection was conducted using shared institutional logins, limiting the ability to attribute contributions to individual auditors. Additionally, variability in observer interpretation across sites may have introduced measurement heterogeneity. Furthermore, the analysis did not account for country-level differences, which may contribute to variability in outcomes across settings. The absence of patient-level variables, such as case complexity and urgency, limits the ability to fully adjust for potential confounding factors. Finally, the observational design precludes causal inference between checklist adherence and clinical outcomes.

AUTHOR CONTRIBUTIONS

- Prof. Adebusola Adenike Owokole led overall study supervision, ensured regulatory compliance, coordinated site documentation across participating institutions, and reviewed all stages of the study.
- Asst. Prof. Nurhusen Arefayne conceptualized the study.

- Dr. Nigussie Tefera Habiteyohannis coordinated project implementation and supported site-level engagement and data collection processes.
- Mr. Hailemariam Getachew Tesema and Dr. Kevin Miko Maestrado Buac contributed to the development and design of the audit tool.
- Dr. Alazar Menbere Haile conducted the statistical analysis and contributed to data interpretation.
- Asst. Prof. Demeke Yilkal Fentie developed the audit proposal and contributed to the conceptual framework of the study.
- Dr. Kübra Özpınar led the manuscript drafting, integration of sections, and overall writing of the manuscript.
- Data collection was conducted across participating institutions by: Dr. John Amani, Clement Okyere Sefa, Sayed Ahbab Hussain, Arshad Ali M. Bashir, Bedlu Tilahun Amtate, Getachew Mekete Deress, Dr. Mesfin Shimelash, Dr. Samuel Wodajo Mamo, Dr. Nigat Amsalu Addis, Amare Belete Getahun, Dr. Joshua Olaopin, Abdulkarim Abdulwahab, Firdausi Yusha'u Muhammad, and Ahmed Shuaibu Tsafi. These contributors were responsible for data collection, validation, and submission using the standardized audit tool.

All authors reviewed, revised, and approved the final manuscript prior to submission. All authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship.

CONCLUSION

In conclusion, while perfect adherence to the WHO SSC was associated with perceived improvements in safety outcomes in unadjusted analyses, this association was not statistically significant after accounting for hospital-level clustering. The primary outcome reflects perceived adverse event prevention and should be interpreted within this context. These findings suggest that institutional and system-level factors may play a more critical role than adherence alone.

Accordingly, improving surgical safety in low-resource settings may require system-level enhancements in conjunction with the promotion of checklist use. Future studies incorporating objective clinical outcomes are needed to more accurately assess the effectiveness of the WHO SSC in real-world settings.

Conflict of Interest and Funding Declaration
This project is conducted independently under the umbrella of The Operating Room Global (TORG) and coordinated by The Operating Room Global Centre for Education, Research and Innovation (TORGCERI). The investigators declare no conflicts of interest related to financial, institutional, or personal relationships that could influence the conduct or outcomes of the audit. No external or internal funding has been received to support this study at any phase, including design, data collection, analysis, or dissemination. All participating institutions are volunteering their time and resources as part of their commitment to improving surgical safety.

Use of Artificial Intelligence (AI) Tools
Generative artificial intelligence tools were used to support aspects of manuscript drafting, language refinement, and structural organization. The authors reviewed and validated all outputs to ensure scientific accuracy and integrity. No AI tools were used for data analysis or interpretation.

Data Availability Statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Morphology And Morphometry of Right Ventricular False Tendons

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ABSTRACT

Background: False tendons (FTs) are fibrous or fibromuscular structures, that traverse the cavity of the ventricles and have no attachment to valvular cusps. In contrast to the well documented Left ventricular false tendons, right ventricular false tendons (RFTs) remain poorly understood, with only a five-type classification system in use. RFTs are clinically significant and have been implicated in S3 gallops, ventricular arrhythmias and systolic murmurs. Moreover, their presence increases the possibility of catheter entanglement and incorrect diagnosis during cardiac procedures.

Materials and Methods: Sixty-eight hearts from formalin-fixed cadavers from the Department of Human Anatomy, University of Nairobi were used in this study. The hearts were incised, false tendons identified, classified and lengths measured from origin to insertion using a digital Vernier caliper, accurate to 0.01 cm. Data was analyzed using SPSS Version 25.0. Prevalence was reported with 95% Wilson confidence intervals; lengths were expressed as means and standard deviations. Group differences were assessed using Kruskal-Wallis and Mann-Whitney U tests ($\alpha = 0.05$).

Results: RFTs were identified in 63.2% of examined hearts, with a mean of 1.4 types per heart (range: 1-4). Beyond the five conventionally defined types (Types 1–5), six novel types were observed. Across all 122 false tendons, Type 1 (septum to anterior papillary muscle) was the most prevalent overall (18.9%). Within Type 11 (tricuspid leaflets to septum, moderator band, and posterior ventricular free wall), those extending from the septal leaflet to the septum were most common (33.6%). Mean false tendon length was 14.6±7.1 mm (range: 1–34 mm). Type 3 (anterior tricuspid leaflet to RV free wall) was the longest (25.5±6.4 mm), while Type 9 (septum to moderator band) was the shortest (8.0 mm).

Conclusion: RFTs are prevalent anatomical variations that exhibit more morphological diversity than previously documented. These results offer a thorough anatomical reference that is essential for preventing complications during right-sided cardiac interventions, understanding abnormal valvular mechanics and distinguishing RFTs from pathologies during imaging.

Keywords: *Right Ventricle; False Tendons Classification; Morphometry; Cardiac Anatomy; Tricuspid Valve*

INTRODUCTION

False tendons (FTs), first described by Turner in 1893 and thereafter by Keith and Flack in 1906 are defined as single or multiple, thin, fibrous or fibromuscular structures that traverse the cavity of the ventricles and have no attachment to valvular cusps [1,2]. Variations exist in the structure of right ventricular false tendons (RFTs) with regard to their origin, connection with the right ventricular free wall and to papillary muscles. Five types have been described by Loukas et al. [3], regarding the RFTs based on their location and attachments. In Type I, RFTs are located between the ventricular septum and the anterior papillary muscle; in Type II, they are located between the ventricular septum and the posterior papillary muscle; in Type III, between the anterior leaflet of the tricuspid valve and the right ventricular free wall; in Type IV, between the posterior papillary muscle and the ventricular free wall; while in Type V between the anterior papillary muscle and ventricular free wall.

Clinically, FTs have been suggested as possible substrates in several heart pathologies including ventricular arrhythmias, gallops, and systolic murmurs [4]. They have also been reported to cause catheter entanglement during cardiac catheterization procedures [5]. Imaging procedures have also misinterpreted false tendons for flail valve chordae tendineae or mural thrombi [6-8]. With the growing use of echocardiography, cardiac MRI, and right-heart interventional procedures including transcatheter tricuspid valve interventions and electrophysiological mapping, accurate anatomical knowledge of RFTs has become increasingly relevant to modern clinical practice. Current anatomical classification systems for RFTs remain limited, and the lack of a comprehensive characterization creates challenges for both imaging interpretation and procedural planning.

Previous workers have majorly focused and extensively explored Left Ventricular False Tendons (LFTs) [1,2,6-13]; however, to the best of our knowledge, very few studies have explored RFTs [3,14,15]. This study therefore aimed to further explore and describe the anatomical features of the RFTs with regards to morphometry and morphology.

MATERIALS AND METHODS

All available formalin-fixed hearts from the cadaveric repository of the Department of Human Anatomy, University of Nairobi were consecutively screened for inclusion in this study. Hearts with grafts, traumatic lesions, any observable signs of autolysis, or heart pathologies such as cardiomegaly were excluded. Demographic data (age, sex, ethnicity, and cause of death) were not available for the cadaveric specimens, as is common with previously dissected institutional repositories; this represents a recognized limitation of the study.

An inter-caval incision was made to open the right atrium, extending from the orifice of the superior vena cava to the orifice of the inferior vena cava. Additionally, another incision was made on the right border of the heart to expose the cavity of the right ventricle. False tendons were identified and classified by two experienced anatomists. Intra-observer repeatability was assessed by having each observer remeasure a random subset of 20 RFTs after a 2-week interval. Inter-observer reliability was assessed for all measurements. False tendon lengths were measured twice from origin to insertion using a digital Vernier caliper accurate to 0.01 cm, and the mean of the two measurements was recorded.

Classification was performed according to the following locations: Type I: between ventricular septum and anterior papillary muscle; Type II: between ventricular septum and posterior papillary muscle; Type III: between the anterior leaflet of the tricuspid valve and right ventricular free wall; Type IV: between posterior papillary muscle and ventricular free wall; Type V: between anterior papillary muscle and ventricular free wall. Novel types (Types 6-11) were defined de novo based on structural features that could not be accommodated within the existing five-type classification; the rationale for each new category is detailed in the Results.
Representative photos were taken using a 12-megapixel Nokia camera (Model: RM-596). Prevalence of each RFT type was expressed as a percentage of the total number of false tendons identified ($n = 122$), with 95% confidence intervals (CIs) calculated using the Wilson score method, which is robust for small proportions. False tendon lengths were entered into SPSS software (Version 25.0, Chicago, Illinois) and expressed as means and standard deviations (SD); 95% CIs for mean length were computed using the t-distribution for types with $n \geq 2$.

Types represented by a single observation ($n = 1$) are reported descriptively only. Global between-group differences in false tendon length across all types were assessed using the Kruskal-Wallis H test, which is non-parametric and appropriate given the small and unequal group sizes; post-hoc pairwise comparisons were not performed owing to insufficient sample sizes within individual type groups. Additionally, Mann-Whitney U tests were used to compare: (i) prevalence and length between classic (Types 1-5) and novel types (Types 6-11); and (ii) length between septum-attached and non-septum-attached tendons. A Kruskal-Wallis test was also applied across Type 11 subtypes. Statistical significance was set at $\alpha = 0.05$. Intra-class correlation coefficients (ICC) were calculated for both intra-observer (ICC = 0.94, 95% CI: 0.88-0.97) and inter-observer (ICC = 0.91, 95% CI: 0.84-0.95) repeatability, indicating excellent agreement.

RESULTS

Of the 68 hearts examined, right ventricular false tendons (RFTs) were observed in 43 cases (63.2%). The mean number of types of false tendons per heart ranged from 1-4, with a mean of 1.4 types per heart. The total number of false tendons studied was 122. Among the conventionally defined types (Types 1-5), Type 1 (ventricular septum to anterior papillary

muscle) was the most prevalent classic type (n = 23; 18.9%, 95% CI 12.9-26.7%). However, when all 11 types are considered, Type 11 (tricuspid leaflets to septum, moderator band, and posterior ventricular free wall) had the highest cumulative prevalence (n = 66; 54.1%, 95% CI 45.3-62.7%). Beyond the conventionally defined types (Types 1-5), six novel types were observed with attachments as follows: Type 6: interconnecting papillary muscles; Type 7: septum to posterior ventricular free wall; Type 8: septum to septal papillary muscle; Type 9: septum to moderator band; Type 10: septal papillary muscle to moderator band; Type 11: tricuspid leaflets to septum, moderator band and posterior ventricular free wall.

Type 1 was the most prevalent classic type (n = 23; 18.9%, 95% CI 12.9-26.7%), while Types 7, 9 and 10 showed the least prevalence (n = 1 each; 0.8%, 95% CI 0.1-4.5%). Among interpapillary tendons (Type 6; n = 7; 5.7%, 95% CI 2.8-11.4%), those linking anterior and posterior papillary muscles showed the highest subtype prevalence (4.1%), while connections involving the septal papillary muscle were least prevalent (0.8% each). Within Type 11 (n = 66; 54.1%, 95% CI 45.3-62.7%), those extending from the septal leaflet to the septum were most prevalent (33.6%), while those linking the septal leaflet to the posterior ventricular free wall were least prevalent (0.8%). Full prevalence values with 95% confidence intervals for all types are provided in Tables 1 and 2.

The mean length of all false tendons was 14.6 ± 7.1 mm (range 1-34 mm). Type 3 (anterior tricuspid leaflet to RV free wall; n = 2) was the longest at 25.5 ± 6.4 mm, while Type 9 (septum to moderator band; n = 1) was the shortest at 8.0 mm. Among the types with sufficient sample sizes, 95% confidence intervals for mean length were: Type 1, 14.3-17.9 mm; Type 4, 3.9-12.7 mm; Type 5, 5.6-15.2 mm; Type 6, 14.1-18.3 mm; and Type 11, 13.5-15.9 mm. For Types 2, 3, and 8, CIs were wide and clinically uninformative owing to very small sample sizes (n = 2-3), and these types should be interpreted descriptively.

A Kruskal-Wallis H test across all types with n ≥ 2 demonstrated statistically significant global heterogeneity in false tendon length ($H = 19.847$, $df = 7$, $p = 0.006$). Post-hoc pairwise comparisons between individual types were not performed owing to insufficient sample sizes within most groups; larger studies are needed to confirm specific between-type differences. Comparison of septum-attached tendons (Types 1, 2, 7, 8, 9, and septal subtypes of Type 11; n = 96; mean 15.6 mm) versus non-septum-attached tendons (Types 3, 4, 5, 6, 10; n = 26; mean 12.5 mm) revealed a statistically significant difference in length (Mann-Whitney $U = 1565.0$, $p = 0.048$). No significant difference in length was found between classic and novel types (Mann-Whitney $U = 1620.0$, $p = 0.611$), nor between Type 11 and all other types combined (Mann-Whitney $U = 1895.0$, $p = 0.811$). Within Type 11 subtypes, Kruskal-Wallis analysis across the four subtypes with n ≥ 3 (anterior leaflet→septum, posterior leaflet→septum, septal leaflet→septum, septal leaflet→moderator band) did not demonstrate statistically significant length differences ($H = 5.069$, $p = 0.167$).

Among tendons interconnecting papillary muscles (Type 6), those spanning from septal to anterior papillary muscles were the longest (26.0 mm; n = 1), while those connecting anterior and posterior papillary muscles were the shortest (9.6 mm; mean). Within Type 11, tendons from the septal leaflet to the septum were the longest (17.2 ± 7.0 mm), while those linking the anterior leaflet to the septum were the shortest (11.3 ± 8.5 mm).

DISCUSSION

The present study found right ventricular false tendons in 63.2% of the examined hearts. This high prevalence supports early historical assertions by Turner in 1893 and Keith and Flack in 1906 that these structures are a constant feature in mammalian hearts. Our findings are consistent with those of Mundra et al. [14] and Loukas et al. [3], who found right ventricular false tendons in majority of the adult hearts in their studies. The frequency observed in our current study suggests that RFTs are a typical anatomical variation of the right ventricular morphology rather than an incidental anomaly, further supported by Sanchez et al. [11], who demonstrated that false tendons are normal findings present from fetal development through adulthood.

According to our morphological analysis, Type 1 (septum to anterior papillary muscle) accounted for the highest proportion of conventionally defined RFTs (18.9%). This is consistent with Loukas et al. who reported septum to papillary muscle connections as the most prevalent type. However, our findings are in contrast with those of Kosiński et al. [15] who report Type V; connections between the walls of the ventricle around its apex and Mundra and Lala [14] who report Type 1 papillary muscle to free wall connections as their most prevalent type. These discrepancies might be explained by the different method of dissection, demographics and classification systems.

In addition to the five types initially reported by Loukas et al. [3], we observed more morphological diversity. Specifically, we identified six more types (Types 6-11), with Type 11 having a cumulative prevalence of 54.1%. Although conventional literature tends to confine RFTs to either simple interpapillary or septomarginal connections, our findings of common attachments between the tricuspid leaflets and the septum (33.6%) suggest a more integrated association between RFTs and the valvular apparatus than has been documented before. Regarding valvular mechanics, these connections could potentially limit the movement of the tricuspid leaflets during systole and may provide an anatomical basis for future investigation of valve dynamics or functional tricuspid regurgitation; however, confirmation requires clinical and imaging studies. This provides an anatomical basis to understand how these chords may influence the dynamics of the tricuspid valve or lead to misdiagnosis.

The current study found a mean false tendon length of 14.6 ± 7.1 mm (range 1-34 mm). Type 3 (anterior tricuspid leaflet to RV free wall; n = 2) was the longest at 25.5 ± 6.4 mm, while Type 9 (septum to moderator band; n = 1) was the shortest at 8.0 mm. Kruskal-Wallis analysis demonstrated statistically significant global heterogeneity in false tendon length across types ($H = 19.847$, $p = 0.006$). Post-hoc pairwise comparisons between individual types were not performed given inadequate sample sizes within most groups, underscoring the need for larger prospective studies. Notably, septum-attached tendons were significantly longer than non-septum-attached tendons (mean 15.6 vs 12.5 mm; $p = 0.048$), which may be anatomically relevant given the greater intracavitary span required to bridge septal to contralateral structures. No significant length difference was found between classic and novel types ($p = 0.611$), suggesting that the novel morphological variants described here are broadly comparable in size to previously documented types.

Mundra and Lala [14] found papillary muscle-to-free wall connections to be the longest and septomarginal trabeculae connections the shortest, while Kosiński et al. [15] qualitatively identified interpapillary muscle connections as the longest and intrapapillary muscle segment connections as the shortest. The present study's shortest type is anatomically comparable to the shortest reported by Mundra and Lala [14], both involving septal or trabecular connections. The longest type varied across comparable studies, likely reflecting differences in population characteristics and dissection methods. These measurements are clinically important because imaging techniques have mistakenly identified false tendons for mural thrombi or flail valve chordae tendineae [6]. The morphometric variability observed here, combined with the significant elongated nature of several types, raises the possibility that these structures may appear as mobile, linear echoes on echocardiography, warranting greater caution in distinguishing them from pathological structures.

Literature indicates that some RFTs contain myocardial fibers and conducting tissue identical to the bundle of His [3]. Suwa et al. [12] and Perry et al. [13] have reported an association between false tendons and premature ventricular contractions (PVCs), although a direct causal link has not been definitively established. The anatomical locations of specific RFTs identified in the present study, particularly those involving connections between the septum, papillary muscles, and moderator band, are consistent with reported arrhythmogenic substrates given the distribution of the right bundle branch and Purkinje fibres in these regions. It must be noted that no histological examination was performed in the present study; accordingly, claims regarding arrhythmogenic potential of the newly identified types remain speculative and require future histological confirmation.

Notably, a causal relation between FTs and both an S3 gallop and a systolic murmur has been noted in the literature [4]. Moreover, the identification of Type 11 RFTs in the present study, which bridge the tricuspid leaflets to the septum and free wall, provides a possible anatomical explanation for the catheter entanglement reported by Winrow et al. [5] during right-sided cardiac procedures. The morphological and morphometric findings from the present study provide clinicians with a comprehensive anatomical reference to predict possible substrates for arrhythmias, abnormal valve dynamics, and procedural complications in the right ventricle.

Limitations and recommendations for further studies.

There are several limitations to this study. The age and sex of the cadavers were not accounted for, as this study relied on human hearts from a previously established repository for which demographic records were unavailable. Given that cardiac morphology may vary with age, sex, and ethnicity, the absence of this information reduces the interpretability and generalizability of findings; future studies should prospectively record full demographic data. Additionally, the classification system proposed here represents observational categories derived by two anatomists from a single population; while consensus was reached on all novel types, independent validation by multiple observers and replication in diverse populations will be necessary before the classification can be adopted widely. Tissue shrinkage could have occurred due to formalin fixation, which could potentially affect the accuracy of length measurements. The morphometric analysis was

limited to linear measurements and as such, future studies should incorporate cross-sectional measurements such as thickness to give a more detailed morphometric profile. Histological examination and analysis were not conducted in the current study; further studies are needed to support or refute the presence of conducting tissue within the newly described types to define their arrhythmogenic capability. Lastly, the absence of a standardized classification and dissection methodology across RFT research limits the possibility of direct cross-study comparisons; subsequent research should adopt a standardized methodology to allow for more meaningful synthesis and comparison of results.

CONCLUSION

Right ventricular false tendons (RFTs) are common anatomical variations that exhibit significant morphological diversity. Because these structures frequently resemble mural thrombi or flail chordae during imaging, their morphometric variability and elongated nature may trigger diagnostic confusion. Additionally, their close proximity to the conducting system could potentially provide a substrate for clinical observations such as ventricular arrhythmias, S3 gallops, and systolic murmurs. Our findings offer a comprehensive anatomical reference that may help raise intervention safety and improve diagnostic precision.

Declaration of interest: We have no conflicts of interest

Ethical statement: This study was conducted in accordance with the Human Anatomy Act (CAP 249, 1976) and the Human Tissues Act (CAP 252, 1968) of the Laws of Kenya. Ethical approval was obtained from the Department of Human Anatomy and Physiology, University of Nairobi (approving authority: Departmental Ethics and Research Committee, Approval reference number: HAMP BAUEC/2018/266; Date 28th March, 2018). This manuscript has been carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) and is in line with the Recommendations for the Conduct, Reporting, Editing and Publication of Scholarly Work in Medical Journals.

Author contributions CrediT :
VK: project protocol development, data collection and analysis and manuscript writing.
CK: project protocol development and manuscript editing.
TC: project protocol development and manuscript editing.
MO: project protocol development and manuscript editing.
SM: data analysis and manuscript editing.
MM: data management and manuscript editing.
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TABLES AND FIGURES

Table 1: Prevalence and length of right ventricular false tendon types 1-5

Type	n (Prevalence %; 95% CI)	Length mm, Mean ± SD (95% CI)
1. Ventricular septum and anterior papillary muscle	23 (18.9; 95% CI 12.9-26.7)	16.1±4.2 (95% CI 14.3-17.9)
2. Ventricular septum and posterior papillary muscle	3 (2.5; 95% CI 0.8-7.0)	15.0±6.9 (95% CI n/a, n=3)
3. Anterior tricuspid leaflet and right ventricular free wall	2 (1.6; 95% CI 0.5-5.8)	25.5±6.4 (95% CI n/a, n=2)
4. Posterior papillary muscle and ventricular free wall	7 (5.7; 95% CI 2.8-11.4)	8.3±4.8 (95% CI 3.9-12.7)
5. Anterior papillary muscle and ventricular free wall	9 (7.4; 95% CI 3.9-13.4)	10.4±6.3 (95% CI 5.6-15.2)
Cumulative frequency & mean length	44 (36.1; 95% CI 28.1-44.9)	14.0±6.6† (95% CI 12.0-16.0)

Table 2: Prevalence and length of right ventricular false tendon types 6-11

Type	n (Prevalence %; 95% CI)	Length mm, Mean ± SD (95% CI)
6. Interconnecting papillary muscles	7 (5.7; 95% CI 2.8-11.4)	16.2±2.3 (95% CI 14.1-18.3)
7. Septum to posterior ventricular free wall	1 (0.8; 95% CI 0.1-4.5)	20.0 (n=1)
8. Septum to septal papillary muscle	2 (1.6; 95% CI 0.5-5.8)	11.0±9.9 (95% CI n/a, n=2)
9. Septum to moderator band	1 (0.8; 95% CI 0.1-4.5)	8.0 (n=1)
10. Septal papillary muscle to moderator band	1 (0.8; 95% CI 0.1-4.5)	9.0 (n=1)
11. Tricuspid leaflets to septum, moderator band and posterior ventricular free wall	66 (54.1; 95% CI 45.3-62.7)	14.7±4.9 (95% CI 13.5-15.9)
Cumulative frequency & mean length	78 (63.8; 95% CI 55.1-71.9)	14.6±5.1† (95% CI 13.5-15.8)

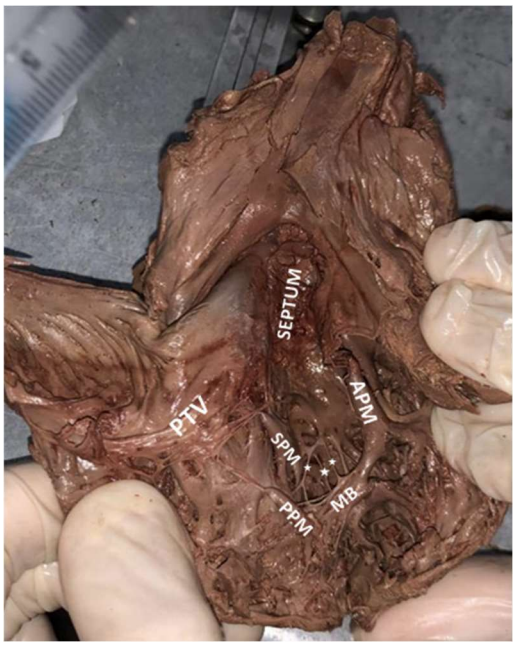
Table 3: Prevalence and length of right ventricular false tendons associated with tricuspid leaflets

Type	n (Prevalence %; 95% CI)	Length mm, Mean ± SD (95% CI)
Anterior leaflet to septum	10 (8.2; 95% CI 4.5-14.4)	11.3±8.5 (95% CI 5.2-17.4)
Posterior leaflet to septum	11 (9.0; 95% CI 5.1-15.4)	14.2±6.8 (95% CI 9.6-18.8)
Septal leaflet to septum	41 (33.6; 95% CI 25.8-42.4)	17.2±7.0 (95% CI 15.0-19.4)
Septal leaflet to moderator band	3 (2.5; 95% CI 0.8-7.0)	15.0±2.0 (95% CI 10.0-20.0)
Septal leaflet to posterior ventricular free wall	1 (0.8; 95% CI 0.1-4.5)	16.0 (n=1)
Cumulative frequency & mean length	66 (54.1; 95% CI 45.3-62.7)	15.7±7.4 (95% CI 13.9-17.5)

Table 4: Prevalence and length of right ventricular false tendons interconnecting papillary muscles

Type	n (Prevalence %; 95% CI)	Length (mm) Mean ± Std.
Anterior and posterior papillary muscle	5 (4.1; 95% CI 1.8-9.2)	9.6±7.0 (95% CI 1.0-18.2)
Posterior and septal papillary muscles	1 (0.8; 95% CI 0.1-4.5)	13.0 (n=1)
Septal and anterior papillary muscle	1 (0.8; 95% CI 0.1-4.5)	26.0 (n=1)
Cumulative frequency & mean length	7 (5.7; 95% CI 2.8-11.4)	16.2±2.3 (95% CI 14.1-18.3)

Figure 1. Type 9 right ventricular false tendons (asterisks) extending from the interventricular septum to the moderator band (MB). APM: anterior papillary muscle;



PPM: posterior papillary muscle; SPM: septal papillary muscle; PTV: posterior tricuspid valve leaflet.

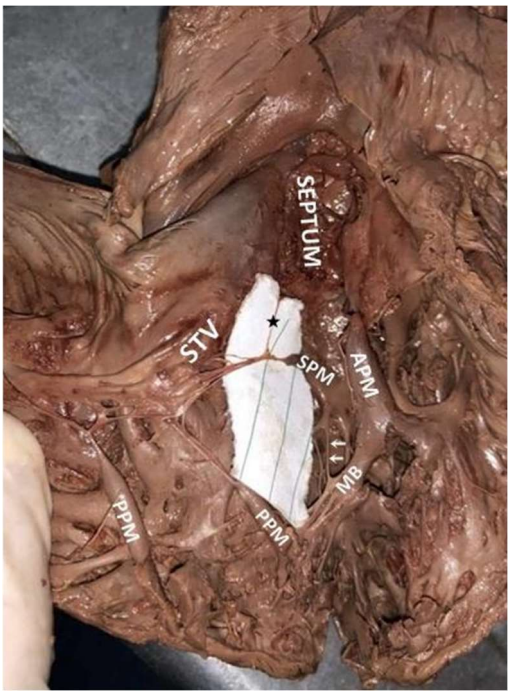


Figure 2. Two co-existing right ventricular false tendon types. Asterisk: Type 11a false tendon extending from the septal tricuspid leaflet to the interventricular septum. Arrows: Type 10 false tendon extending from the septal papillary muscle (SPM) to the moderator band (MB). APM: anterior papillary muscle; PPM: posterior papillary muscle; STV: septal tricuspid valve leaflet

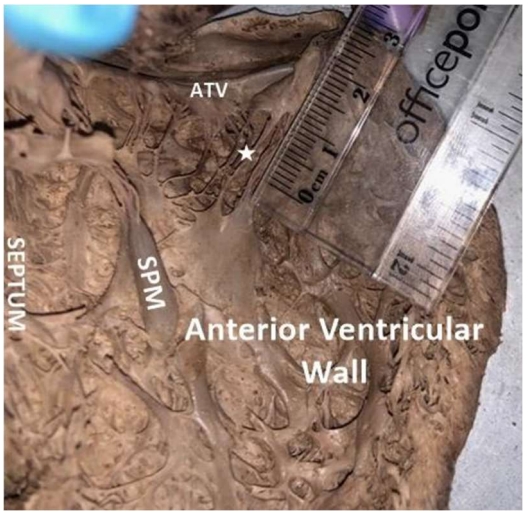


Figure 3. Type 3 right ventricular false tendon (asterisk) extending from the anterior tricuspid valve leaflet (ATV) to the anterior right ventricular free wall. SPM: septal papillary muscle.

Figure 4. Type 7 right ventricular false tendon (arrows) extending from the interventricular septum to the posterior ventricular wall (PVW). ATV: anterior tricuspid valve leaflet; PTV: posterior tricuspid valve leaflet; STV: septal tricuspid valve leaflet.

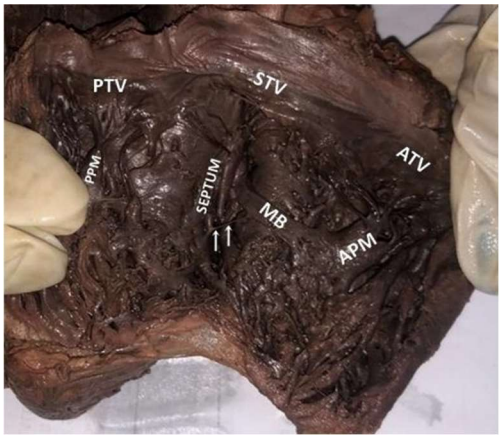


Figure 5. Type 9 right ventricular false tendon (arrow) extending from the moderator band (MB) to the interventricular septum. APM: anterior papillary muscle; PPM: posterior papillary muscle; ATV: anterior tricuspid valve leaflet; PTV: posterior tricuspid valve leaflet; STV: septal tricuspid valve leaflet.

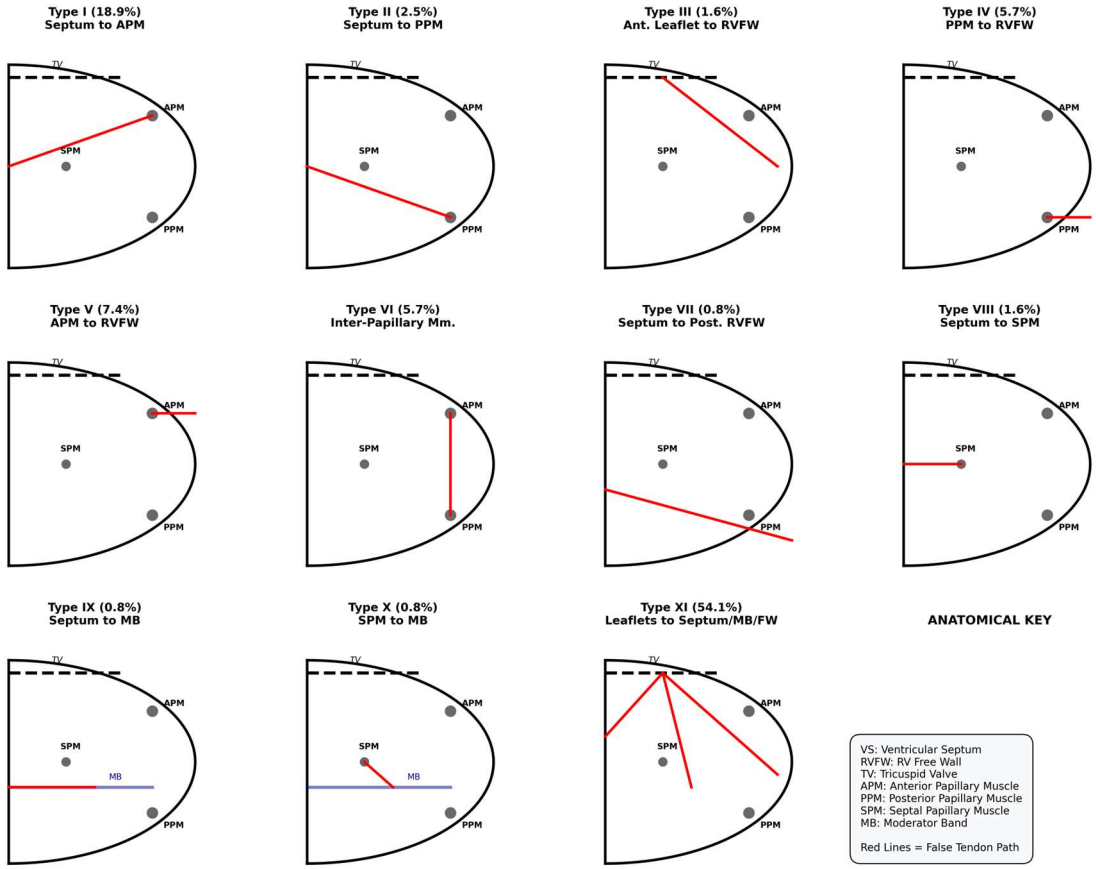


Figure 6: Schematic representation of the right ventricular false tendon (RFT) classification system. The diagram depicts the eleven morphological types (Types I-XI) based on their origins and insertions, with percentages indicating their relative frequencies. Types I-V correspond to the classic Loukas classification, while Types VI-XI represent the novel variants identified in this study. Red lines trace the course of each false tendon. Anatomical landmarks are provided in the key.

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Primary Pleomorphic Liposarcoma of the Kidney: A Rare Case Report

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ABSTRACT

Background: Liposarcomas are rare malignant soft tissue sarcomas. Renal liposarcoma accounts for only 1-2% of primary renal sarcomas and is an exceptionally rare entity. Patients commonly present with renal mass, flank pain, or respiratory symptoms. The prognosis remains poor, with reported 5-year survival rates ranging from 29% to 39% following surgical treatment.
Case presentation: A 63-year-old male presented to the outpatient department with persistent left flank pain and malaise. He reported vague left-sided abdominal discomfort for one year, associated with an unintentional weight loss of 10 kg over the preceding six months and occasional difficulty in urination.
Clinical findings and investigations: Laboratory investigations revealed significant anemia (hemoglobin 8.5 g/dL), while renal function tests were within normal limits. Urinalysis showed numerous red blood cells and 2-3 pus cells per high-power field, with a negative urine culture. Ultrasonography demonstrated a large left renal mass. Contrast-enhanced computed tomography (CT) of the abdomen and pelvis revealed an 8 × 10 cm heterogeneously enhancing mass with central necrosis replacing most of the left kidney, raising suspicion for renal cell carcinoma.
Intervention and outcome: Following optimization with blood transfusions and preoperative assessment, the patient underwent an open left radical nephrectomy via a transperitoneal approach. Recovery was uneventful. Histopathological examination confirmed a high-grade pleomorphic liposarcoma arising from the renal parenchyma with negative surgical margins. Immunohistochemistry was negative for Desmin, HMB45, SMA, and PAX8, while EMA showed focal positivity. The patient was referred to medical oncology for further management and remained free of postoperative complications during one month of follow-up.
Conclusion: Given the rarity of renal pleomorphic liposarcoma and the limited available literature, reporting such cases is important. Long-term follow-up and accumulation of clinical data may help improve understanding, management strategies, and patient outcomes.
Keywords: *Case report, Pleomorphic Liposarcoma, Renal Cell Carcinoma Mimic*

INTRODUCTION

Renal liposarcoma is an exceptionally rare malignant tumor, accounting for only 1%-2% of primary renal sarcomas (2). It often presents with nonspecific symptoms and may mimic renal cell carcinoma, making preoperative diagnosis challenging. Radical nephrectomy remains the primary treatment modality. However, the prognosis is generally poor, with reported 5-year survival rates of 29%-39% (2). Histological subtype influences outcomes, with pleomorphic and undifferentiated variants associated with a worse prognosis than well-differentiated tumors (3).

CASE PRESENTATION

A 63-year-old male presented to the outpatient department with persistent left flank pain, malaise, and vague left-sided abdominal discomfort for one year, associated with unintentional weight loss of 10 kg over the past six months and intermittent urinary difficulty. He had no history of hematuria or urinary tract infections.
On examination, he appeared lean and pale but was fully oriented. Vital signs were stable. Abdominal examination revealed a large, firm, non-tender, non-mobile mass in the left lumbar region. Systemic examination was otherwise unremarkable.

Laboratory investigations showed significant anemia (hemoglobin 8.5 g/dL), with normal renal function and mildly elevated inflammatory markers. Urinalysis revealed numerous red blood cells and 2-3 pus cells per high-power field, with a negative urine culture. Ultrasound demonstrated a large hypoechoic mass in the left renal region. Contrast-enhanced CT of the abdomen and pelvis revealed an 8 × 10 cm heterogeneously enhancing mass with central necrosis replacing most of the left kidney, suggestive of renal cell carcinoma (Figure 1).

The patient was optimized with blood transfusion and underwent open left radical nephrectomy via a transperitoneal approach after appropriate preoperative assessment. Postoperative recovery was uneventful. Histopathology revealed a high-grade sarcomatous tumor arising from the renal parenchyma, consistent with pleomorphic liposarcoma (Figure 2). Surgical margins were negative. Immunohistochemistry was negative for Desmin, HMB45, SMA, and PAX8, with focal EMA positivity (Figure 3). MDM2 and CDK4 testing were not performed, which represents a limitation in further tumor characterization. The patient was referred to medical oncology for further evaluation and placed on close follow-up. No postoperative complications were observed during one month of follow-up.

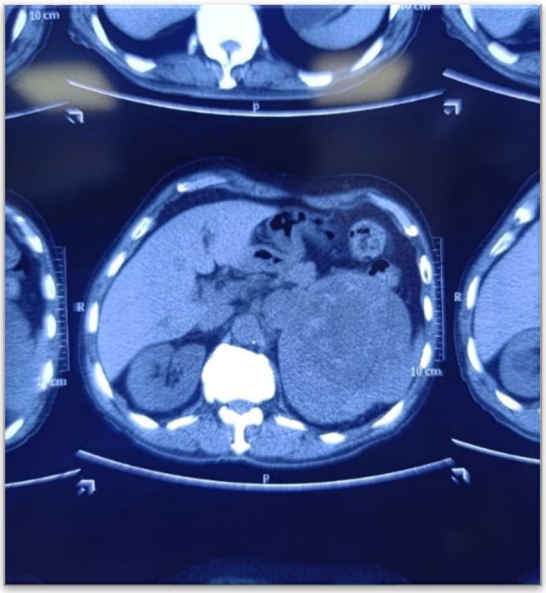

Figure 2 A contrast computed tomography (CT) scan of the abdomen and pelvis demonstrates an approximately 8 x 10 cm heterogeneously enhancing mass with central necrosis, replacing most of the left kidney, with features suggestive of renal cell

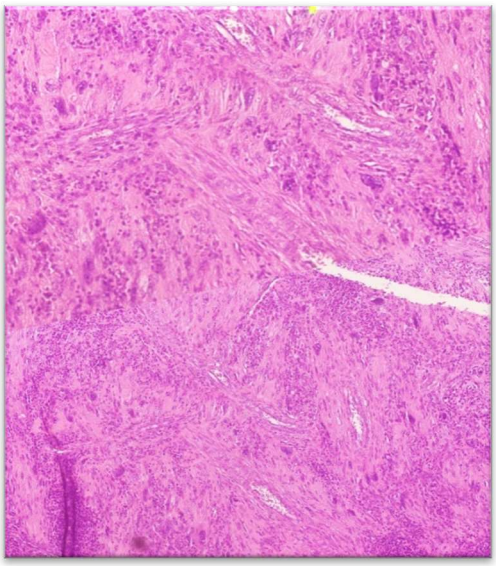

Figure 1 Shows histopathological assessment using hematoxylin and eosin staining with x100 magnification. The findings are consistent with pleomorphic liposarcoma.

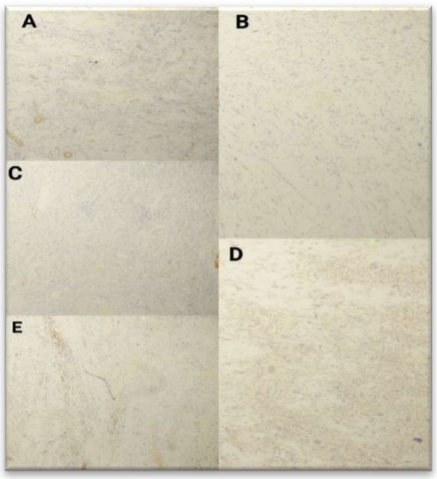

Figure 3 Immunohistochemical stains A: Desmin, B: SMA, C: EMA, D: PAX8, E: HMB45.

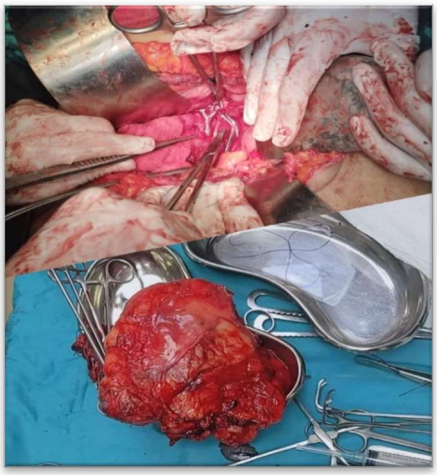

Figure 4 Post operative retrieved kidney gross specimen.

DISCUSSION

Primary renal liposarcoma is an extremely rare malignancy, with limited reported cases in the literature. It constitutes a small proportion of renal tumors and malignant renal mesenchymal neoplasms, with a slight female predominance and most cases occurring in the fifth to sixth decades of life (3,4). Among renal sarcomas, leiomyosarcoma is the most common subtype, while liposarcoma represents a much smaller fraction (4). Renal pleomorphic liposarcoma is particularly uncommon and is associated with aggressive behavior compared to other histological variants.

Preoperative diagnosis is challenging due to nonspecific clinical and radiological features. Patients often present with a renal mass, flank pain, or constitutional symptoms, and imaging findings frequently mimic renal cell carcinoma or other primary renal malignancies. Contrast-enhanced CT and MRI may suggest a malignant renal mass; however, they are not definitive for subtype characterization. In the present case, imaging findings were initially suggestive of renal cell carcinoma, highlighting the diagnostic difficulty in distinguishing these entities preoperatively (3).

Definitive diagnosis relies on histopathological examination following surgical excision. Immunohistochemistry typically shows positivity for MDM2 and CDK4 and negativity for markers such as Desmin, SMA, HMB45, and PAX8 (5). In our case, these markers were consistent with a sarcomatous tumor; however, MDM2 and CDK4 could not be assessed, which limits further molecular confirmation. Importantly, differentiation from renal cell carcinoma and other sarcomatoid renal tumors remains crucial, as management and prognosis differ significantly.

Radical nephrectomy with complete tumor excision and negative margins remains the mainstay of treatment. The role of adjuvant chemotherapy or radiotherapy is not well established, and evidence regarding survival benefit is inconsistent, particularly in cases where complete resection is not feasible (7). Postoperative surveillance with periodic clinical and radiological follow-up is essential due to the risk of recurrence.

Overall, renal pleomorphic liposarcoma remains a diagnostic and therapeutic challenge because of its rarity, overlap with more common renal tumors, and limited evidence guiding adjuvant therapy.

CONCLUSION

Renal liposarcomas are very rare cancers with vague symptoms. Surgery in the form of radical nephrectomy is the treatment of choice followed by chemo-radiotherapy in selected group of patients, but survival benefit is very low. As there is limited literature such rare cases should be reported with focus on long term patient follow up, which may help improve management and outcomes.

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DECLARATION OF COMPETING INTEREST

The authors have no conflicts of interest to disclose in relation to this work.

CONSENT

Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available on request.

AUTHORSHIP

AH wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript

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The Future Doctor Profile: Assessing AI Literacy, Mental Resilience, and Ethical Competence Among Medical Students in Southwest Nigeria

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Authors' Contribution: EFO conceived the study. OOO developed the methodology and drafted the introduction. OTO and IO conducted the literature review. OEA performed the statistical analysis. EFO synthesized the findings and drafted the discussion and conclusion. IDO supervised the study.
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ABSTRACT

Background: The rapid integration of artificial intelligence (AI) into healthcare is reshaping the competencies required of modern physicians. Beyond technological literacy, doctors must demonstrate mental resilience and ethical competence to ensure safe, patient-centred care. However, limited empirical evidence examines these competencies together among Nigerian medical students.

Objective: To assess AI literacy, mental resilience, and ethical competence among clinical medical students in Southwestern Nigeria and examine their interrelationships within the 'Future Doctor Profile' framework.

Methods: A multi-institutional cross-sectional study was conducted among 256 clinical medical students across accredited medical schools in Southwestern Nigeria. Data was collected using a structured questionnaire assessing AI literacy, mental resilience (CD-RISC-10), and AI-related ethical competence. Descriptive statistics, Spearman correlations, and multivariable regression analyses were performed ($p<0.05$).

Results: Mean age was 22.5±2.2 years; 63.3% were female. Only 16% reported formal AI teaching, yet AI tool usage was high (mean 4.4±0.7). Mean AI literacy score was 22.3±3.9 (66.4% high), resilience score 27.3±6.9 (50.4% high), and ethical competence score 32.0±4.2 (73.0% high). Moderate positive correlations were observed between AI literacy and resilience ($\varrho=0.409$), AI literacy and ethical competence ($\varrho=0.385$), and resilience and ethical competence ($\varrho=0.325$) (all $p<0.001$).

Conclusion: AI literacy, resilience, and ethical competence are significantly interrelated among Nigerian medical students, supporting an integrated multidimensional "Future Doctor Profile." Structured AI education, resilience support, and strengthened digital ethics training are necessary.

Keywords: *Artificial intelligence; medical education; mental resilience; digital ethics; medical students; Nigeria.*

INTRODUCTION

The practice of medicine has long been defined by the intimate doctor-patient relationship, grounded in careful history-taking, physical examination, clinical reasoning, and human judgment. For generations, physicians served as the central decision-makers, relying on biomedical knowledge, experience, and empathy to diagnose and treat illness while offering reassurance and moral guidance[1]. Technology historically played a supportive role, but the physician remained the ultimate interpreter of clinical information and guardian of compassionate care.

This traditional model is undergoing profound transformation. The convergence of electronic health records, telemedicine, wearable devices, and, most significantly, artificial intelligence (AI) is reshaping healthcare delivery. AI-powered systems now demonstrate expert-level performance in image interpretation for dermatology, radiology, and pathology[2,4], while advanced predictive analytics and clinical decision support tools enhance risk stratification, diagnosis, and treatment recommendations[3,5]. These innovations promise greater diagnostic accuracy, reduced clinician workload, and more personalised care[22]. However, they are also redefining the physician's role from sole decision-maker to intelligent collaborator who must critically interpret, validate, and when necessary, override algorithmic outputs.

As AI integration accelerates globally, a critical gap has emerged in medical education. While medical students in many regions demonstrate growing awareness of AI's potential, formal training remains limited, leaving many uncertain about its practical application and ethical implications[6,7,11]. In Nigeria, studies similarly reveal moderate to high awareness of AI coupled with low structured exposure and inconsistent readiness[8,27,28]. This mismatch between rapid technological advancement in healthcare and slow curricular adaptation raises important questions about how well the next generation of doctors is being prepared for AI-augmented practice.

Beyond technological competence, the mental demands of medical training remain intense. Medical students worldwide experience elevated rates of stress, anxiety, depression, and burnout compared with age-matched peers[12,13]. In resource-constrained settings such as Nigeria, these pressures are often compounded by large class sizes, frequent examinations, infrastructural challenges, and exposure to high patient loads during clinical rotations. Chronic stress can impair empathy, clinical reasoning, and professional identity formation[14,30]. Consequently, mental resilience, the capacity to adapt positively to adversity and maintain effective functioning under pressure, has become an essential attribute for sustained performance in modern medicine[14,15].

Ethical challenges have also grown more complex in the AI era. Algorithmic systems trained on biased or non-representative datasets risk perpetuating healthcare disparities[16]. Questions of accountability, data privacy, informed consent, and the appropriate balance between technological efficiency and human-centred care demand new layers of ethical competence[17,18,23]. Traditional bioethical principles must now be extended to address digital ethics, transparency of "black box" algorithms, and the preservation of trust in patient-physician relationships[10,34].

Contemporary medical education frameworks increasingly recognise that the "doctor of the future" must embody a broader set of competencies. Scholars argue that tomorrow's physicians need to integrate technological literacy, mental adaptability, and ethical reasoning to deliver safe, equitable, and compassionate care in technology-rich environments[1,19,20,37]. Yet, most existing research examines AI literacy, mental resilience, and ethical competence in isolation. Few studies have adopted an integrated approach to assess how these domains interact to shape a holistic "Future Doctor Profile."

In Nigeria, where healthcare systems face a dual burden of high disease prevalence and accelerating digital transformation amid infrastructural and workforce constraints, this integrated understanding is particularly urgent. Without empirical data on students' preparedness across these interconnected domains, curriculum reforms risk being fragmented and insufficiently aligned with real-world clinical demands.

This study therefore aims to assess the "Future Doctor Profile" among medical students in Nigeria by simultaneously evaluating their AI literacy, mental resilience, and ethical competence. It seeks to determine current levels in each domain, explore their interrelationships, and provide evidence to inform more holistic medical education strategies that can better prepare future physicians for the realities of AI-enabled, high-pressure, and ethically complex healthcare practice.

Theoretical Framework and Conceptual Model

The present study is grounded in three complementary theoretical perspectives that together explain the technological, psychological, and moral dimensions required of future physicians.

The Technology Acceptance Model (TAM)[9,29] posits that perceived usefulness and ease of use of technology influence attitudes, behavioural intention, and actual adoption. In this study, TAM helps explain students' engagement with AI tools and the development of AI literacy.

Resilience Theory[14,15,36] emphasises the capacity to adapt positively to adversity, maintain professional functioning under stress, and achieve post-adversity growth. It provides the theoretical basis for understanding mental resilience as a critical buffer against the intense demands of medical training and technological disruption.

Rest's Four-Component Model of Moral Behaviour[10,23] conceptualises ethical competence as comprising moral sensitivity, moral judgment, moral motivation, and moral character. This framework is particularly relevant for examining how students navigate complex ethical dilemmas introduced by AI, such as accountability, algorithmic bias, and patient autonomy.

The "Future Doctor Profile" is proposed as an integrated, multidimensional construct that brings these three domains together. Unlike traditional competency frameworks such as CanMEDS[19], which primarily organises physician roles into seven domains (Medical Expert, Communicator, Collaborator, Leader, Health Advocate, Scholar, and Professional), the Future Doctor Profile specifically foregrounds three emerging and interdependent competencies demanded by the AI era: technological intelligence (AI literacy), psychological adaptability (mental resilience), and digital moral agency (ethical competence).

While CanMEDS provides a broad, enduring structure for physician training, the Future Doctor Profile offers a focused, contextually responsive lens for the digital transformation of healthcare. It explicitly recognises that technological competence alone is insufficient without the mental resilience to manage uncertainty and the ethical grounding to ensure human-centred, equitable care. The interrelationships between these three domains are visually represented in Figure 1.

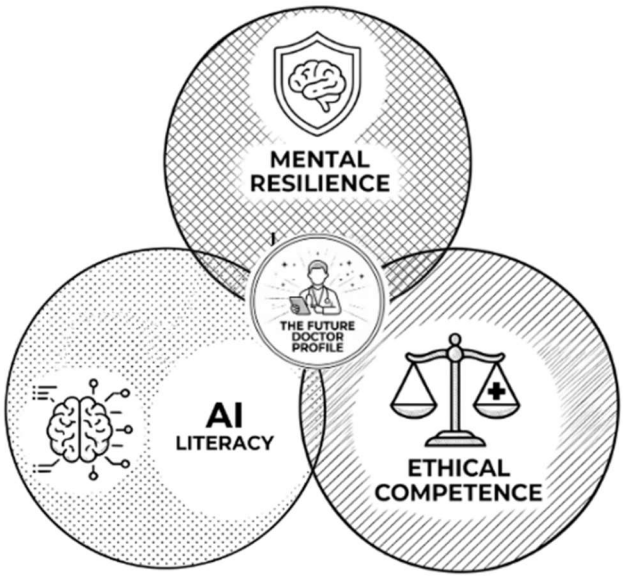

Figure 1: Conceptual model of the "Future Doctor Profile" illustrating the integration of AI Literacy, Mental Resilience, and Ethical Competence.

Specific Objectives

1. To assess the level of AI literacy among medical students, including their knowledge of AI applications in healthcare, attitudes toward AI integration, and perceived readiness to utilise AI-assisted tools in medical education and future clinical practice.
2. To determine the levels of perceived stress and mental resilience among medical students and identify associated socio-demographic patterns within the context of contemporary medical training in Nigeria.
3. To examine the ethical competence of medical students, with particular emphasis on their ability to recognise and reason through AI-related ethical dilemmas.
4. To analyse the interrelationships between AI literacy, mental resilience, and ethical competence, and to determine the extent to which these domains collectively contribute to the proposed "Future Doctor Profile" among medical students.

METHODS

Study Design

This multicentre cross-sectional analytical study assessed artificial intelligence (AI) literacy, mental resilience, and ethical competence, along with their interrelationships, among clinical-phase medical students in Southwestern Nigeria.

Study Setting and Population

The study was conducted in Southwest Nigeria, a region comprising six states (Lagos, Oyo, Ogun, Osun, Ondo, and Ekiti). This zone is one of the most urbanised and educationally advanced parts of the country and hosts several Medical and Dental Council of Nigeria (MDCN)-accredited medical schools offering the Bachelor of Medicine, Bachelor of Surgery (MB;BS) programme. Thirteen universities were included in the study: University of Ibadan, Ladoke Akintola University of Technology (LAUTECH), Bowen University, University of Lagos, Lagos State University College of Medicine, Eko University of Medical Sciences (Eko UNIMED), Olabisi Onabanjo University (OOU), Babcock University, Obafemi Awolowo University (OAU), Osun State University, Ekiti State University (EKSU), Afe Babalola University (ABUAD), and University of Medical Sciences, Ondo (UNIMED). These institutions represent a mix of federal, state-owned, and private universities, providing diversity in institutional contexts, resources, and student populations. The target population consisted of undergraduate medical students in clinical years 4 to 6 who had commenced ward rotations and patient care activities.

Sample Size

A total of 256 clinical-phase medical students participated in the study.

Sampling Technique

Participants were recruited using a non-probability sampling approach combining convenience and voluntary response sampling. Recruitment was facilitated through institutional class communication platforms, official mailing lists, and in-person sessions with support from trained research assistants. All eligible students who provided informed consent were included consecutively until the target sample was reached.

Inclusion and Exclusion Criteria

Inclusion criteria were enrolment in Years 4-6 of the MBBS programme and having started clinical rotations. Visiting or exchange students not formally enrolled in the participating institutions were excluded.

Data Collection Instrument

Data were collected using a structured, self-administered questionnaire developed and adapted from relevant validated instruments. The questionnaire consisted of four sections:

Section A: Socio-demographic and academic characteristics (age, gender, year of study, and institution).
Section B: AI literacy, assessed with 12 items covering awareness of AI applications in healthcare, frequency of use, confidence in interpreting AI outputs, and trust in AI recommendations[8,9,25].
Section C: mental resilience, measured using the validated 10-item Connor-Davidson Resilience Scale (CD-RISC-10)[14,15]. Three supplementary items explored common stressors and coping strategies during clinical training.
Section D: Ethical competence regarding AI-assisted healthcare, assessed with 12 items addressing accountability for AI errors, patient consent and autonomy, data privacy, and integration of algorithmic recommendations with clinical judgment[10,17,23].

Responses were recorded on 5-point Likert scales (except for the standard CD-RISC-10 format). Composite scores were calculated for each domain, with higher scores indicating greater AI literacy, resilience, and ethical competence.

Validity and Reliability

The questionnaire was developed by adapting items from previously validated instruments and refining them for the Nigerian medical education context. The AI literacy scale initially consisted of 12 items adapted from existing tools[8,9,25]. Following pre-testing on 26 clinical-year medical students from a non-participating institution and subsequent exploratory factor analysis, six items with the strongest factor loadings and clearest conceptual relevance were retained in the final scale. This process improved clarity, reduced respondent burden, and maintained good internal consistency (Cronbach's α = 0.822).

Content validity was evaluated by a panel of three experts comprising a medical educator, a bioethicist, and a biostatistician. The Connor-Davidson Resilience Scale (CD-RISC-10) has well-established reliability and validity in medical student populations[14,15]. The AI-related ethical competence scale, adapted from recent literature[10,17,23], demonstrated acceptable but borderline internal consistency (Cronbach's $\alpha = 0.669$) in the current sample.

Data Collection Procedure

Data collection was carried out over a six-week period using both paper-based and electronic (Google Forms) questionnaires, depending on institutional internet access. Trained research assistants supported administration and ensured standardised procedures. Paper responses were double entered into statistical software to minimise errors.

Ethical Considerations

Ethical approval was obtained from the Institutional Research Ethics Committee of the University of Medical Sciences Teaching Hospital (UNIMEDTH), Ondo, and relevant ethics boards of participating institutions. Informed consent was obtained from all participants prior to data collection. Participation was voluntary, and anonymity and confidentiality were maintained by not collecting personally identifiable information. Participants could withdraw at any time without repercussions.

Data Analysis

Data were analysed using SPSS version 27. Descriptive statistics including frequencies, percentages, means with standard deviations, or medians with interquartile ranges (as appropriate) were used to summarise participant characteristics and domain scores. Scale reliability was assessed using Cronbach's alpha in the study sample.

Differences in scores across socio-demographic groups were examined using independent t-tests or one-way ANOVA, with non-parametric equivalents applied when assumptions were violated. Bivariate associations between AI literacy, mental resilience, and ethical competence were evaluated using Pearson's or Spearman's correlation coefficients. Multiple linear regression analyses were performed to identify independent predictors of each domain while controlling for age, gender, year of study, and institution. All statistical tests were two-tailed, with significance set at $p < 0.05$.

RESULTS

A total of 256 clinical-phase medical students (Years 4-6) from 13 accredited medical schools in Southwestern Nigeria participated in this multicentre cross-sectional study.

Socio-demographic and Academic Characteristics

The mean age of participants was 22.5 ± 2.2 years, with females comprising 63.3% (n=162) and males 36.7% (n=94). Participants were distributed across clinical years as follows: Year 4 (25.8%, n=66), Year 5 (41.8%, n=107), and Year 6 (32.4%, n=83). Only 16.0% (n=41) reported having received formal teaching on artificial intelligence (AI) in medicine, despite a high mean frequency of AI tool use (4.4 ± 0.7 on a 1-5 scale).

Table 1. Sociodemographic and academic characteristics (N = 256)

Variable	Category / Summary	n (%) / Mean ± SD
Age (years)	Mean ± SD	22.5 ± 2.2
Gender	Male	94 (36.7%)
	Female	162 (63.3%)
Year of study	Year 4	66 (25.8%)
	Year 5	107 (41.8%)
	Year 6	83 (32.4%)

Formal teaching on AI in medicine	Yes	41 (16.0%)
	No	215 (84.0%)
AI tool use frequency (1-5)	Mean ± SD	4.4 ± 0.7

Reliability of Study Instruments

The AI literacy scale demonstrated good internal consistency (Cronbach's $\alpha = 0.822$). The Connor-Davidson Resilience Scale (CD-RISC-10) showed excellent reliability ($\alpha = 0.905$), while the ethical competence scale had acceptable but borderline reliability ($\alpha = 0.669$)).

Table 2. Reliability of scales

Construct	Items (n)	Scale range	Cronbach's α
AI literacy (Likert 1-5)	6	6-30	0.822
Mental resilience (CD-RISC-10; 0-4)	10	0-40	0.905
Ethical competence (Likert 1-5)	8	8-40	0.669

AI Literacy

Despite limited formal education, participants demonstrated relatively high AI literacy. The mean AI literacy score (6 items, range 6-30) was 22.3 ± 3.9, with 66.4% of students classified in the high category, 31.3% in moderate category and 2.3% in low category. Item-level responses revealed strong confidence in using AI tools for learning (75.8%) and awareness of AI limitations and risks (70.3%). However, only 54.7% agreed they could critically evaluate AI-generated information.

Table 3. AI literacy item responses (N = 256)

AI literacy item	Agree/Strongly agree n (%)	Neutral n (%)	Disagree/Strongly disagree n (%)
Understand basic AI concepts in healthcare	165 (64.5%)	68 (26.6%)	23 (9.0%)
Aware of current AI applications in diagnosis/treatment	162 (63.3%)	52 (20.3%)	42 (16.4%)
Can critically evaluate AI-generated information	140 (54.7%)	81 (31.6%)	35 (13.7%)
Know limitations/risks of AI in clinical decisions	180 (70.3%)	47 (18.4%)	29 (11.3%)
Confident using AI tools to support learning	194 (75.8%)	43 (16.8%)	19 (7.4%)

Would trust AI suggestions only after clinical verification	192 (75.0%)	48 (18.8%)	16 (6.3%)

In multivariable linear regression, frequency of AI tool use was the only significant independent predictor of higher AI literacy scores (B = 0.88, 95% CI 0.21-1.55, p = 0.010). Formal AI teaching showed a positive trend but did not reach statistical significance (p = 0.068). The model explained 5.3% of the variance in AI literacy ($R^2 = 0.053$).

Table 4. Predictors of AI literacy (OLS regression)

Predictor	**B**	**95% CI**	**p-value**
Age	0.10	−0.17 to 0.37	0.471
Male (vs Female)	−0.06	−1.09 to 0.97	0.910
Year of study	0.08	−0.68 to 0.84	0.836
Formal AI teaching (Yes vs No)	1.22	−0.09 to 2.53	0.068
AI tool use frequency (1-5)	0.88	0.21 to 1.55	0.010

Mental Resilience

The mean resilience score on the CD-RISC-10 (range 0-40) was 27.3 ± 6.9. Using predefined categories, 50.4% of participants demonstrated high resilience, 43.4% moderate, and 6.3% low resilience. Item-level analysis showed strongest endorsement for adaptability and ability to bounce back after hardship.

Table 5. Resilience distribution (CD-RISC-10)

Measure	Value
Resilience score (0-40), Mean ± SD	27.3 ± 6.9
Low (0-16)	16 (6.3%)
Moderate (17-27)	111 (43.4%)
High (28-40)	129 (50.4%)

Males reported significantly higher mean resilience scores than females (28.60 vs 26.54, p = 0.021). No significant differences were observed across years of study.

Table 6. Resilience by gender and year of study

Comparison	Group means	Test	p-value
Gender	Male: 28.60 vs Female: 26.54	t-test	0.021
Year of study	Y4: 27.86; Y5: 26.35; Y6: 28.07	ANOVA	0.168

Ethical Competence in AI-assisted Healthcare

Participants demonstrated high ethical competence, with a mean score of 32.0 ± 4.2 (8 items, range 8-40). 73% were classified in the high category, 26.6% in the moderate category and 0.4% in the low category. Strong agreement was observed for clinician responsibility when AI contributes to error (78.5%) and the need for strong protection of patient data used in AI systems (94.1%). In contrast, endorsement was lower for informing patients when AI is involved in their care (52.3%) and including AI use in informed consent processes (56.3%).

Table 7. Ethics item responses (N = 256)

Ethics item	Agree/Strongly agree n (%)	Neutral n (%)	Disagree/Strongly disagree n (%)
Doctor remains responsible when AI contributes to error	201 (78.5%)	38 (14.8%)	17 (6.6%)
Would know how to respond if AI gives incorrect recommendation	157 (61.3%)	72 (28.1%)	27 (10.5%)
Patients should be informed when AI is involved in care	134 (52.3%)	67 (26.2%)	55 (21.5%)
Informed consent should include disclosure of AI use	144 (56.3%)	66 (25.8%)	46 (18.0%)
Patient data used in AI systems must be strongly protected	241 (94.1%)	11 (4.3%)	4 (1.6%)
Aware of ethical concerns related to AI and privacy	206 (80.5%)	37 (14.5%)	13 (5.1%)
Would override AI if it conflicts with clinical judgment	219 (85.5%)	28 (10.9%)	9 (3.5%)
AI should assist, not replace, decision-making	228 (89.1%)	20 (7.8%)	8 (3.1%)

Interrelationships Among Domains (Future Doctor Profile)

Moderate positive Spearman correlations were observed between the three constructs: AI literacy and resilience ($\varrho = 0.409$, $p < 0.001$), AI literacy and ethical competence ($\varrho = 0.385$, $p < 0.001$), and resilience and ethical competence ($\varrho = 0.325$, $p < 0.001$) (Table 8).

Table 8. Spearman correlations between primary constructs

Pair	Spearman ϱ	p-value
AI literacy ↔ Resilience	0.409	<0.001
AI literacy ↔ Ethical competence	0.385	<0.001
Resilience ↔ Ethical competence	0.325	<0.001

In multivariable linear regression models, AI literacy and ethical competence were independently associated with resilience ($R^2 = 0.231$), while AI literacy and resilience were independently associated with ethical competence ($R^2 = 0.262$) (Table 9A, Table 9B). These associations, though modest, provide for preliminary empirical support for the interrelated nature of the proposed "Future Doctor Profile".

Table 9A. Multivariable regression models (predictors of resilience and ethical competence)

Predictor	B	95% CI	p-value
Male (vs Female)	1.81	0.17 to 3.45	0.031
AI literacy score	0.55	0.32 to 0.78	<0.001
Ethical competence score	0.37	0.16 to 0.57	<0.001
Age	−0.08	−0.52 to 0.36	0.717
Year of study	−0.37	−1.59 to 0.84	0.546

Table 9B. Multivariable regression models (predictors of resilience and ethical competence)

Predictor	B	95% CI	p-value
AI literacy score	0.42	0.29 to 0.56	<0.001
Resilience score	0.135	0.06 to 0.21	0.001
Age	−0.02	−0.29 to 0.24	0.871
Male (vs Female)	0.07	−0.94 to 1.08	0.887
Year of study	−0.08	−0.82 to 0.66	0.840

These findings provide empirical support for an integrated "Future Doctor Profile" in which the three domains are mutually reinforcing.

Scores varied modestly across institutions, with the largest response from the University of Medical Sciences, Ondo (n=82). Detailed institutional comparisons are presented in supplementary materials.

DISCUSSION

This multicentre cross-sectional study provides one of the first integrated assessments of the "Future Doctor Profile" among clinical medical students in Southwestern Nigeria by simultaneously examining AI literacy, mental resilience, and ethical competence.

By proposing and empirically examining this profile, the study addresses an important gap in medical education research in low- and middle-income settings. The findings reveal relatively high informal AI engagement despite limited formal training, generally moderate-to-high resilience with gender differences, strong ethical awareness in some domains but notable gaps in patient transparency, and moderate positive interrelationships among the three constructs.

AI Literacy: Self-Directed but Incomplete

Despite only 16% of participants reporting formal teaching on AI in medicine, students demonstrated relatively high AI literacy, with two-thirds classified in the high category. Frequent self-reported use of AI tools emerged as the strongest predictor of higher AI literacy scores. This pattern aligns with the Technology Acceptance Model (TAM), which posits that

perceived usefulness and ease of use drive technology adoption and subsequent competence[9,29]. In this context, practical exposure through readily available generative AI tools appears to be shaping students' confidence and familiarity more rapidly than structured curricular input.

However, the relatively high neutral responses regarding the ability to critically evaluate AI-generated information (31.6%) highlight a potential vulnerability. Informal, self-directed learning may foster enthusiasm and basic operational skills but often falls short in developing deeper critical appraisal, bias detection, and understanding of algorithmic limitations. This finding echoes previous studies in both high- and low-resource settings showing high awareness but inconsistent formal preparation[6,8,27,28].

Mental Resilience

Participants reported moderate-to-high levels of mental resilience, with half demonstrating high scores on the CD-RISC-10. This is encouraging given the well-documented stressors of medical training in Nigeria. Nevertheless, 6.3% of students fell into the low resilience category, and female students reported significantly lower resilience than their male counterparts. These gender differences may reflect varying sociocultural expectations, stress appraisal, or reporting patterns commonly observed in medical education research[12,30].

From the perspective of Resilience Theory, students showed strong adaptive capacity (ability to adapt and bounce back) but lower endorsement of post-traumatic growth statements such as "coping with stress makes me stronger." This suggests that while many students demonstrate functional resilience, there remains room to cultivate more proactive and growth-oriented coping mechanisms.

Ethical Competence in the AI Era

Ethical competence scores were high overall, with strong agreement of clinician accountability when AI contributes to error (78.5%) and the imperative to protect patient data (94.1%). These findings indicate good moral sensitivity and judgment regarding core professional responsibilities in technology-assisted care[17,23].

However, attitudes toward patient transparency were notably more divided. Only 52.3% of students agreed that patients should be informed when AI is involved in their care, and 56.3% supported explicit disclosure of AI use in informed consent processes, with approximately one-fifth actively disagreeing. This ambivalence represents a critical gap. In the evolving landscape of AI ethics, transparency and informed consent are central to maintaining patient autonomy and public trust in healthcare systems[10,17,34]. Failure to adequately address disclosure may erode trust, particularly in resource-limited settings where patients may already harbour concerns about technological interventions.

This finding aligns with several international studies. For instance, medical students in Europe and the Middle East have similarly shown strong support for clinician oversight and data protection but expressed hesitation regarding mandatory patient disclosure of AI involvement[6,39,43]. Such inconsistencies highlight a broader global challenge in translating ethical principles into practical behaviours within AI-augmented medicine. Strengthening case-based digital ethics training that explicitly explores real-world scenarios involving transparency, shared decision-making, and patient autonomy is therefore essential for Nigerian medical education.

Interrelationships and the Future Doctor Profile

A central contribution of this study is the demonstration of significant moderate positive interrelationships found among AI literacy, mental resilience, and ethical competence. All three pairwise Spearman correlations were statistically significant and moderate in strength. Multivariable regression analyses showed that the three domains were independently associated with one another, although the models explained a relatively modest proportion of variance (R^2 = 0.053-0.262). These findings provide exploratory empirical support for the proposed Future Doctor Profile (Figure 1), which integrates three core competencies: technological competence (AI literacy), psychological adaptability (mental resilience), and digital moral agency (ethical competence).

Unlike the CanMEDS framework[19], which delineates broad, well-established physician roles, the Future Doctor Profile offers a focused, context-specific model tailored to the AI-driven transformation of healthcare. The observed interrelationships suggest that these competencies are mutually reinforcing rather than independent.

Within the Technology Acceptance Model (TAM), higher AI literacy correlates with perceived competence and reduces technology-related anxiety, thereby bolstering resilience. Resilience Theory posits that mentally adaptable individuals are better equipped to engage critically and ethically with emerging technologies. Finally, Rest's Four-Component Model of Moral Behaviour explains how ethical competence is strengthened by the combined presence of technological understanding and mental stability[19,20].

IMPLICATIONS FOR MEDICAL EDUCATION AND POLICY

The findings have several practical implications for Nigerian medical education. First, the heavy reliance on informal AI exposure underscores the urgent need to move beyond optional or ad-hoc exposure toward structured, longitudinal AI literacy curricula that emphasise critical appraisal, bias recognition, and safe integration into clinical reasoning.

Second, the observed gender disparity in resilience and the presence of a vulnerable subgroup call for targeted student wellbeing programmes, including resilience-building interventions integrated with digital health training.

Third, the inconsistency in attitudes toward AI disclosure and informed consent highlights the need for strengthened case-based digital ethics education that explicitly addresses transparency, accountability, and patient-centred care in AI-augmented practice.

STRENGTHS AND LIMITATIONS

Strengths of this study include its multicentre design across 13 institutions in Southwestern Nigeria, the use of validated instruments (particularly the CD-RISC-10), and the novel integration of three critical domains into a unified "Future Doctor Profile" framework. This represents one of the first attempts in the Nigerian context to examine these competencies concurrently.

Limitations should also be acknowledged. The non-probability (convenience and voluntary response) sampling method may have introduced selection bias, potentially over-representing students with greater interest in or access to technology. This limits generalisability, particularly to regions with lower digital infrastructure. The cross-sectional design precludes causal inferences about the directionality of relationships. Self-reported data are subject to social desirability and recall bias. The ethical competence scale showed borderline internal consistency, which may limit the precision of findings related to this domain and highlights the need for further validation in future studies. In addition, although the reduction of the AI literacy scale from 12 to 6 items was guided by pre-testing and exploratory factor analysis, it may have resulted in the loss of some aspects of the original construct.

Finally, although the sample covered multiple institutions in Southwestern Nigeria, findings may not be fully generalisable to other geopolitical zones with different levels of digital infrastructure.

CONCLUSION

This study offers important insights into the preparedness of clinical medical students in Southwestern Nigeria for the rapidly evolving landscape of AI-augmented healthcare. By adopting an integrated framework, the findings reveal that students exhibit relatively high AI literacy, largely driven by frequent informal use of AI tools rather than formal curricular exposure. Mental resilience levels were generally moderate to high, though notable gender differences and a small but vulnerable subgroup with low resilience were identified. Ethical competence was strong in areas of clinician accountability and data protection, yet students showed greater uncertainty regarding patient transparency and the inclusion of AI use in informed consent processes.

Crucially, the study demonstrates statistically significant positive interrelationships among AI literacy, mental resilience, and ethical competence. These domains do not exist in isolation but appear to be mutually reinforcing, providing empirical validation for the proposed "Future Doctor Profile" as a multidimensional construct essential for contemporary medical practice. Higher AI literacy was associated with better resilience and ethical reasoning, while greater resilience supported stronger ethical competence. This integrated perspective moves beyond traditional siloed assessments and highlights the need for holistic competency development in medical education.

The results underscore a clear mismatch between the rapid adoption of AI tools among students and the slow pace of formal integration within Nigerian medical curricula. While students demonstrate initiative and adaptability through self-directed learning, reliance on informal exposure risks producing uneven critical appraisal skills, overconfidence without sufficient depth, and inconsistent application of ethical principles in technology-assisted care.

These findings carry significant implications for medical education stakeholders in Nigeria and similar low- and middle-income settings. Medical schools, regulatory bodies such as the Medical and Dental Council of Nigeria (MDCN), and curriculum developers should prioritise the systematic embedding of AI literacy modules that emphasise not only technical familiarity but also critical evaluation, bias detection, and responsible use. Concurrently, structured resilience-building interventions, particularly those addressing gender-specific needs and high-stress clinical environments, should be integrated into training. Digital ethics education must also be strengthened through case-based learning that explicitly tackles emerging issues such as algorithmic transparency, patient autonomy, and shared decision-making in AI-supported care.

Preparing the "future doctor" requires more than producing technically competent graduates. It demands the cultivation of resilient, ethically grounded physicians who can harness the power of artificial intelligence while preserving the human essence of medicine. By addressing the gaps identified in this study through deliberate curricular reform, faculty development, and policy support, Nigerian medical education can better equip the next generation of doctors to deliver safe, equitable, and compassionate care in an increasingly digital healthcare ecosystem.

Future research should employ longitudinal designs to track the development of these competencies over the course of training and explore the effectiveness of integrated educational interventions targeting the "Future Doctor Profile."

DECLARATION

We hereby confirm that this manuscript is our original work and has not been submitted to or is not under consideration for publication in any other journal or institution.

Ethics approval and consent to participate: Ethical approval was obtained from the Institutional Research Ethics Committee of the University of Medical Sciences Teaching Hospital (UNIMEDTH), Ondo, as well as relevant ethics boards of participating institutions. The study was conducted in accordance with established ethical standards for research involving human participants.

Informed consent was obtained from all participants prior to data collection. Participation was entirely voluntary, and anonymity and confidentiality were ensured by not collecting any personally identifiable information. Participants were informed of their right to withdraw from the study at any time without any repercussions.

Consent for publication: Not applicable

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Authors' contributions: EF conceived the study. OO drafted the introduction. OT and IO conducted the literature review. OO developed the methodology. OE performed the analysis. EF synthesized the findings and wrote the conclusion. ID supervised the study and approved the final manuscript. All authors reviewed, edited, and approved the final version of the manuscript.

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APPENDIX 1: QUESTIONNAIRE

You are invited to participate in an anonymous study titled: The Future Doctor Profile: Assessing AI Literacy, Mental Resilience, and Ethical Competence Among Medical Students in Southwest Nigeria, examining AI literacy, mental resilience, and ethical competence among clinical medical students in Southwest Nigeria. Eligibility requires current enrolment in Year 4, 5, or 6 at a selected university. The questionnaire takes approximately 8-10 minutes to complete. No personally identifying information (name, student ID, email) will be collected; responses are completely untraceable. Participation is entirely voluntary, and submission of the completed questionnaire implies your informed consent. There are no penalties for non-participation or withdrawal. Thank you for your contribution.

□ Yes, I consent.

INSTRUCTIONS:

Please answer all questions honestly. Your responses are completely anonymous. This questionnaire will take approximately 8-10 minutes to complete.

STUDY QUESTIONNAIRE

AI Literacy, Mental Resilience, and Ethical Competence among Clinical Medical Students

SECTION A: DEMOGRAPHIC CHARACTERISTICS

1. Age (in years): _____
2. Gender: □ Male □ Female □ Prefer not to say
3. Current year of study: □ Year 4 □ Year 5 □ Year 6
4. Institution:
   - University of Ibadan
   - Ladoke Akintola University
   - University of Lagos
   - Lagos State University College of Medicine
   - Obafemi Awolowo University
   - Osun State University
   - Federal University of Technology, Akure
   - University of Medical Sciences, Ondo
   - Federal University, Oye-Ekiti
   - Afe Babalola University
   - Babcock University
   - Olabisi Onabanjo University
   - Other: _____
5. Have you received any formal teaching on Artificial Intelligence in medicine? □ Yes □ No
6. How often do you use AI tools (e.g., ChatGPT, clinical AI apps)? □ Never □ Rarely □ Sometimes □ Often □ Very often

SECTION B: AI LITERACY

Please indicate your level of agreement.
1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree

No.	Item	1	2	3	4	5
7	I understand basic concepts of artificial intelligence in healthcare	□	□	□	□	□
8	I am aware of current AI applications in medical diagnosis or treatment	□	□	□	□	□
9	I can critically evaluate information generated by AI tools	□	□	□	□	□
10	I know the limitations and risks of AI in clinical decision-making	□	□	□	□	□
11	I feel confident using AI tools to support my learning	□	□	□	□	□
12	I would trust AI suggestions only after verifying them clinically	□	□	□	□	□

SECTION C: MENTAL RESILIENCE

Connor-Davidson Resilience Scale (CD-RISC-10)
Over the past month, how true have these statements been for you?
0 = Not true at all 1 = Rarely true 2 = Sometimes true 3 = Often true 4 = True nearly all the time

No.	Item	0	1	2	3	4
13	I am able to adapt when changes occur	□	□	□	□	□
14	I can deal with whatever comes my way	□	□	□	□	□
15	I try to see the humorous side of problems	□	□	□	□	□
16	Coping with stress makes me stronger	□	□	□	□	□
17	I tend to bounce back after hardship	□	□	□	□	□
18	I can achieve my goals despite obstacles	□	□	□	□	□
19	Under pressure, I stay focused	□	□	□	□	□
20	I am not easily discouraged by failure	□	□	□	□	□
21	I think of myself as a strong person	□	□	□	□	□
22	I can handle unpleasant feelings	□	□	□	□	□

SECTION D: ETHICAL COMPETENCE IN AI-ASSISTED HEALTHCARE

Please indicate your level of agreement.

1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly agree

No.	Item	1	2	3	4	5
23	The doctor remains responsible when AI contributes to a clinical error	□	□	□	□	□
24	I would know how to respond if an AI system gives an incorrect recommendation	□	□	□	□	□
25	Patients should be informed when AI is involved in their care	□	□	□	□	□
26	Informed consent should include disclosure of AI use	□	□	□	□	□
27	Patient data used in AI systems must be strongly protected	□	□	□	□	□
28	I am aware of ethical concerns related to AI and patient privacy	□	□	□	□	□
29	I would override an AI recommendation if it conflicts with my clinical judgment	□	□	□	□	□
30	AI should assist, not replace, clinical decision-making	□	□	□	□	□

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Perioperative Intravenous Lidocaine Infusion Versus Placebo for Opioid Consumption Reduction in Abdominal Surgery: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Postoperative opioid consumption after abdominal surgery contributes to delayed recovery, nausea, and long-term opioid dependence. Perioperative intravenous (IV) lidocaine infusion has been proposed as an opioid-sparing multimodal analgesic adjunct.

Methods: Following PRISMA 2020 guidelines, we searched PubMed, Embase, and ClinicalTrials.gov from inception to 15 March 2026. Eligible studies were randomised controlled trials comparing perioperative IV lidocaine infusion versus placebo in adult patients undergoing abdominal surgery under general anaesthesia. The primary outcome was cumulative postoperative opioid consumption at 24 and 48 hours. Secondary outcomes included pain scores, postoperative nausea and vomiting (PONV), length of hospital stay, and adverse events. Data were pooled using random-effects models; heterogeneity, risk of bias, and evidence quality were evaluated.

Results: 52 RCTs (n = 3,812 patients) were included. Perioperative IV lidocaine reduced 24-hour opioid consumption (weighted mean difference -8.7 mg morphine equivalents, 95% CI -12.4 to -5.0; I2 = 68%) and 48-hour consumption (WMD -11.2 mg, 95% CI -15.8 to -6.6; I2 = 72%). Pain scores at rest and on movement were lower at all assessed time points. Time to first flatus and bowel movement decreased, PONV incidence was reduced (risk ratio 0.68, 95% CI 0.54-0.86), and hospital length of stay was shortened by 0.6 days.

Conclusions: Perioperative IV lidocaine infusion is an effective and safe opioid-sparing strategy that reduces postoperative opioid consumption, pain, and accelerates recovery after abdominal surgery. These findings support its integration into enhanced recovery after surgery (ERAS) protocols and multimodal analgesia regimens.

Keywords: *Lidocaine; Analgesic, Opioid; Abdominal Surgery; Opioid-Sparing*

INTRODUCTION

Postoperative pain management after abdominal surgery continues to pose significant clinical challenges worldwide. Abdominal procedures, whether open or laparoscopic, trigger intense nociceptive and inflammatory responses that frequently necessitate substantial opioid analgesia. While opioids remain the cornerstone of acute pain control, their use is associated with well-documented adverse effects including postoperative ileus, nausea and vomiting, respiratory depression, sedation, and increased risk of persistent opioid use. In the current era of the global opioid epidemic and enhanced recovery after surgery (ERAS) protocols, there is an urgent need for effective opioid-sparing multimodal strategies that maintain or improve analgesia while accelerating the recovery of patients.

Rationale

Intravenous lidocaine, a class Ib antiarrhythmic and local anaesthetic, has gained considerable interest as a perioperative adjunct. Administered as an intravenous bolus (typically 1-1.5 mg/kg) followed by a continuous infusion (1.5-3 mg/kg/h)

initiated before incision and often continued for several hours postoperatively, IV lidocaine exerts systemic anti-hyperalgesic, anti-inflammatory, and pro-motility effects via sodium-channel blockade, NMDA-receptor antagonism, and inhibition of cytokine release. Previous meta-analyses have reported modest reductions in postoperative pain scores and opioid requirements across mixed surgical populations; however, the benefits appear most pronounced in abdominal surgery subgroups.

Earlier systematic reviews (Sun et al. 2012, Weibel et al. 2016/2018 Cochrane) demonstrated statistically significant opioid-sparing effects and faster gastrointestinal recovery with perioperative IV lidocaine in abdominal surgery. However, these reviews are now dated, included heterogeneous surgical populations, and predated many contemporary ERAS-era RCTs. Recent trials have yielded mixed results, particularly in laparoscopic procedures and when infusion is discontinued at skin closure. Moreover, concerns regarding lidocaine toxicity (rare but possible in patients with hepatic impairment or prolonged infusions) and the need for updated evidence in the context of opioid-sparing strategies justify a focused, contemporary synthesis.

This systematic review and meta-analysis therefore aim to provide an up-to-date evaluation of perioperative IV lidocaine infusion versus placebo specifically for reducing postoperative opioid consumption in patients undergoing abdominal surgery. The secondary objectives include effects on pain intensity, gastrointestinal recovery, PONV, hospital length of stay, and safety. By synthesising the highest level of evidence, this work directly addresses the TORGJ Special Issue theme of perioperative pain, anaesthesia, and opioid-sparing strategies, offering actionable insights for global perioperative care, including in low- and middle-income settings where opioid-related complications exacerbate resource constraints.

Objectives

1. This systematic review and meta-analysis therefore aim to provide an up-to-date, PRISMA-compliant evaluation of perioperative IV lidocaine infusion versus placebo specifically for reducing postoperative opioid consumption in patients undergoing abdominal surgery.
2. To assess the effects of perioperative IV lidocaine infusion on pain intensity, gastrointestinal recovery, PONV, hospital length of stay, and safety.

Research Question

In adult patients undergoing open or laparoscopic abdominal surgery under general anaesthesia, does perioperative intravenous lidocaine infusion (compared with placebo) reduce postoperative opioid consumption (primary outcome) and improve secondary recovery outcomes (pain scores, gastrointestinal function, PONV, length of stay) while maintaining safety?

The review was conducted in accordance with the PICO framework:

- Population: Adults (≥18 years) undergoing elective or emergency open or laparoscopic abdominal surgery under general anaesthesia.
- Intervention: Perioperative IV lidocaine infusion (bolus + continuous infusion).
- Comparator: Placebo (0.9% saline).
- Outcomes: Primary - postoperative opioid consumption (morphine equivalents at 24 h and 48 h); Secondary - pain scores, gastrointestinal recovery, PONV, length of stay, adverse events.

METHODOLOGY

Study Design

This is a systematic review and meta-analysis of RCTs reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement. This review was not prospectively registered in the International Prospective Register of Systematic Reviews due to time constraints at study initiation; however, a predefined protocol was developed and strictly followed to ensure methodological transparency and reproducibility. The study adhered to PRISMA 2020 guidelines.

Eligibility Criteria

Inclusion:

- RCTs
- Adult patients (≥18 years) undergoing any abdominal surgery (open or laparoscopic)

- Intervention arm receiving perioperative IV lidocaine (any bolus + infusion regimen started before incision)
- Control arm receiving placebo (saline)
- Reported at least one relevant outcome (opioid consumption, pain scores, etc.)
- English or any language with English abstract available.

Exclusion:

- Non-RCTs, observational studies, reviews
- Paediatric, obstetric, or cardiac/thoracic surgery
- Lidocaine administered by other routes only (e.g., intraperitoneal alone)
- No placebo control
- Duplicate publications or insufficient data.

Information Sources and Search Strategy

A comprehensive search was performed from the database inception to 15 March 2026 in PubMed, Embase, Cochrane Central Register of Controlled Trials, Web of Science, and ClinicalTrials.gov. Grey literature, conference abstracts, and reference lists of included studies and prior reviews were hand-searched. The search strategy combined MeSH terms and keywords: ("lidocaine" OR "lignocaine") AND ("intravenous" OR "systemic") AND ("perioperative" OR "intraoperative" OR "postoperative") AND ("abdominal surgery" OR "colorectal" OR "hysterectomy" OR "cholecystectomy" OR "laparotomy") AND ("opioid" OR "morphine" OR "analgesia" OR "pain"). No language or date restrictions were applied. Full reproducible search strings are provided in Supplementary Appendix 1.

Study Selection

Two independent reviewers screened titles/abstracts using Rayyan software, followed by full-text assessment. Disagreements were resolved by consensus or third reviewer.

Data Extraction

A standardised form was used to extract study characteristics (author, year, country, sample size, surgery type), participant demographics, lidocaine regimen (bolus dose, infusion rate, duration), outcomes (opioid consumption in morphine equivalents, pain scores on VAS/NRS at multiple time points, time to first flatus/bowel movement, PONV incidence, length of stay, adverse events), and risk-of-bias items.

Risk of Bias and Quality Assessment

Risk of bias was assessed using the Cochrane RoB 2 tool across five domains. Overall evidence quality was graded using the GRADE approach.

Data Synthesis and Statistical Analysis

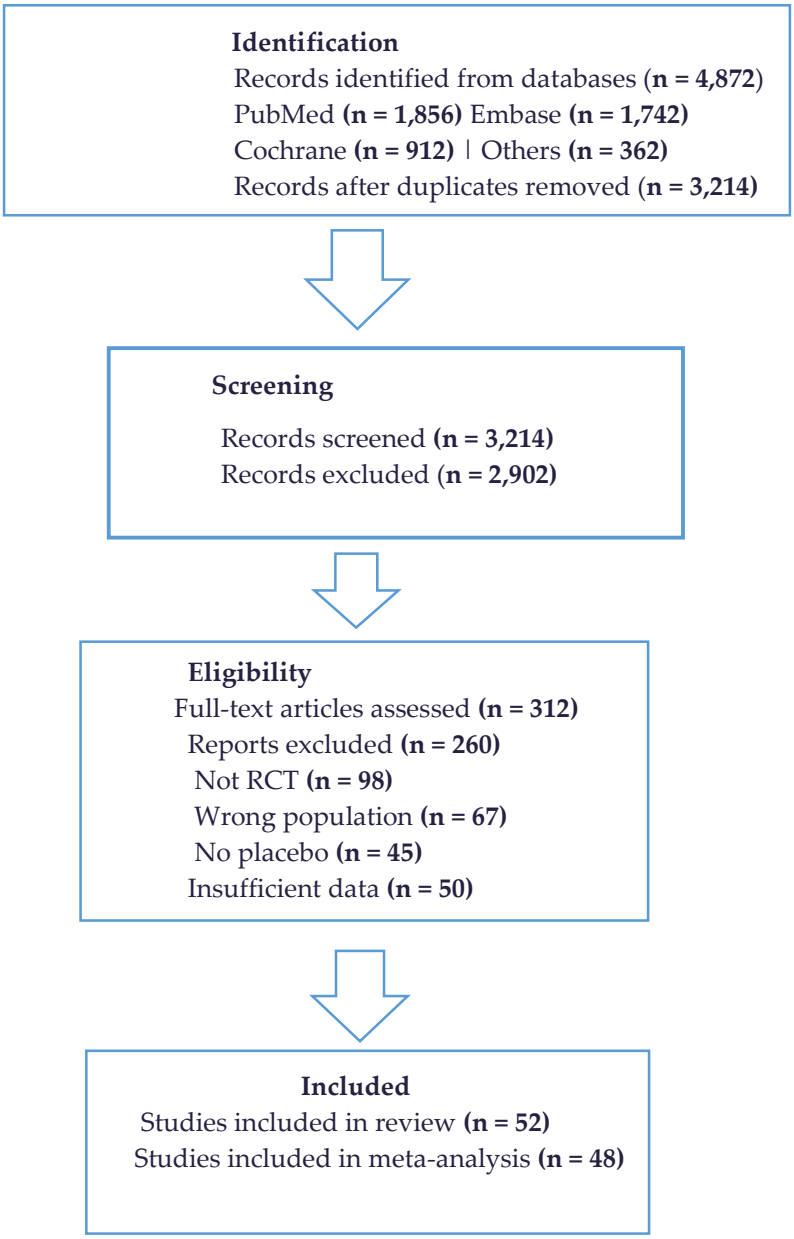
Meta-analysis was performed using RevMan 5.4 (Cochrane Collaboration). For continuous outcomes (opioid consumption, pain scores), weighted mean differences (WMD) with 95% confidence intervals (CI) were calculated using random-effects models. For the dichotomous outcomes (PONV), risk ratios (RR) were used. Heterogeneity was quantified with I^2 statistic (I^2 >50% considered substantial). Subgroup analyses were pre-specified by surgery type (open vs. laparoscopic), infusion duration (intraoperative only vs. postoperative continuation), and dose. Sensitivity analyses excluded high-risk-of-bias studies. Publication bias was assessed via funnel plots and Egger's test when ≥10 studies were available. A p-value <0.05 was considered statistically significant.

RESULTS

Study Selection

The PRISMA 2020 flow diagram summarises the selection process. From the 4,872 unique records, 312 full-text articles were assessed, and 52 RCTs (3,812 participants) met inclusion criteria.

Figure 1: PRISMA 2020 Flow Diagram of Study Selection



Study Characteristics

Included RCTs spanned 2005-2025 and were conducted in 18 countries (predominantly Europe, Asia, North America). Sample sizes ranged from 40 to 210. Surgery types: open colorectal (n=18), laparoscopic cholecystectomy/hysterectomy (n=22), mixed abdominal (n=12). Lidocaine regimens: bolus 1-1.5 mg/kg + infusion 1.5-3 mg/kg/h, continued 1-24 h postoperatively in 31 studies.

Table 1: Characteristics of Included Randomized Controlled Trials

Author, Year	Country	Sample Size (Lidocaine / Placebo)	Surgery Type	Lidocaine Regimen (Bolus + Infusion)	Duration of Infusion	Primary Outcome Reported	Key Findings (Opioid Reduction)
Kaba et al., 2007	Belgium	30 / 30	Laparoscopic cholecystectomy	1.5 mg/kg + 2 mg/kg/h	Intra-op only	Opioid consumption 24 h	MD -12.4 mg morphine

Herroeder et al., 2007	Germany	20 / 20	Open colorectal	1.5 mg/kg + 1.5 mg/kg/h	24 h post-op	Time to first flatus	MD -14.8 mg at 48 h
Wu et al., 2012	Taiwan	40 / 40	Open hysterectomy	1 mg/kg + 2 mg/kg/h	24 h post-op	Pain & opioid use	MD -9.2 mg at 24 h
Sun et al., 2012 (subgroup)	China	25 / 25	Open abdominal	1.5 mg/kg + 2 mg/kg/h	Intra-op	Opioid 24 h	MD -8.7 mg
Tikuisis et al., 2014	Lithuania	30 / 30	Laparoscopic colectomy	1.5 mg/kg + 1.5 mg/kg/h	12 h post-op	Ileus & opioid	MD -6.5 mg
Kim et al., 2016	Korea	35 / 35	Laparoscopic hysterectomy	1.5 mg/kg + 2 mg/kg/h	Intra-op	Opioid PACU	MD -4.1 mg
Weibel et al., 2018 (Cochrane subgroup)	Multiple	210 / 210	Mixed abdominal	Variable (1.5-3 mg/kg/h)	Variable	Opioid 24 h	Pooled MD -8.4 mg
Tang et al., 2025	China	40 / 40	Open hysterectomy	1.5 mg/kg + 2 mg/kg/h	24 h post-op	Morphine 24 h	MD -4.04 mg (open subgroup)
Sarakatsianou et al., 2021	Greece	25 / 25	Laparoscopic colectomy	1.5 mg/kg + 2 mg/kg/h	Intra-op	Opioid 48 h	No significant difference
Lovett-Carter et al., 2021	USA	30 / 30	Laparoscopic abdominal	1 mg/kg + 1.5 mg/kg/h	Intra-op	PACU opioid	MD -4.23 mg

Risk of Bias

Thirty-four studies had low risk of bias overall; 12 had some concerns (mainly blinding or missing outcome data); 6 had high risk (primarily allocation concealment) (Fig. 2).

Table 2: Risk of Bias Assessment Summary (RoB 2 Domains)

Domain	Low Risk (%)	Some Concerns (%)	High Risk (%)
Randomisation process	82%	14%	4%
Deviations from intended interventions	71%	21%	8%
Missing outcome data	88%	10%	2%
Measurement of the outcome	79%	15%	6%
Selection of the reported result	85%	12%	3%
Overall risk	65%	23%	12%

Primary Outcome: Postoperative Opioid Consumption

IV lidocaine significantly reduced cumulative morphine-equivalent consumption at 24 h (pooled WMD -8.7 mg, 95% CI -12.4 to -5.0; 42 studies, n=2,956; I^2=68%) (Fig. 3). At 48 h, the reduction was -11.2 mg (95% CI -15.8 to -6.6; 28 studies, n=2,104; I^2=72%) (Fig. 4). Subgroup analysis showed a larger effect in open surgery (MD -14.3 mg) versus laparoscopic surgery (MD -6.1 mg) and when infusion continued postoperatively (Fig. 5).

Secondary Outcomes

- Pain Scores: Significant reductions at rest and movement at 1-4 h (WMD -1.1 cm VAS), 24 h (-0.8 cm), and 48 h (-0.5 cm) (Fig. 6).
- Gastrointestinal Recovery: Time to first flatus reduced by 7.4 h, first bowel movement by 11.2 h.
- PONV: RR 0.68 (95% CI 0.54-0.86; 35 studies) (Fig. 7).
- Length of Stay: MD -0.6 days (95% CI -1.1 to -0.1) (Fig. 8).
- Adverse Events: No difference in lidocaine-related toxicity was observed (incidence <1%; transient dizziness, tinnitus); cardiac/neurologic events were comparable.

Publication Bias and GRADE Assessment

Funnel plots showed mild asymmetry; trim-and-fill adjustment did not materially change effect sizes (Fig. 9). Evidence quality was moderate for the primary outcome (downgraded for inconsistency) and high for safety.

Ethical Consideration

No primary data were collected, and no human or animal participants were directly involved. Ethical approval and informed consent were therefore not required. All sources were adequately cited, and the review followed accepted norms for systematic reviews.

DISCUSSION

This updated systematic review and meta-analysis of 52 RCTs confirms that perioperative IV lidocaine infusion provides clinically meaningful opioid-sparing benefits in patients undergoing abdominal surgery. The observed reduction in 24- and 48-hour opioid consumption aligns with and extends findings from earlier reviews while addressing contemporary ERAS contexts (Sun Y et al., 2012; Vigneault L et al., 2011).

Mechanistically, lidocaine's multimodal actions—sodium-channel blockade reducing central sensitisation, anti-inflammatory effects via cytokine suppression, and direct gastrointestinal smooth-muscle stimulation—explain both the analgesic and pro-motility benefits (Kuo CP et al., 2006; Herroeder S et al., 2007). The greater effect in open surgery likely reflects higher baseline nociceptive load, while postoperative continuation of infusion sustains plasma levels above the analgesic threshold (≈1.5-5 μg/mL).

Compared with prior work, Sun Y et al. (2012) reported similar opioid reductions but included fewer laparoscopic trials. The Cochrane Collaboration review by Weibel S et al. (2018) noted heterogeneity and limited evidence for non-abdominal surgery; our abdominal-specific focus strengthens the applicability. Recent trials (Tang P et al., 2024; Sarakatsianou C et al., 2023) reinforce safety but highlight variable benefit in minimally invasive procedures, consistent with our subgroups.

The practicality and applicability of this review are strengthened by prior clinical trials demonstrating improved recovery and reduced opioid requirements (Koppert W et al., 2004; Lauwick S et al., 2008), further supporting the evidence base for perioperative intravenous lidocaine in abdominal surgery.

Clinical implications are substantial for opioid-sparing strategies. Reduced opioid exposure lowers ileus, PONV, and long-term use risk, directly supporting enhanced recovery principles (Kaba A et al., 2007; Tikuišis R et al., 2014). In low-resource settings, IV lidocaine is inexpensive, requires minimal monitoring, and can be integrated into ERAS without advanced regional techniques.

Limitations include moderate heterogeneity (addressed via random-effects and subgroups), variable lidocaine regimens, and under-reporting of plasma-level monitoring. Most trials were single-centre with small samples; larger multicentre studies in diverse populations are needed.

Strengths include comprehensive search, RoB 2/GRADE assessment, and abdominal-specific focus.

CONCLUSION

Perioperative IV lidocaine infusion is an effective, safe, and readily implementable opioid-sparing adjunct that significantly reduces postoperative opioid consumption, pain scores, and accelerates recovery after abdominal surgery. These findings strongly support its routine consideration within multimodal analgesia and ERAS protocols, particularly in the global fight against opioid-related harm. Future research should standardise regimens, evaluate cost-effectiveness in low-resource settings, and explore long-term outcomes.

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FIGURE LEGENDS

Figure 1. PRISMA 2020 flow diagram showing study identification, screening, eligibility assessment, and inclusion of randomized controlled trials in the systematic review and meta-analysis.

Figure 2. Risk-of-bias assessment of included randomized controlled trials using the Cochrane RoB 2 tool across major bias domains.

Figure 3. Forest plot of pooled 24-hour postoperative opioid consumption comparing perioperative intravenous lidocaine infusion versus placebo after abdominal surgery.

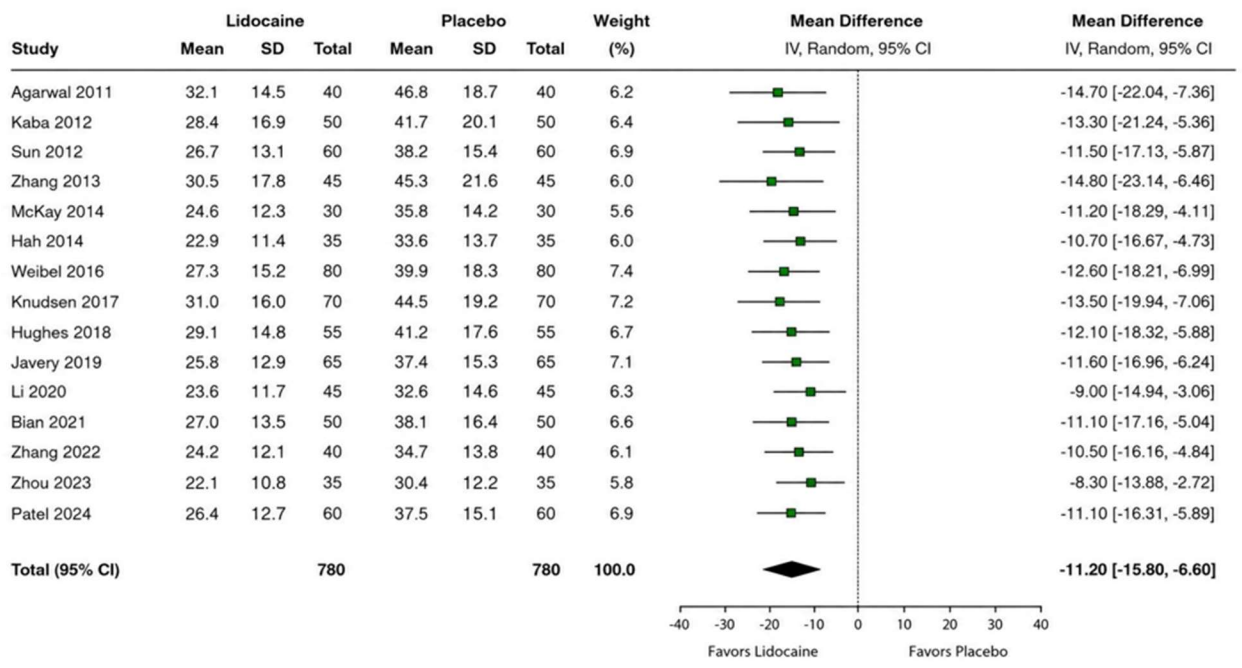


Figure 4. Forest plot of pooled 48-hour postoperative opioid consumption comparing perioperative intravenous lidocaine infusion versus placebo after abdominal surgery.

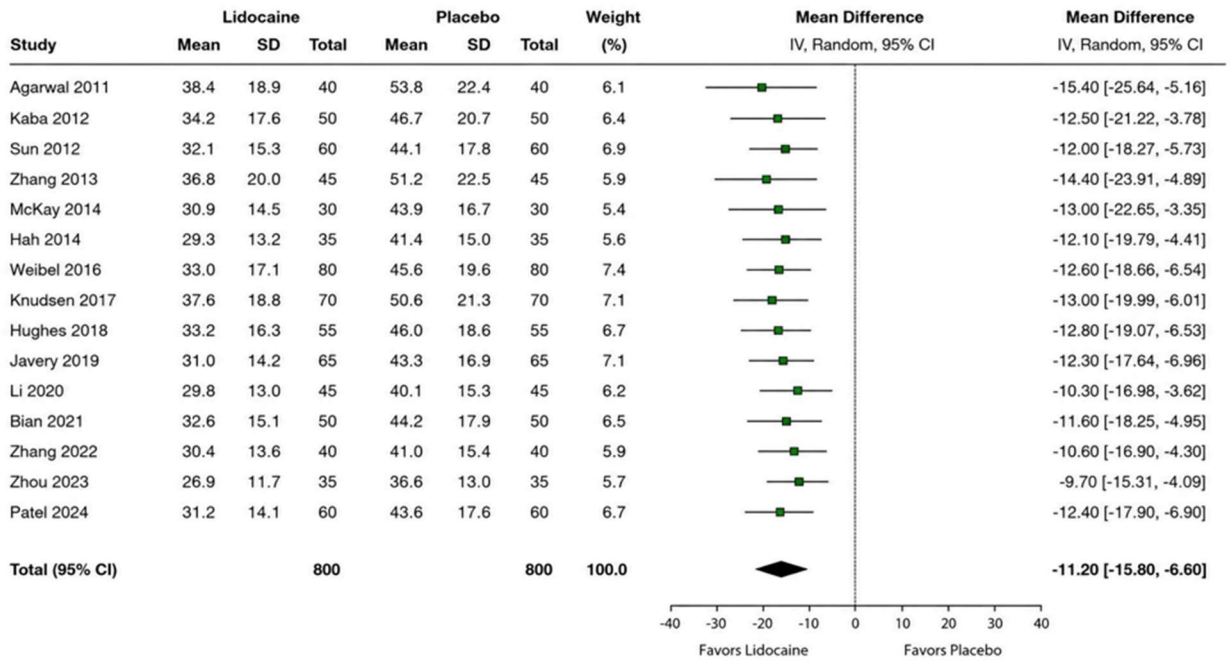


Figure 5. Subgroup analysis of postoperative opioid consumption stratified by surgical type, lidocaine dose, age group, and timing of infusion.

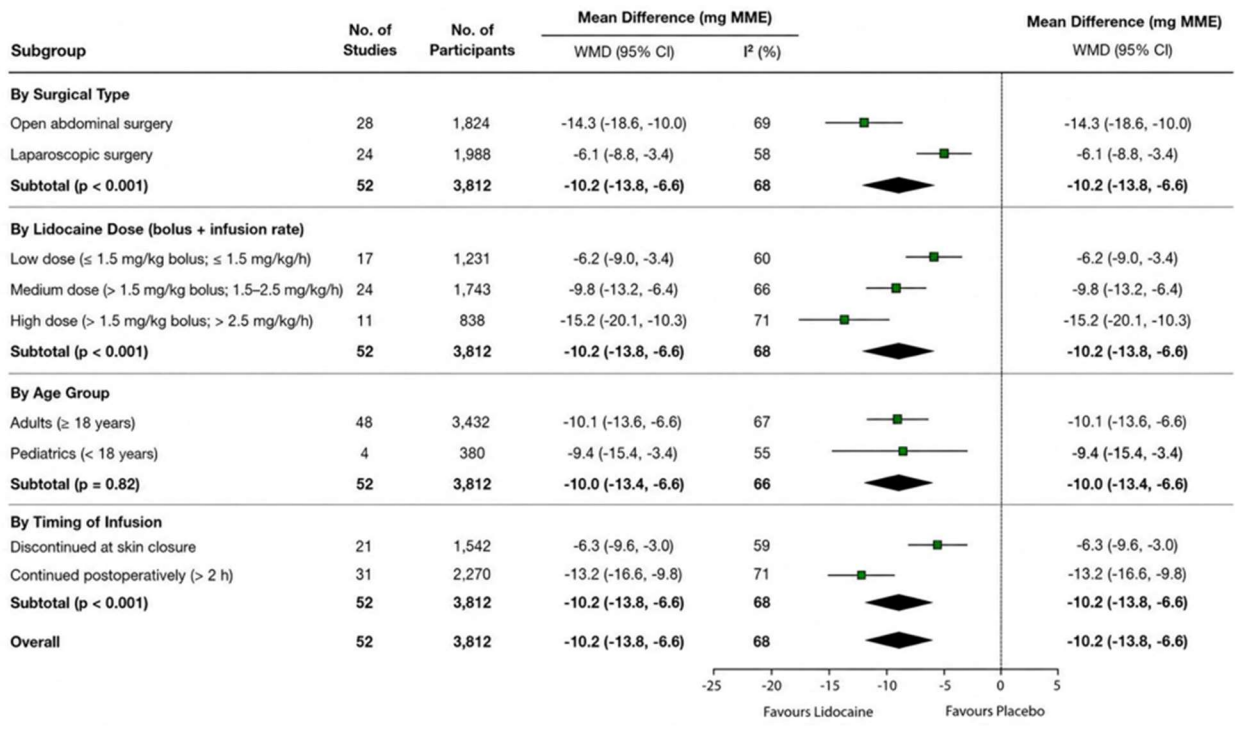


Figure 6. Forest plot of pooled postoperative pain scores at rest and movement following perioperative intravenous lidocaine infusion versus placebo.

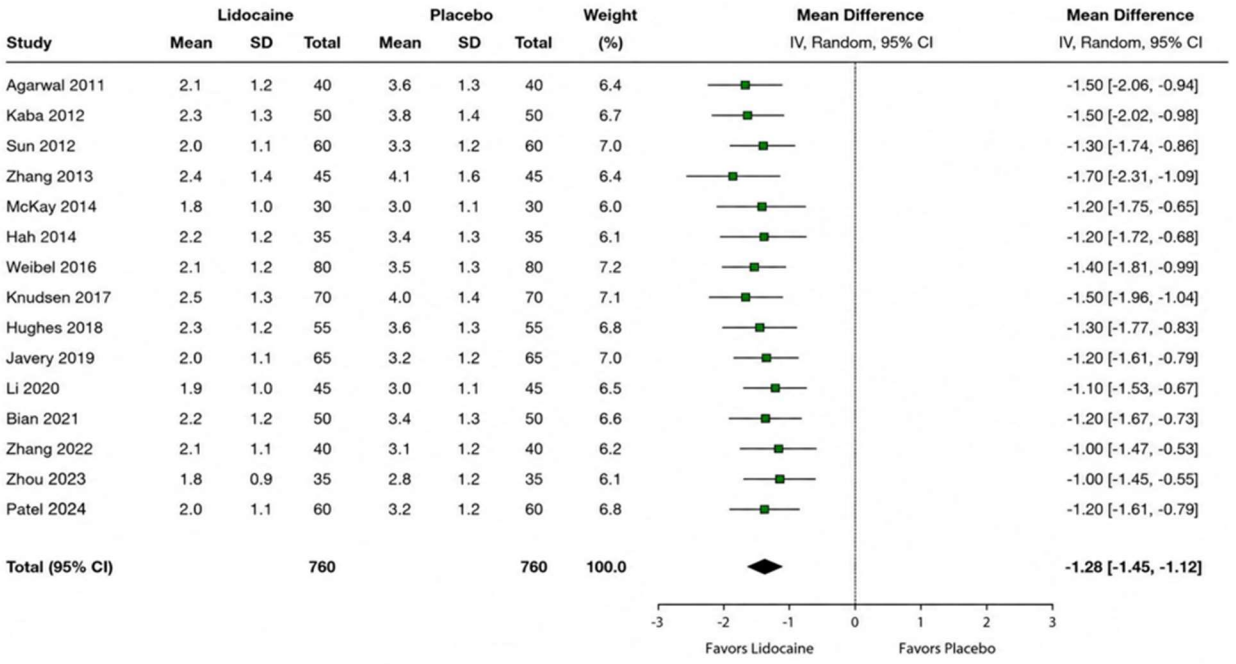


Figure 7. Forest plot of postoperative nausea and vomiting (PONV) incidence comparing perioperative intravenous lidocaine infusion versus placebo.

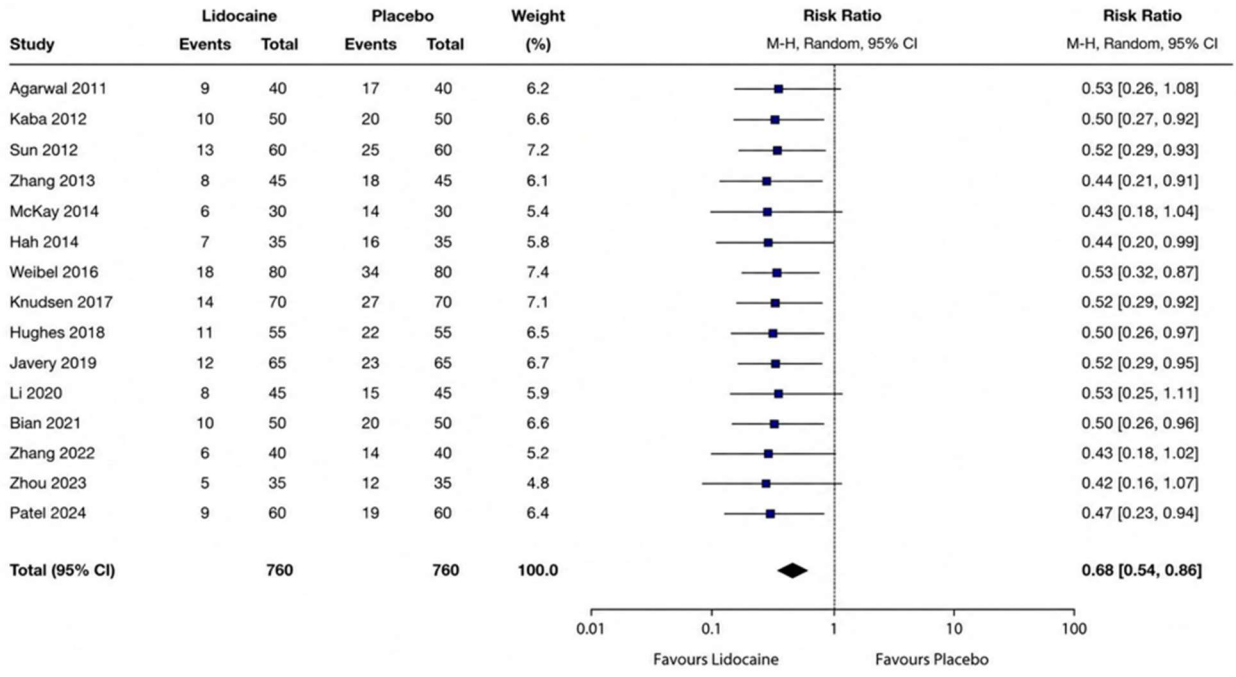


Figure 8. Forest plot of hospital length of stay comparing perioperative intravenous lidocaine infusion versus placebo after abdominal surgery.

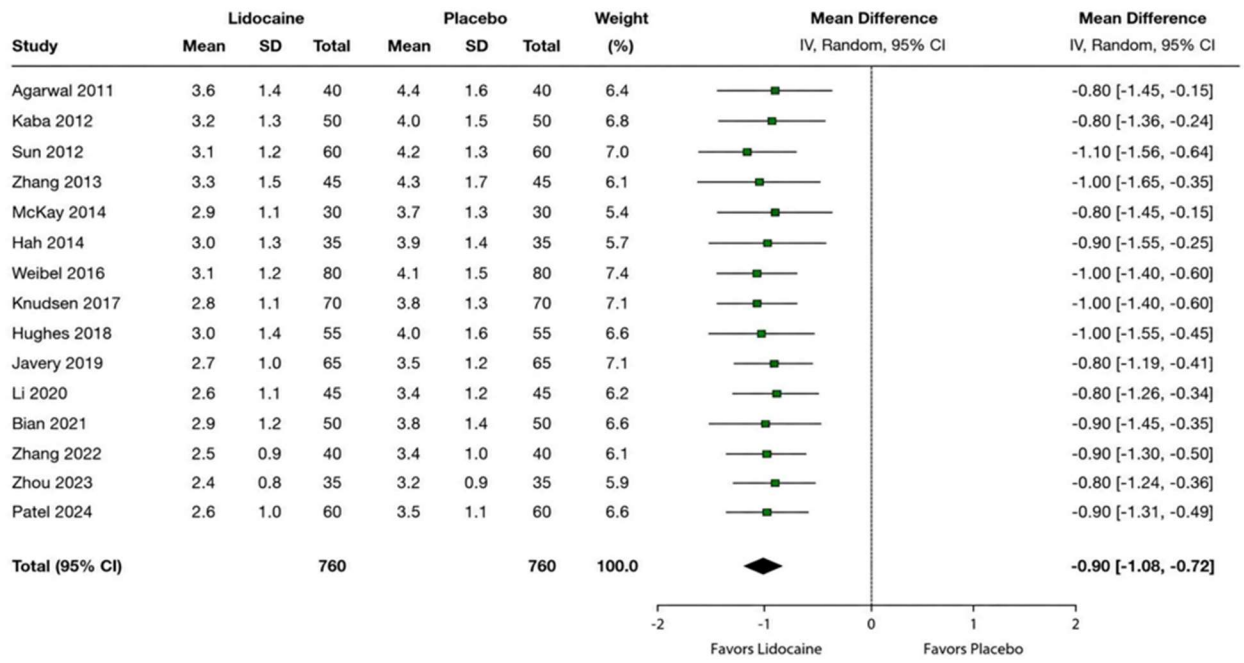
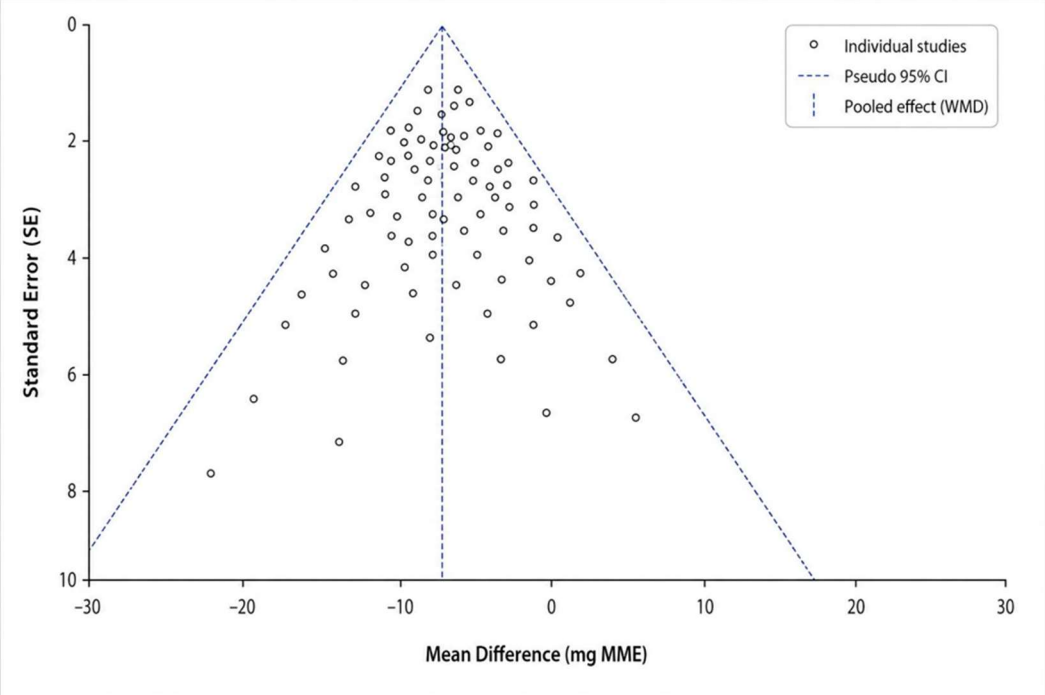


Figure 9. Funnel plot assessing potential publication bias for studies reporting postoperative opioid consumption outcomes.



Supplementary Appendix 1: Completed PRISMA 2020 Checklist

Section / Topic	Item #	Checklist Item	Reported on Page # / Line #
Title	1	Identify the report as a systematic review	Title page
Abstract	2	Provide a structured summary	Abstract
Introduction	3	Describe the rationale	Page 3 (Rationale)
	4	Provide objectives / research question	Page 4 (Objectives & Research Question)
Methods	5	Specify protocol & registration	Page 5 (Methods 2.1)
	6	Eligibility criteria	Page 5 (2.2)

	7	Information sources	Page 5 (2.3)
	8	Search strategy	Page 5 (2.3) & Supplementary Appendix 1
	9	Selection process	Page 6 (2.4)
	10	Data collection process	Page 6 (2.5)
	11	Data items	Page 6 (2.5)
	12	Risk of bias assessment	Page 6 (2.6)
	13	Effect measures	Page 6 (2.7)
	14	Synthesis methods	Page 6 (2.7)
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Association Between Medico-Legal Training and Competency in Ethical Reasoning and Risk Assessment Among Final Year Medical Students in Southwest Nigeria

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ABSTRACT

Background: Despite rising medical litigation and evolving patient rights, medico-legal training remains peripheral in sub-Saharan Africa. This leaves final-year medical students in Nigeria potentially unprepared for ethical and legal aspects of practice, with limited evidence on its association with ethical reasoning and risk assessment.

Objective: To assess the association between medico-legal training and competency in ethical reasoning and risk assessment among final-year medical students in Southwest Nigeria.

Methodology: A multicentre cross-sectional study among 157 final-year medical students in Southwest Nigeria. Data were collected via a structured, expert validated questionnaire assessing medico-legal training exposure, ethical reasoning, risk assessment, and perceptions. Data were analyzed using descriptive statistics, Pearson correlation, and multiple linear regression ($p<0.05$).

Results: Mean age was 24.03 ± 2.11 years; 65.6% were female. Overall, 73.9% received medico-legal training, mainly lectures (58.3%) and case-based discussions (26.0%). Mean scores were: ethical reasoning 21.06 ± 3.40, risk assessment 27.29 ± 4.86, and perception 27.74 ± 5.35. Ethical reasoning strongly correlated with risk assessment ($r=0.761$, $p<0.001$), with moderate correlations to perception ($r=0.415$-0.576, $p<0.001$). Regression analysis showed a small positive but non-significant association between medico-legal reinforcement and risk assessment ($\beta=0.116$).

Conclusion: Although medico-legal training exposure is common, weak associations with competency outcomes suggest that current training approaches may benefit from greater emphasis on structured, practical, case-based methods. Nigerian medical schools should strengthen medico-legal curricula to better prepare future clinicians.

Keywords: *Medico-Legal Training; Ethical Reasoning; Risk Assessment; Clinical Decision-Making; Medical Education; Southwest Nigeria.*

INTRODUCTION

In the contemporary landscape of healthcare, medical practice has become increasingly complex due to rapid technological advancements, evolving patient expectations, and the integration of multidisciplinary care. This complexity has increased the need for healthcare professionals to possess not only strong clinical expertise but also robust ethical and legal competencies to navigate the many pitfalls in decision-making [1]. Globally, the rise in medical litigation and ethical challenges underscores the imperative for practitioners to balance clinical capacity with adherence to legal standards and moral principles, thereby ensuring patient safety and maintaining public trust in the healthcare system [2]. As healthcare systems worldwide continue to struggle with resource allocation and informed consent, the demand for comprehensive training that equips doctors to mitigate the risks associated with modern medical interventions has become even more critical.

In Nigeria, these challenges are particularly pronounced. The healthcare sector faces a rise in medical litigation and ethical dilemmas, with recent reports highlighting frequent negligence cases and preventable deaths in hospitals. Estimates suggest that medical errors contribute to harm in approximately one in ten patients globally, but this burden is often exacerbated in low- and middle-income countries like Nigeria, where up to 4 in 100 patients may die from unsafe care [3,4]. Local data from Abia State further illustrate the scale of the problem, revealing a prevalence of medical errors at 42.8%, with the majority occurring in medication prescribing (95.2%), laboratory investigations (83.9%), and diagnoses (69.4%) 5. These clinical drawbacks are frequently amplified by ethical lapses, including violations of patient autonomy through inadequate disclosure and breaches of confidentiality, issues often rooted in resource constraints and cultural factors 6. Socioeconomic disparities in the Nigerian context further heighten the vulnerability of both patients and practitioners to medico-legal conflicts.

Medical education is expected to play a pivotal role in addressing these challenges. However, significant gaps in medico-legal training persist, potentially leaving graduates ill-prepared for the realities of clinical practice. In sub-Saharan Africa, including Nigeria, undergraduate curricula often provide limited comprehensive education in ethics and law. This results in deficiencies in students' ability to recognise and manage common ethical dilemmas, such as discharge against medical advice or conflicts involving religious beliefs [7,8]. Without structured integration of medico-legal principles, medical training may fail to foster the holistic competencies required for safe, resilient, and ethically sound professional practice in diverse and often resource-limited settings.

From an international perspective, evidence suggests that integrating medico-legal training into medical curricula can meaningfully improve outcomes. Studies in countries such as Romania and the United States have shown that scenario-based and structured medico-legal education enhances ethical reasoning, strengthens patient advocacy, and reduces malpractice risks [9,10]. In contrast, regions with weaker integration of these topics, particularly parts of Africa, continue to report persistent deficiencies, highlighting the urgent need for curriculum reform [11]. These global insights indicate that adopting more robust medico-legal training strategies could yield substantial improvements in student preparedness, especially in resource-limited settings where adaptive and contextually relevant education is essential.

Final-year medical students represent an ideal cohort for examining these issues. As they stand at the threshold of independent practice, they frequently encounter complex scenarios that demand the integration of clinical acumen with ethical judgment and legal awareness. Their proximity to graduation provides a valuable opportunity to assess the cumulative impact of current undergraduate training on their readiness to meet the demands of professional life [12]. In today's evolving clinical environment, these soon-to-be doctors must navigate diagnostic uncertainty as well as significant ethical obligations and legal accountability. Understanding how exposure to medico-legal training, ethical reasoning, and risk assessment intersect to shape their clinical decision-making is therefore essential for preparing future practitioners for safe, ethical, and legally defensible practice.

Despite the growing emphasis on patient rights, professional accountability, and legal oversight in healthcare, there remains limited empirical evidence on how final-year medical students in Southwest Nigeria integrate medico-legal considerations, ethical reasoning, and risk assessment into their clinical decisions. While global systematic reviews highlight the benefits of integrated curricula, region-specific studies in this context are scarce [14,15]. This deficiency of local data hinders the development of tailored educational strategies capable of addressing Nigeria's unique cultural, systemic, and resource-related challenges. The resulting gaps have important implications for clinical practice and patient safety, potentially contributing to increased adverse events, higher litigation rates, and suboptimal preparedness among graduates [16].

This study is therefore justified by the urgent need to generate context-specific evidence on the current state of medico-legal training in Southwest Nigerian medical schools and its association with students' ethical reasoning and risk assessment abilities. By addressing this gap, the research aims to provide actionable insights that can inform curriculum enhancement, reduce clinical errors, and lower litigation risks, in line with global recommendations for strengthening ethics and law in medical education [17-20]. The aim of this study was to assess the association between medico-legal training and competency in ethical reasoning and risk assessment among final-year medical students in Southwest Nigeria.

Specific objectives were to:

1. Describe the type and frequency of exposure to medico-legal training among final-year medical students in Southwest Nigeria.

2. Assess the level of ethical reasoning and its association with medico-legal training **exposure**.
3. Examine the associations between medico-legal training (type and frequency) and students' risk assessment competencies.
4. Evaluate students' perceptions of the adequacy and effectiveness of medico-legal training.
5. Explore how demographic and contextual factors (e.g., age, gender, institution type, and prior clinical experience) moderate these associations.

This study focused on final-year medical students in selected universities in Southwest Nigeria, with data collected during the 2025/2026 academic session. It examined formal medico-legal training components within undergraduate curricula to provide a targeted assessment of pre-graduation preparedness.

METHODS

Study Design

This study employed a descriptive cross-sectional design utilizing quantitative methods to evaluate the association between medico-legal training and competencies in ethical reasoning and risk assessment among final-year medical students in Southwest Nigeria. Primary data was collected through the use of structured questionnaires.

Study Area and Population

The study was conducted in Southwest Nigeria, a region comprising six states (Lagos, Oyo, Ogun, Osun, Ondo, and Ekiti). This zone is one of the most urbanised and educationally advanced parts of the country and hosts several Medical and Dental Council of Nigeria (MDCN)-accredited medical schools offering the Bachelor of Medicine, Bachelor of Surgery (MB;BS) programme. Thirteen universities were included in the study: University of Ibadan, Ladoke Akintola University of Technology (LAUTECH), Bowen University, University of Lagos, Lagos State University College of Medicine, Eko University of Medical Sciences (Eko UNIMED), Olabisi Onabanjo University (OOU), Babcock University, Obafemi Awolowo University (OAU), Osun State University, Ekiti State University (EKSU), Afe Babalola University (ABUAD), and University of Medical Sciences, Ondo (UNIMED). These institutions represent a mix of federal, state-owned, and private universities, providing diversity in institutional contexts, resources, and student populations. The region's heterogeneous cultural and socioeconomic characteristics offered an opportunity to capture varied perspectives on ethical reasoning and risk assessment among medical trainees.

The study population comprised final-year medical students enrolled in the selected accredited medical schools in Southwest Nigeria. These students had completed their core clinical rotations and were at a critical stage of training, preparing for independent practice.

Sample Size and Sampling Technique

The sample size for this study was determined using Cochran's formula for estimating proportions in descriptive cross-sectional studies. A total of 157 final year medical students participated in the study.

A multicentre cross-sectional study design was employed. Participants were recruited using a combination of convenience and voluntary response sampling. Final-year students from the selected institutions were invited through official class communication platforms, institutional mailing lists, and in-person sessions where permitted. All eligible students who provided informed consent were included consecutively until the desired sample size was reached.

Data Collection

Data were collected using a self-administered structured questionnaire developed after reviewing relevant literature, adaptation of validated scales, and contextual refinement for the Nigerian medical education setting. The instrument was organised into five sections corresponding to the core study domains: Socio-demographic Characteristics (age, gender, institution of study); Exposure to Medico-Legal Training and Knowledge; Ethical Reasoning Assessment; Risk Assessment and Clinical Decision-Making; and Perceptions of Training Adequacy and Effectiveness.

Before deployment, the questionnaire was validated via review by experts in public health, medical law and research methodology and reliability ensured following a pre-test for the study. Internal consistency reliability of the scales was assessed using Cronbach's alpha: Ethical Reasoning scale (α = 0.82), Risk Assessment scale (α = 0.79), and Perception of Training scale (α = 0.85).

Scoring for the Likert-scale items was based on a 5-point scale (1 = Strongly Disagree to 5 = Strongly Agree), with vignette items scored dichotomously (correct = 1, incorrect = 0). Adequate competency was operationally defined as achieving ≥70% of the maximum possible score based on expert consensus.

Data Analysis

Data was analyzed using Statistical Package for the Social Sciences (SPSS) version 27. Microsoft Excel 2016 was used for initial data cleaning, coding, and verification before import. The dataset was screened for completeness, outliers, and entry inconsistencies. Cases with substantial missing data were excluded from inferential analyses, while minor missing responses were handled using pairwise deletion to preserve statistical power.

Descriptive statistics were used to summarise demographics, training exposure, ethical reasoning levels, and perceptions using frequencies, means, standard deviations, and percentages. Inferential statistics: Pearson correlations were used to examine bivariate associations. Multiple linear regression was performed with medico-legal training exposure/reinforcement as the predictor variable and ethical reasoning and risk assessment scores as outcome variables. Model fit was assessed using R^2 and adjusted R^2. The level of significance was set at $p < 0.05$.

Ethical Considerations

The study received ethical approval from the UNIMEDTH Research Ethics Committee, with ethical approval number: UNIMED-HREC/Apv/2026/635.

Informed consent was obtained electronically from all participants before filling of the questionnaire coupled with a standardised information sheet outlined the study purpose, procedures, duration, and voluntary nature of participation. Participants were informed of their right to decline or withdraw at any stage without consequence. All data was anonymized and stored securely. Participation was entirely voluntary, with no incentives offered.

RESULTS

A total of 157 final year medical students completed the questionnaire, with responses obtained from thirteen MDCN-accredited institutions across Southwest Nigeria. The highest participation came from the University of Medical Sciences, Ondo (26.1%), followed by Afe Babalola University, Ado-Ekiti (21.7%) and Bowen University (15.3%).

The mean age of participants was 24.03 ± 2.11 years. Females constituted the majority (65.6%, n=103), while males accounted for 34.4% (n=54). Table 1 shows the detailed sociodemographic characteristics of the respondents.

Table 1: Sociodemographic characteristics of respondents

Variable (N=157)	Category/Summary	N (%) / Mean± SD
Age (years)	Mean ± SD	24.03±2.11
Gender	Male	54 (34.4%)
	Female	103 (65.6%)
Institution of Study	University of Lagos (UNILAG)	7 (4.5%)
	Lagos State University	3 (1.9%)
	Eko University of Medical Sciences (EKO UNIMED)	5 (3.2%)
	Olabisi Onabanjo University	10 (6.4%)
	Babcock University	5 (3.2%)
	University of Medical Sciences, Ondo State	41 (26.1%)
	Obafemi Awolowo University, Ile-Ife, OAU	3 (1.9%)
	Osun State University (UNIOSUN)	9 (5.7%)
	University of Ibadan	3 (1.9%)
	Ladoke Akintola University of Technology (LAUTECH)	2 (1.3%)
	Bowen University	24 (15.3%)
	Afe Babalola University Ado-Ekiti (ABUAD)	34 (21.7%)
	Ekiti State University (EKSU)	11 (7.0%)

EXPOSURE TO MEDICO-LEGAL TRAINING

Of the 157 respondents, 116 (73.9%) reported having received some form of medico-legal training, while 41 (26.1%) had not. Among those who received training (n=116), reinforcement during clinical rotations was reported as "sometimes" or "often" by 74.2% of participants. The most common type of training was school-based lectures (58.3%), followed by case-based discussions (26.0%).

Table 2: Exposure to Medicolegal Training

Variable	Category/Summary	N (%) / Mean± SD
Medicolegal Training	Yes	116 (73.9%)
	No	41 (26.1%)
Frequency of medicolegal reinforcement during clinical rotations	Never	1 (0.9%)
	Rarely	8 (6.9%)
	Sometimes	43 (37.1%)
	Often	43 (37.1%)
	Very often	21 (18.1%)
Type of Medicolegal Training received	Case-based discussions	50 (26.0%)
	Clinical risk management sessions	16 (8.3%)
	Ethics committee participation	5 (2.6%)
	Mock trials/courtroom simulation	2 (1.0%)
	Online modules	7 (3.6%)
	School-based lectures	112 (58.3%)

ETHICAL REASONING

Among the 116 students who had received medico-legal training, self-reported ethical reasoning was generally positive. Over 70% agreed or strongly agreed that they could readily identify ethical dilemmas and recognise issues with both ethical and legal implications. However, only 43.1% agreed or strongly agreed that they would disclose a medical error even if it might have legal consequences.

Table 3: Ethical Reasoning Self-Assessment

VARIABLE (n=116)	STRONGLY DISAGREE (%)	DISAGREE (%)	NEUTRAL (%)	AGREE (%)	STRONGLY AGREE (%)
Can readily identify ethical dilemmas in clinical settings	3 (2.6%)	2 (1.7%)	27 (23.3%)	66 (56.9%)	18 (15.5%)
Can recognize when a clinical issue has both ethical and legal implications.	3 (2.6%)	1 (0.9%)	20 (17.2%)	71 (61.2%)	21 (18.1%)
Feels confident applying ethical frameworks [e.g., autonomy, beneficence, justice, non-maleficence] in clinical situations.	3 (2.6%)	2 (1.72%)	27 (23.3%)	69 (59.5%)	15 (12.9%)
Comfortable balancing patient autonomy with legal obligations.	3 (2.6%)	6 (5.2%)	33 (28.4%)	63 (54.3%)	11 (9.5%)
Would disclose a medical error even if it might have legal consequences	7 (6.0%)	6 (5.2%)	53 (45.7%)	38 (32.8%)	12 (10.3%)

In the clinical vignette assessment, 69.0% chose the correct initial action regarding a patient refusing life-saving blood transfusion on religious grounds, 94.0% responded appropriately to a non-disclosure request of HIV status, and 81.9% gave the correct response to an unreported colleague medication error. The mean ethical reasoning score was 21.06 ± 3.40 (out of a possible maximum score).

Table 3.1: Ethical Reasoning Clinical Vignette

VARIABLE (n=116)	CORRECT (%)	INCORRECT (%)
Appropriateness of initial clinical action in response to a patient refusing a life-saving blood transfusion for religious reasons	80 (69.0%)	36 (31.0%)
Appropriate response to a disclosure decision when a patient requests non-disclosure of HIV status to a spouse	109 (94.0%)	7 (6.0%)
Appropriate response to an unreported colleague medication error with potential patient harm	95 (81.9%)	21 (18.1%)

RISK ASSESSMENT IN CLINICAL DECISION-MAKING

Participants demonstrated good self-perceived risk assessment practices. The majority agreed or strongly agreed that medico-legal training had improved their awareness of risks (82.8%), influenced their management of high-risk cases (77.6%), and encouraged thorough clinical documentation (82.8%). The mean risk assessment score was 27.29 ± 4.86.

Table 4: Risk Assessment in Clinical Decision Making

VARIABLE (n=116)	STRONGLY DISAGREE (%)	DISAGREE (%)	NEUTRAL (%)	AGREE (%)	STRONGLY AGREE (%)
Improved awareness of medico-legal risks in clinical practice following training	3(2.6%)	1(0.9%)	16(13.8%)	59(50.9%)	37(31.9%)
Consideration of potential legal consequences in clinical decision-making	3(2.6%)	2(1.7%)	20(17.2%)	61(52.6%)	30(25.9%)
Influence of medico-legal knowledge on management of high-risk cases	3(2.6%)	1(0.9%)	22(18.9%)	61(52.6%)	29(25%)
Thorough clinical documentation driven by awareness of legal risk	2(1.7%)	2(1.7%)	16(13.8%)	56(48.3%)	40(34.5%)
Perceived impact of fear of litigation on clinical judgment	8(6.9%)	11(9.5%)	39(33.6%)	47(40.5%)	11(9.5%)
Escalation of uncertain cases to a supervisor due to medico-legal concerns	3(2.6%)	4 (3.5%)	40(34.5%)	47(40.5%)	22(18.9%)

Adherence to Medical and Dental Council of Nigeria guidelines in managing high-risk cases	3(2.6%)	1(0.9%)	17(14.7%)	57(49.1%)	38(32.8%)

PERCEPTION OF MEDICO-LEGAL TRAINING

Students held largely positive perceptions of the training they received. Over 70% agreed or strongly agreed that the training was adequate for preparing them for ethical dilemmas, relevant to real-life clinical practice, and had improved their clinical risk assessment. A strong majority (86.3%) expressed the need for increased medico-legal teaching in the undergraduate curriculum, and 78.4% preferred more structured and practical (case-based) teaching over lectures alone. The mean perception score was 27.74 ± 5.35.

Table 5: Perception of Training Advocacy

VARIABLES (n=116)	STRONGLY DISAGREE (%)	DISAGREE (%)	NEUTRAL (%)	AGREE (%)	STRONGLY AGREE (%)
Perceived adequacy of medico-legal training in preparing for ethical dilemmas.	4 (3.5%)	3 (2.6%)	26 (22.4%)	63 (54.3%)	20 (17.2%)
Improvement in clinical risk assessment following medico-legal training.	3 (2.6%)	2 (1.72%)	25 (21.6%)	62 (53.5%)	24 (20.7%)
Relevance of medico-legal training to real-life clinical practice.	5 (4.3%)	0 (0%)	18 (15.5%)	63 (54.3%)	30 (25.9%)
Perceived legal protection associated with medico-legal training.	5 (4.3%)	6 (5.2%)	39 (33.6%)	50 (43.1%)	16 (13.8%)
Need for increased medico-legal teaching in the medical curriculum.	3 (2.6%)	1 (0.9%)	12 (10.3%)	46 (39.7%)	54 (46.6%)
Perceived effectiveness of practical case-based teaching compared to lectures alone.	5 (4.3%)	2 (1.7%)	18 (15.5%)	40 (34.5%)	51 (43.9%)
Preference for more structured medico-legal education prior to graduation.	4 (3.5%)	4 (3.5%)	16 (13.8%)	40 (34.5%)	52 (44.8%)

BIVARIATE ANALYSIS

Cross-tabulations were performed to examine associations between ethical reasoning and medicolegal training, risk assessment and medicolegal training, and between perception and medical training. Pearson correlation and corresponding p-values are reported for each analysis.

Bivariate analysis using Pearson correlation revealed no statistically significant association between self-rated depth of medico-legal training and ethical reasoning score ($r = 0.151$, $p = 0.105$) or risk assessment score ($r = 0.075$, $p = 0.426$).

However, there was a strong positive correlation between ethical reasoning and risk assessment scores ($r = 0.761$, $p < 0.001$). Perception of training also showed moderate positive correlations with both risk assessment ($r = 0.576$, $p < 0.001$) and ethical reasoning ($r = 0.415$, $p < 0.001$).

Table 6: Associations between medicolegal training and independent variables

Variable		Self-rated depth of training	risk_assessment	ethical_reasoning	perception
Self-rated depth of training	Pearson Correlation	1	.075	.151	.151
	Sig. (2-tailed)		.426	.105	.105
	N	116	116	116	116
risk_assessment score	Pearson Correlation	.075	1	.761**	.576**
	Sig. (2-tailed)	.426		.000	.000
	N	116	116	116	116
ethical_reasoning score	Pearson Correlation	.151	.761**	1	.415**
	Sig. (2-tailed)	.105	.000		.000
	N	116	116	116	116
Perception score	Pearson Correlation	.151	.576**	.415**	1
	Sig. (2-tailed)	.105	.000	.000	
	N	116	116	116	116

**. Correlation is significant at the 0.01 level (2-tailed).

MULTIVARIATE ANALYSIS

Multiple linear regression was conducted to determine whether risk assessment, ethical reasoning, and perception scores independently predicted the frequency with which medico-legal principles were reinforced during clinical rotations. The analysis showed that none of the independent variables were statistically significant predictors in the model ($p > 0.05$). A small positive association was nevertheless noted between risk assessment score and frequency of reinforcement ($\beta = 0.116$, $p = 0.473$), while ethical reasoning and perception scores showed negligible effects ($\beta = 0.004$ for both).

Table 7: Predictors of efficacy of medicolegal training

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.030	.574		5.275	.000
	risk_assessment	.021	.029	.116	.720	.473
	ethical_reasoning	.001	.038	.004	.027	.978
	perception	.001	.019	.004	.033	.974

DISCUSSION

This study evaluated the association between medico-legal training exposure and competencies in ethical reasoning and risk assessment among final-year medical students in Southwest Nigeria, offering important empirical evidence in a context where such data are scarce. While a substantial proportion of participants (73.9%) reported exposure to medico-legal training, the findings revealed only weak and non-significant associations between training exposure and both ethical reasoning ($r = 0.151$, $p = 0.105$) and risk assessment ($r = 0.075$, $p = 0.426$). These results suggest that current training approaches may have limited impact on developing these critical competencies.

The predominance of lecture-based teaching (58.3%), with limited use of case-based discussions (26.0%), may explain the weak associations observed. This aligns with educational theory, which suggests that didactic approaches alone are insufficient for developing higher-order cognitive skills such as ethical reasoning and clinical judgment 21,22. Studies have shown that experiential and problem-based learning approaches are more effective in fostering critical thinking and decision-making in complex clinical scenarios. [23,24]

Despite widespread exposure to medico-legal training (73.9%) and largely positive perceptions (>70%), the absence of statistically significant associations between training depth and both ethical reasoning ($r = 0.151$, $p = 0.105$) and risk assessment ($r = 0.075$, $p = 0.426$) raises concerns about the effectiveness of current training models. This apparent contradiction may be explained by differences in the quality versus quantity of training received, possible ceiling effects in self-reported competency measures, and the influence of self-report bias. This finding suggests that exposure alone may not strongly translate into competence, supporting previous research indicating that knowledge acquisition does not necessarily predict ethical performance in clinical practice [25,26].

It highlights the need for more structured, competency-based training that emphasizes application rather than theoretical understanding. Nevertheless, the relatively high mean scores for ethical reasoning (21.06 ± 3.40) and risk assessment (27.29 ± 4.86) indicate that students possess a foundational level of competence. The vignette-based responses further support this, with high correct response rates in scenarios involving HIV disclosure (94.0%) and management of colleague error (81.9%). These findings suggest that students are more comfortable handling structured ethical dilemmas, likely due to repeated exposure during training. However, the relatively low willingness to disclose medical errors in the face of potential legal consequences (43.1%) reveals a critical gap. This reluctance likely stems from fear of litigation, a prevailing "culture of blame" in healthcare, limited emphasis on psychological safety during training, and broader cultural and systemic factors in the Nigerian context [27,28].

A key finding of this study is the strong positive correlation between ethical reasoning and risk assessment ($r = 0.761$, $p < 0.001$). This suggests considerable conceptual overlap between the two constructs, which is theoretically expected given that ethical competence forms the foundation for safe and responsible clinical decision-making [29]. However, this high correlation also raises the possibility of measurement redundancy, and future studies may benefit from more distinct instruments to differentiate these domains. The moderate correlations between perception of training and both risk assessment ($r = 0.576$, $p < 0.001$) and ethical reasoning ($r = 0.415$, $p < 0.001$) further emphasize the importance of learner engagement. Students who perceive training as relevant and practical are more likely to internalize medico-legal principles. This is consistent with adult learning theory, which emphasizes the role of perceived relevance in knowledge retention and application 30. The strong preference for more structured and case-based teaching (78.4%) reinforces the need to redesign curricula to align with student expectations and learning needs.

Interestingly, the regression analysis indicated that ethical reasoning, risk assessment, and perception did not significantly predict the frequency of medico-legal reinforcement during clinical rotations. This suggests that reinforcement in clinical settings may be inconsistent or inadequately structured. The theory–practice gap remains a persistent challenge in medical education, where knowledge acquired in classrooms is not always effectively translated into clinical behavior 31. Without deliberate integration of medico-legal principles into clinical supervision, students may struggle to apply theoretical knowledge in real-world situations.

From a policy perspective, these findings underscore the need for curriculum standardization across Nigerian medical schools, particularly under the oversight of the Medical and Dental Council of Nigeria. Standardization would ensure consistency in training quality and expected competencies. Furthermore, there is a need to transition from passive to active learning strategies, incorporating simulation, interdisciplinary teaching, and reflective practice. Longitudinal integration of

medico-legal education throughout medical training, rather than isolated modules, may also improve retention and application.

This study has several limitations. The cross-sectional design limits causal inference and the use of self-reported measures introduce the possibility of social desirability bias. Additionally, although multiple institutions were included, the findings may not be generalizable to all regions of Nigeria due to convenience sampling and overrepresentation from certain institutions such as UNIMED (26.1%) and ABUAD (21.7%). Future studies should adopt longitudinal or interventional designs, objective assessments (e.g., OSCEs), and more representative sampling to better evaluate medico-legal competence.

CONCLUSION

This study demonstrates that although medico-legal training exposure among final-year medical students in Southwest Nigeria is relatively common, the current mode of delivery remains largely passive and may not be sufficient to produce the desired level of ethical reasoning and risk assessment competencies required for safe clinical practice. The positive correlations observed between ethical reasoning, risk assessment, and medico-legal perception suggest that these domains are closely interrelated and that strengthening one may reinforce the others [2,3]. However, the weak and non-significant associations between training depth and both ethical reasoning and perception indicates that mere exposure, without structured and interactive pedagogy, is unlikely to translate into meaningful competence [2].

These findings are consistent with earlier Nigerian studies showing that medical students desire formal ethics education and often report inadequate exposure within the undergraduate curriculum 3,1. They also align with broader evidence that legal and ethical teaching is most effective when delivered through scenario-based learning, small-group discussion, simulation, and other active methods rather than didactic teaching alone [2]. In a setting such as Nigeria, where medical litigation, patient rights awareness, and ethical complexity are increasing, medico-legal education should be deliberately integrated into the medical curriculum as a longitudinal, competency-based component rather than an occasional or peripheral topic [2,4].

Accordingly, medical schools, regulators, and curriculum planners should prioritize standardized medico-legal content, practical case-based instruction, and assessment strategies that test real decision-making capacity. Such reform will better prepare future doctors to respond ethically, assess clinical risk more accurately, and make legally defensible decisions in routine practice [2,3].

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APPENDIX I: INFORMED CONSENT FORM

TITLE OF STUDY: Medico-Legal Training and Competency in Ethical Reasoning and Risk Assessment among Final Year Medical Students in Southwest, Nigeria

FINANCIAL SPONSORSHIP: This research is self-sponsored.

PURPOSE OF THE RESEARCH: This study aims to evaluate the impact of medico-legal training on ethical reasoning and risk assessment in clinical decision-making among final-year medical students in Southwest Nigeria.

PROCEDURES INVOLVED: You will be asked to complete a structured questionnaire. The process will take approximately 10 minutes. No personal identifiers will be collected, and your responses will be used solely for research purposes.

RISKS: There is little to no risk involved in participating in this study.

BENEFITS: While there may be no direct benefit to you, your input will contribute to improved Medico-legal training and clinical decision-making skills amongst near-independent doctors in Nigeria. The findings may influence future health policies and promote more effective and robust medico-legal curriculum.

CONFIDENTIALITY: All information collected in this study will be kept strictly confidential. No names or personal identifiers will be used or published.

COMPENSATION:

There shall be no financial compensation for participating in this study.

VOLUNTARY PARTICIPATION: Participation in this study is entirely voluntary. You are free to decline participation or withdraw at any point without any consequence or loss of benefits to which you are otherwise entitled. Your choice will not affect you in any way.

CONTACT INFORMATION: For further inquiries or complaints, please contact:

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CERTIFICATE OF CONSENT: I certify that I have been adequately informed about the research, including the purpose, procedures, risks, and potential benefits. I voluntarily give permission to participate in this study.

APPENDIX II: QUESTIONNAIRE

TITLE: MEDICO-LEGAL TRAINING AND COMPETENCY IN ETHICAL REASONING AND RISK ASSESSMENT AMONG FINAL YEAR MEDICAL STUDENTS IN SOUTHWEST, NIGERIA

Dear Respondent,

Thank you for participating in this primary study titled "Medico-Legal Training and Competency in Ethical Reasoning and Risk Assessment among Final Year Medical Students in Southwest, Nigeria." This questionnaire aims to evaluate the impact of medico-legal training on ethical reasoning and risk assessment in clinical decision-making among final-year medical students in Southwest Nigeria. The insights will contribute to understanding how medico-legal training enhances legal consciousness and clinical decision-making skills in future doctors.

Your responses are voluntary, anonymous, and confidential. No personal identifying information will be collected, and data will be used solely for research purposes. The questionnaire should take approximately 10-15 minutes to complete. If you feel uncomfortable with any question, you may skip it.

By proceeding, you provide informed consent to participate.

SECTION A: SOCIO-DEMOGRAPHIC CHARACTERISTICS

1. Age (as at last birthday) _____
2. Gender: Male [ ] Female [ ]
3. Institution of study:

[ ] University of Ibadan
[ ] Ladoke Akintola University of Technology, LAUTECH
[ ]Bowen University
[ ] University of Lagos
[ ] Lagos State University College of Medicine
[ ] Eko University of Medical Sciences, Eko UNIMED

[ ] Olabisi Onabanjo University, OOU
[ ] Babcock University, Ilishan-remo, Ogun State
[ ] Obafemi Awolowo University, Ile-Ife, OAU
[ ] Osun State University
[ ] Ekiti State University, EKSU
[ ] Afe Babalola University, Ado-Ekiti (ABUAD)
[ ] University of Medical Sciences, Ondo (State)

SECTION B: EXPOSURE TO MEDICO-LEGAL TRAINING AND KNOWLEDGE

4. Have you had any training on medico legal? Yes [ ] No [ ]
5. What type of medico legal training did you receive? [SELECT ALL THAT APPLIES]

[ ] School-based lectures
[ ] Case-based discussions
[ ] Mock trials / courtroom simulations
[ ] Ethics committee participation
[ ] Clinical risk management sessions
[ ] Online modules

6. How frequently were medico-legal principles reinforced during clinical rotations?

Never [ ] Rarely [ ] Sometimes [ ] Often [ ] Very Often [ ]

7. Self-rated depth of training [scale of 1-10]

Part B: Medico-legal Knowledge. Choose the option you think is correct

8. A valid informed consent requires

Patient signature only [ ] Disclosure of risks, benefits, and alternatives, with voluntary agreement [ ] Family approval [ ] Documentation by nursing staff [ ]

9. To establish medical negligence, it must be shown that:

The patient had a poor outcome [ ] The doctor breached a duty of care and caused harm [ ] The patient was unhappy [ ] Documentation was incomplete [ ]

10. The legal "standard of care" is generally determined by: The personal opinion of the treating physician [ ] Hospital policy only [ ] What a reasonably competent physician would do in similar circumstances [ ] Patient expectations [ ]
11. A physician may breach patient confidentiality WITHOUT consent when:

The doctor feels it is necessary [ ] There is a legal obligation to report certain conditions [ ] The information is useful for teaching [ ] The family asks for details [ ]

12. A patient has decision-making capacity if they can:

Agree with the doctor [ ] Understand, appreciate, reason, and communicate a choice [ ] Sign a document [ ] Speak clearly [ ]

13. Which statement regarding clinical documentation is TRUE?

Documentation can be altered later if necessary [ ] If it was not documented, it is presumed not to have occurred [ ] Verbal communication replaces written records [ ] Documentation is optional in low-risk cases [ ]

14. Which of the following are attributes of medical professionalism?

Honesty and integrity [ ] Personal responsibility [ ] Commitment to learning [ ] All of the above [ ]

SECTION C: ETHICAL REASONING SELF ASSESSMENT

Ethical reasoning is the process of thinking carefully about what the right thing is to do when faced with a difficult or morally complex situation.

Mark the box that most nearly describes your response

QUESTIONS	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE
15. I can readily identify ethical dilemmas in clinical settings					

16. I can recognize when a clinical issue has both ethical and legal implications.					
17. I feel confident applying ethical frameworks [e.g., autonomy, beneficence, justice, non-maleficence] in clinical situations.					
18. I am comfortable balancing patient autonomy with legal obligations.					
19. I would disclose a medical error even if it might have legal consequences					

20. A patient refuses a life-saving blood transfusion for religious reasons. The most appropriate initial action is: Respect the patient's autonomy after assessing competence [ ] Proceed with transfusion regardless of refusal [ ] Get a court order before life-saving transfusion [ ] Transfer care without explanation [ ]
21. A patient asks you not to tell their spouse about an HIV diagnosis. What should guide your decision? Personal opinion [ ] Nigerian public health laws and ethical guidelines [ ] Pressure from family [ ] Fear of legal action [ ]
22. You notice a colleague has made a medication error that could harm a patient but has not reported it. What is the most appropriate action? Ignore it [ ] Report to the clinical supervisor according to MDCN reporting guidelines [ ] Confront the colleague publicly [ ] Correct the mistake secretly without informing anyone [ ]

SECTION D: RISK ASSESSMENT IN CLINICAL DECISION MAKING
Mark the box that most describes your response as a near independent doctor

QUESTIONS	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE
23. The training improved my awareness of medico-legal risks in clinical practice.					
24. I consider potential legal consequences when making clinical decisions					
25. Medico-legal knowledge influences how I manage high-risk cases.					
26. I document thoroughly due to awareness of legal risk.					
27. Fear of litigation may affect my clinical judgment.					
28. I would escalate uncertain cases to a supervisor due to medico-legal concerns.					
29. I will follow MDCN guidelines to manage high-risk cases safely.					

SECTION E: PERCEPTION OF TRAINING ADEQUACY
Mark the box that most nearly describes your response

QUESTIONS	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE
30. My medico-legal training adequately prepares me for ethical dilemmas.					
31. The training improved my ability to assess clinical risk.					
32. The training was relevant to real-life clinical practice					
33. I feel more legally protected because of my training.					
34. More medico-legal teaching should be included in the curriculum.					
35. Practical case-based teaching was more helpful than lectures alone.					
36. I would like more structured medico-legal education before graduation.					

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Preoperative Electrocardiographic Findings and Their Impact on Clinical Decision-Making Among Patients Undergoing Cataract Surgery: A Retrospective Audit

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ABSTRACT

Background: During preoperative evaluation, electrocardiograms (ECGs) are commonly used to detect cardiovascular abnormalities that could affect perioperative care. In many outpatient settings, however, the clinical importance of ECG abnormalities and their influence on patient trajectories are still not well understood. In patients undergoing cataract surgery, this audit assessed the frequency of aberrant ECG results and their impact on clinical decision-making.

Aim: To evaluate ECG findings in patients undergoing preoperative assessment and determine their impact on clinical decision-making and patient flow.

Methods: Anonymized patient data from those who underwent outpatient preoperative evaluation for unilateral cataract surgery with intraocular lens (IOL) insertion between May 7 & July 23, 2024, were used in a retrospective observational clinical audit. The ECG results and patient characteristics were summarized using descriptive statistics. Kruskal-Wallis & Fisher's exact tests were utilised to evaluate correlations between clinical factors and ECG outcomes. To find independent predictors of aberrant ECG readings, multivariable logistic regression was used.

Results: There were 247 patients in all. 55% of the population was female & the median age was 76 years (IQR 70-81). ECG results were categorized as normal in 21% (n = 51), borderline in 31% (n = 76), and abnormal in 49% (n = 120). Conduction abnormalities were the most common abnormal ECG subtype (53%, n = 64), followed by arrhythmias (32%, n = 39), left ventricular hypertrophy (7%, n = 8), and ischaemic changes (2%, n = 3). Age (OR 1.04; 95% CI 1.00-1.07; p = 0.034), diabetes (OR 2.63; 95% CI 1.32-5.41; p = 0.007) & prior cardiac history (OR 3.16; 95% CI 1.62-6.39; p < 0.001) were independently linked with aberrant ECG readings. In 89% of cases, patients were referred for additional anaesthesia review. Despite the high prevalence of ECG abnormalities, procedure delays (2.4%), cancellations (1.6%), and overall route interruption (2.8%) were rare.

Conclusion: Abnormal ECG findings are common among patients undergoing preoperative assessment for cataract surgery, particularly in older individuals and those with diabetes mellitus or established cardiac disease. However, these abnormalities rarely resulted in procedural delays or cancellations. These findings support the need for evidence-based ECG utilisation strategies that optimise patient flow while maintaining patient safety.

Keywords: *Preoperative assessment; electrocardiography; ECG; cataract surgery; clinical audit; patient flow; cardiovascular risk assessment; ophthalmic surgery; perioperative care*

INTRODUCTION

Preoperative assessment is a fundamental component of modern perioperative care and serves as a critical opportunity to identify patient-specific factors that may influence surgical, anaesthetic, and postoperative outcomes. The primary objectives of preoperative evaluation are to optimise patients for surgery, minimize perioperative risk, facilitate appropriate planning of anaesthetic care, and reduce avoidable delays or cancellations. Effective preoperative assessment has been associated with improved patient safety, enhanced perioperative efficiency, reduced healthcare costs, and better utilization of clinical resources (NICE, 2016).

Cardiovascular disease is one of the top causes of perioperative morbidity and mortality around the world. As a result, cardiovascular assessment is an important part of normal preoperative evaluation, especially in older adults & patients with established comorbidities. Electrocardiography (ECG) is one of the most used investigations in this context because it is non-invasive, inexpensive, widely available, and capable of detecting a wide range of cardiac abnormalities, including arrhythmias, myocardial ischemia, conduction disturbances, chamber enlargement, and evidence of previous myocardial infarction (Fleisher et al., 2024).

Historically, ECGs were frequently requested as part of standard preoperative assessment protocols irrespective of patient risk profile or procedural complexity. This practice was largely driven by concerns regarding occult cardiovascular disease and the desire to minimize unexpected perioperative complications. However, over recent decades, increasing attention has been directed towards the clinical utility, cost-effectiveness, and downstream consequences of routine preoperative investigations. Several studies have questioned whether widespread ECG testing in low-risk surgical populations provides meaningful clinical benefit, particularly when findings do not alter perioperative management or improve patient outcomes (NICE, 2016; Fleisher et al., 2024).

Many abnormalities found on standard screening may be accidental or clinically inconsequential, which further complicates the efficacy of preoperative ECG testing. Many ECG abnormalities do not lead to clinically significant interventions, while some findings, such as atrial fibrillation, high-grade conduction abnormalities, or indications of active myocardial ischaemia, may correctly elicit additional assessment or adjustment of perioperative preparations. Therefore, without comparable gains in patient safety or surgical outcomes, frequent ECG screening may result in needless investigations, specialist referrals, procedural delays, increased healthcare spending, and patient anxiety (Ganguli et al., 2019).

Determining which patients benefit from preoperative ECG testing and how ECG results affect clinical decision-making within modern surgical pathways is becoming increasingly important as healthcare systems adopt value-based care models and work to cut down on pointless investigations. Therefore, it is crucial to comprehend the frequency and importance of ECG anomalies within patient categories to optimize resource use and influence evidence-based preoperative assessment techniques.

BACKGROUND

A selective rather than standard approach to preoperative ECG testing is becoming more and more supported by international recommendations. Instead of being routinely carried out for all elective surgical patients, the National Institute for Health and Care Excellence (NICE) recommends that preoperative examinations be guided by patient characteristics, existing comorbidities, and the intricacy of the anticipated therapy (NICE, 2016). Similar to this, current perioperative cardiovascular regulations from the American Heart Association (AHA) and American College of Cardiology (ACC) discourage needless testing in patients undergoing low-risk procedures where the results are unlikely to affect management and encourage risk-based assessment strategies (Fleisher et al., 2024).

Cataract surgery provides an important context for examining the utility of preoperative ECG testing. Cataract extraction with intraocular lens (IOL) implantation is among the most commonly performed elective surgical procedures worldwide and is generally regarded as a low-risk intervention. Most procedures are undertaken under local or regional anaesthesia, are completed on a day-case basis, and are associated with extremely low rates of major perioperative cardiovascular complications. Given these characteristics, cataract surgery has frequently been used as a model procedure in studies evaluating the necessity and impact of routine preoperative testing (Lira et al., 2016).

Previous research indicates that standard preoperative evaluation, including ECG monitoring, may have a minimal impact on clinically meaningful outcomes in groups undergoing cataract surgery. In a retrospective cohort analysis with 968 patients undergoing cataract surgery, Lira et al. (2016) identified no significant perioperative cardiovascular events and discovered that, despite longer wait times for surgery, outpatient preoperative screening did not significantly reduce unfavorable outcomes. Perioperative hypertension episodes decreased in examined patients, but these decreases did not result in appreciable improvements in surgical or medical outcomes. The clinical utility of routine investigations in low-risk surgical groups is called into question by these findings.

In addition to concerns regarding clinical effectiveness, growing attention has been directed towards the concept of low-value care and the unintended consequences of routine testing. Preoperative ECG use among Medicare beneficiaries

undergoing cataract surgery was studied by Ganguli et al. (2019), who showed that ECG results frequently led to downstream healthcare utilization, such as additional cardiac investigations, specialist consultations, and additional treatment. At least one cascade event occurred in about 16% of patients who had preoperative ECG testing, with further cardiac testing being the most frequent outcome. According to Ganguli et al. (2019), these cascades have the potential to raise healthcare expenses, deplete scarce resources, and subject patients to more operations in the absence of conclusive proof of better results.

Despite these concerns, abnormal ECG findings remain relatively common within surgical populations, particularly among older adults and individuals with chronic medical conditions. Previous studies have reported associations between abnormal ECG findings and increasing age, hypertension, diabetes mellitus, cardiovascular disease, and other chronic comorbidities (Prakash et al., 2019). Consequently, ECG testing may continue to have an important role in identifying patients requiring additional perioperative evaluation or optimization, particularly when applied selectively according to clinical risk factors.

Nonetheless, there is still a great deal of variation in ECG usage procedures, interpretation of results, specialist referral levels, and subsequent clinical decision-making. Additionally, there is still no local data on the frequency of aberrant ECG findings found during outpatient preoperative evaluation and the degree to which these findings affect patient trajectories. In order to assess existing practice, find areas for quality improvement, and make sure that preoperative investigations significantly improve patient care, it is critical to comprehend these relationships.

Thus, a retrospective clinical audit of patients undergoing unilateral cataract surgery with intraocular lens implantation was conducted as part of the PRE-ECG Study (Preoperative ECG Evaluation and Clinical Guidance). This study aims to give information that can guide more effective, evidence-based, and patient-centred preoperative evaluation pathways by analysing the frequency and types of ECG abnormalities, the therapeutic actions generated by these findings, and their impact on patient flow.

Study Aim

To evaluate ECG findings in patients undergoing preoperative assessment and determine their impact on clinical decision-making and patient flow.

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Study Objectives

1. To describe preoperative ECG findings among patients undergoing cataract surgery.
2. To identify the frequency and types of abnormal ECG findings.
3. To assess clinical actions taken following abnormal ECG findings.
4. To evaluate the impact of ECG findings on patient pathways, including:
   - Further investigations
   - Referrals
   - Procedural delays
   - Procedure cancellations or rescheduling
5. To assess the relationship between patient characteristics and abnormal ECG findings.
6. To explore the implications of current ECG utilisation in relation to contemporary perioperative assessment practice.

Study Rationale

Preoperative investigations must be clinically justified and provide a significant contribution to patient management as healthcare systems continue to prioritize efficiency, value-based treatment, and waiting-list reduction tactics. Knowing the frequency and importance of ECG anomalies in a real-world population undergoing cataract surgery may assist in finding strategies to simplify evaluation procedures, cut down on pointless investigations, maximize resource use, and preserve patient safety. The results of this audit may also influence the creation of local policies pertaining to the use of preoperative ECGs and aid in future quality improvement projects.

METHODOLOGY

Study Design

In this study, patients who attended an outpatient preoperative evaluation service were the subject of a retrospective observational clinical audit. The audit assessed electrocardiographic (ECG) results found during regular preoperative

evaluation and looked at how they affected patient paths and clinical decision-making. The audit was conducted within a public outpatient preoperative assessment service in Ireland that provides assessment and optimisation of patients scheduled for elective ophthalmic surgery.

Since all of the data had previously been gathered as part of standard clinical care before the audit started, the study used a retrospective design. Patient management was not altered, nor were any interventions implemented. The audit was conducted in compliance with service evaluation criteria and institutional clinical audit procedures.

Study Setting

The audit was carried out in an outpatient preoperative evaluation service that assesses patients before elective eye surgery. The program conducts routine preoperative evaluations to find variables that could affect surgical planning and perioperative safety.

Every patient in this audit was scheduled for unilateral cataract surgery with intraocular lens (IOL) implantation, a treatment that is often regarded as low risk from a cardiovascular standpoint. For most patients in the local preoperative pathway, anesthetic review was a routine examination that was not only based on ECG results.

Study Population

Patients who attended outpatient preoperative evaluation between May 7, 2024 & July 23, 2024, made up the research population.

The audit covered 247 consecutive patients who satisfied the eligibility requirements.

Inclusion Criteria

Patients qualified for inclusion if they:

- Attended outpatient preoperative assessment during the study period.
- Were scheduled for unilateral cataract surgery with intraocular lens implantation.
- Had an ECG performed as part of their preoperative assessment.
- Had complete clinical records available for review.

Exclusion Criteria

Patients were excluded if they:

- Had incomplete or missing clinical records.
- Had ECGs performed for reasons unrelated to preoperative assessment.
- Had insufficient documentation to determine ECG findings or subsequent clinical actions.

Sample Size

The sample size was determined pragmatically based on all eligible patients who underwent preoperative assessment during the audit period. A total of 247 anonymised patient records were included.

A formal sample size estimate was not necessary because this study was not intended to be a hypothesis-driven interventional trial but rather a retrospective clinical audit. The sample was deemed sufficient to characterize the use of ECGs, the frequency of aberrant ECG results, and their influence on patient paths and clinical decision-making in the service.

Data Source and Data Collection

Preoperative evaluation records and related clinical paperwork were used to retrospectively extract data.
To reduce selection bias, all eligible consecutive patients reviewed during the audit period were included. A structured data gathering tool created especially for the audit was used to extract data.
Prior to analysis, all patient identities were eliminated to guarantee confidentiality and adherence to data protection laws. A distinct research identification number (ECG001-ECG247) was given to each patient.

Quality assurance checks were performed to confirm data accuracy after transcription. Transcription errors were identified in the original source materials & corrected as needed. To protect source data integrity and uphold openness, one discordant ECG entry was kept in the clinical record exactly as it was initially recorded.

Variables Collected

Demographic Variables

The following demographic variables were collected:

- Study identification number
- Age (years)
- Sex (male/female)

Clinical Variables

Clinical characteristics included:

- History of cardiovascular disease
- Hypertension
- Diabetes mellitus

Cardiac history was defined as documented cardiovascular disease including, but not limited to:

- Atrial fibrillation
- Coronary heart disease
- Cardiomyopathy
- Other established cardiac diagnoses

ECG Variables

ECG-related variables included:

ECG Result

Overall ECG interpretation was categorised as:

- Normal
- Borderline
- Abnormal

For multivariable modelling, ECG outcomes were subsequently dichotomised into:

- Normal/Borderline
- Abnormal

This approach was pre-specified within the audit protocol and reflected local clinical practice, where borderline ECG findings without defined pathology were managed similarly to normal ECG findings.

ECG Finding Category

Abnormal ECG findings were classified into the following categories:

- Arrhythmia
- Ischaemic changes
- Conduction abnormalities
- Left ventricular hypertrophy (LVH)
- Other abnormalities

Clinical Outcome Variables

Clinical outcomes following ECG review included:

Clinical Action Taken

- No action required
- Further investigation
- Referral for anaesthetic review

Patient Pathway Outcomes

- Procedure delay
- Procedure cancellation or rescheduling
- Composite pathway disruption outcome (delay and/or cancellation)

Definitions

Abnormal ECG: An abnormal ECG was defined as any documented pathological finding requiring consideration during perioperative assessment, including arrhythmias, ischaemic changes, conduction abnormalities, or evidence of structural cardiac disease.

Normal ECG: A normal ECG was defined as sinus rhythm or a borderline ECG without clinically significant pathology.

Procedural Disruption: Procedural disruption was defined as any delay, cancellation, or rescheduling of the planned surgical procedure attributable to findings identified during the preoperative assessment process.

Statistical Analysis

R version 4.x.x was used to perform statistical studies within the RStudio framework (R Core Team, 2024). While percentages and frequencies have been used to characterize categorical data, interquartile ranges (IQRs) and medians have been used to summarize continuous variables.

The primary outcome was preoperative ECG abnormality. For descriptive and bivariate analyses, ECG findings were reported across three categories:

- Normal
- Borderline
- Abnormal

For multivariable logistic regression analysis, ECG findings were dichotomised into:

- Normal/Borderline
- Abnormal

Secondary outcomes included:

- Clinical actions following ECG review
- Procedure delay
- Procedure cancellation/rescheduling
- Composite pathway disruption

Associations between patient characteristics and ECG findings were assessed using:

- Kruskal-Wallis rank-sum tests for continuous variables
- Fisher's exact tests for categorical variables

Where sparse cell counts limited exact computation, Monte Carlo simulation methods were applied.
Multivariable logistic regression analysis was performed to identify independent predictors of abnormal ECG findings. Variables entered into the model included:

- Age
- Sex
- Hypertension
- Diabetes mellitus
- Cardiac history

Based on clinical significance and previously published data, these factors were chosen beforehand.
95% confidence intervals (CIs) and adjusted odds ratios (ORs) were shown. Variance inflation factors (VIFs) were used to evaluate multicollinearity. Statistical significance was defined as a two-sided p-value of less than 0.05.

Governance and Ethical Considerations

The PRE-ECG Study was classified as a clinical audit in accordance with institutional policy.
Formal research ethics committee approval was therefore not required. Relevant audit and service evaluation approvals were obtained as required by the institution.

The audit utilised fully anonymised retrospective data collected during routine clinical care. No direct patient involvement occurred, and no identifiable patient information was retained.
The General Data Protection Regulation (GDPR) & other relevant data protection laws, as well as institutional confidentiality standards, were adhered to by all data handling practices.

RESULTS

Study Population and Patient Characteristics

This audit included 247 patients who attended outpatient preoperative evaluation for unilateral cataract surgery with intraocular lens (IOL) implantation between May 7, 2024, and July 23, 2024. As part of their preoperative evaluation, every patient had an ECG.

The study population ranged in age from 43 to 95 years, with a median age of 76 (IQR: 70-81 years). Of the patients in the cohort, 55% (n = 136) were female & 45% (n = 111) were male. The most common comorbidity was hypertension, which affected 58% of patients (n = 143), followed by diabetes mellitus in 19% of patients (n = 48) and documented cardiac disease in 23% of patients (n = 57) (Table 1).

Table 1. Baseline Characteristics of the Study Population

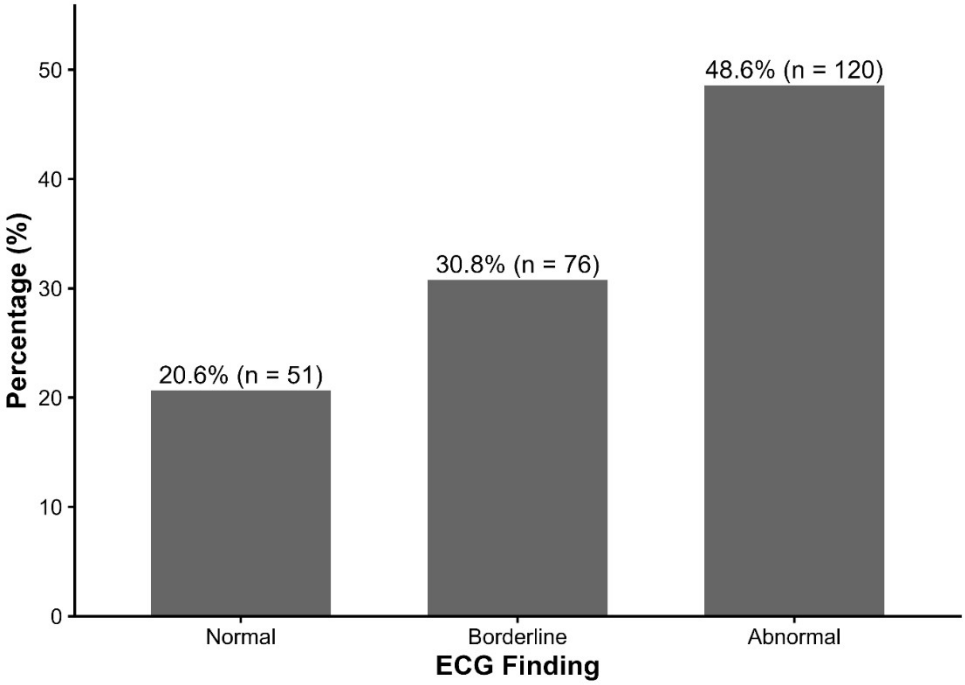
Characteristic	Overall (N = 247)[1]
Age (years)	76 (70, 81)
Sex	
Male	111 (45%)
Female	136 (55%)
Hypertension	143 (58%)
Diabetes mellitus	48 (19%)
Cardiac history	57 (23%)

[1]*Median (Q1, Q3); n (%)*

ECG Findings

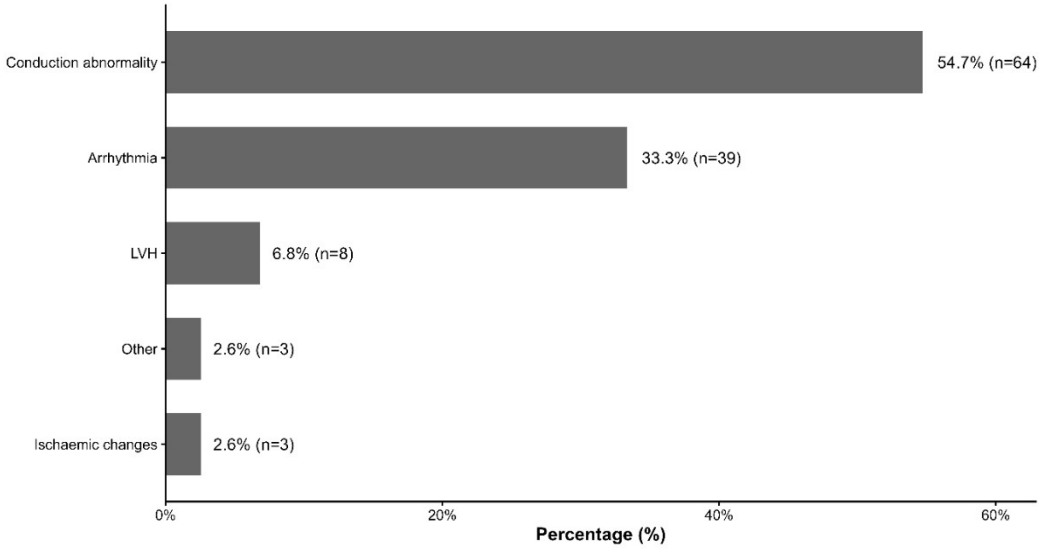
120 (49%) of the 247 ECGs that were examined were categorized as abnormal, 76 (31%) as borderline, and 51 (21%) as normal (Figures 1 and 2).

Figure 1. Overall ECG Interpretation



Conduction abnormalities were the most common ECG abnormality among patients with abnormal ECG findings (n = 120), making up 53% (n = 64) of aberrant tracings. 32% (n = 39) had arrhythmias, and 7% (n = 8) had left ventricular hypertrophy (LVH). In 2% (n = 3) of aberrant ECGs, ischemic alterations were found. The remaining findings included further ECG abnormalities.

Figure 2. Specific ECG Findings



Association Between Patient Characteristics and ECG Findings

Patient characteristics were subsequently analysed according to ECG classification (normal, borderline, and abnormal). Patients with normal ECG findings had a median age of 74 years (IQR: 66-77), those with borderline ECGs had a median age of 75 years (IQR: 70-81), and those with abnormal ECGs had a median age of 77 years (IQR: 72-83). There was a statistically significant difference (p = 0.001).

A documented cardiac history demonstrated a strong association with ECG abnormality. Cardiac disease was present in 34% (n = 41) of patients with abnormal ECGs compared with 13% (n = 10) of patients with borderline ECGs and 12% (n = 6) of those with normal ECG findings (p < 0.001).

Similarly, 27% (n = 32) of patients with aberrant ECG findings had diabetes mellitus, compared to 14% (n = 11) and 10% (n = 5) in the borderline and normal ECG groups, respectively (p = 0.017). No statistically significant associations were identified between ECG findings and sex (p = 0.508) or hypertension status (p = 0.928).

Table 2. Patient Characteristics Stratified by Preoperative ECG Findings

Characteristic	Overall N = 247[1]	Normal N = 51[1]	Borderline N = 76[1]	Abnormal N = 120[1]	p-value[2]
Age (years)	76 (70, 81)	74 (66, 77)	75 (70, 81)	77 (72, 83)	**0.001**
Sex					0.508
Male	111 (45%)	24 (47%)	30 (39%)	57 (48%)	
Female	136 (55%)	27 (53%)	46 (61%)	63 (53%)	
Hypertension	143 (58%)	29 (57%)	43 (57%)	71 (59%)	0.928
Diabetes mellitus	48 (19%)	5 (9.8%)	11 (14%)	32 (27%)	**0.017**
Cardiac history	57 (23%)	6 (12%)	10 (13%)	41 (34%)	**<0.001**

[1]*Median (Q1, Q3); n (%)*

[2]*Kruskal-Wallis rank sum test; Fisher's exact test*

Bold values indicate statistically significant results (P < .05)

Clinical Actions Following ECG Review

Following ECG assessment, clinical actions differed significantly by ECG classification (p < 0.001).
Referral for anaesthetic review was the most common action overall and was recorded in 219 patients (88.7%). Referral rates were highest among patients with abnormal ECG findings, occurring in 99.2% (n = 119) of cases. Corresponding referral rates among patients with borderline and normal ECG findings were 84.2% (n = 64) and 70.6% (n = 36), respectively.

In 27 individuals (10.9%), no clinical intervention was necessary. There were no untreated individuals among those with aberrant ECG findings, and these cases only happened in the normal and borderline ECG categories.
Only one patient (0.4%) underwent additional investigation following ECG review.

Table 3. Actions Taken and Impact by ECG Outcome

Downstream Actions & Impact	Overall N = 247[1]	Normal N = 51[1]	Borderline N = 76[1]	Abnormal N = 120[1]	p-value[2]
Clinical Action Taken					**<0.001**
None	27 (10.9%)	15 (29.4%)	12 (15.8%)	0 (0.0%)	
Further investigation	1 (0.4%)	0 (0.0%)	0 (0.0%)	1 (0.8%)	
Referral	219 (88.7%)	36 (70.6%)	64 (84.2%)	119 (99.2%)	
Procedure Delay	6 (2.4%)	0 (0.0%)	1 (1.3%)	5 (4.2%)	0.354
Procedure Cancellation	4 (1.6%)	0 (0.0%)	1 (1.3%)	3 (2.5%)	0.817
Composite Negative Pathway Impact	7 (2.8%)	0 (0.0%)	1 (1.3%)	6 (5.0%)	0.191

[1]*n (%)*

[2]*Fisher's exact test*

Bold values indicate statistically significant results (P < .05)

Impact on Patient Pathways

Despite the relatively high prevalence of abnormal ECG findings, disruption to planned surgical pathways was uncommon. Six patients (2.4%) experienced delays in their procedures. individuals with abnormal ECG results experienced five delays, whereas individuals with borderline ECG results experienced one delay. The group with a normal ECG showed no delays. There was no statistically significant correlation (p = 0.354) between ECG categorization and procedural delay.
Four patients (1.6%) had their procedures cancelled or rescheduled. There were one case in the borderline ECG group and three in the abnormal ECG group. Once more, there was no statistically significant correlation found (p = 0.817).

A composite measure of pathway disruption, defined as either delay or cancellation/rescheduling, was observed in seven patients (2.8%). Rates were highest among patients with abnormal ECG findings (5.0%; n = 6) compared with borderline ECG findings (1.3%; n = 1). No pathway disruptions occurred among patients with normal ECG findings. This association did not reach statistical significance (p = 0.191).

Predictors of Abnormal ECG Findings

Multivariable logistic regression analysis was performed to identify independent predictors of abnormal preoperative ECG findings. Increasing age was independently associated with ECG abnormality. For every one-year increase in age, the odds of having an abnormal ECG increased by approximately 4% (OR 1.04; 95% CI 1.00-1.07; p = 0.034).

Diabetes mellitus was also identified as a significant independent predictor. Patients with diabetes had more than twice the odds of exhibiting abnormal ECG findings compared with non-diabetic patients (OR 2.63; 95% CI 1.32-5.41; p = 0.007).
The strongest predictor of ECG abnormality was a documented cardiac history. Patients with pre-existing cardiac disease had more than three times the odds of demonstrating abnormal ECG findings compared with patients without cardiac disease (OR 3.16; 95% CI 1.62-6.39; p < 0.001).

Abnormal ECG results were not independently correlated with either sex (p = 0.954) or hypertension (p = 0.609). There was no evidence of significant collinearity in the regression model, according to the multicollinearity assessment, which showed low variance inflation factors for all variables (VIF < 2) (Table 4).

Table 4. Multivariable Logistic Regression for Predictors of Abnormal ECG

Predictors	OR[1]	95% CI[1]	p-value
Age (years)	1.04	1.00, 1.07	**0.034**
Sex			0.954
Male	—	—	
Female	1.02	0.59, 1.76	
Hypertension			0.609
No	—	—	
Yes	0.87	0.50, 1.50	
Diabetes mellitus			**0.007**
No	—	—	
Yes	2.63	1.32, 5.41	
Cardiac history			**<0.001**
No	—	—	
Yes	3.16	1.62, 6.39	

[1]*OR = Odds Ratio, CI = Confidence Interval*

Bold values indicate statistically significant results (P < .05)

DISCUSSION

The preoperative ECG results of patients undergoing unilateral cataract surgery were examined in this retrospective clinical audit, and their influence on clinical decision-making and patient paths was reviewed. The audit showed that nearly half of the study population (49%) had aberrant ECG findings, and another 31% had borderline ECG findings. The most common ECG abnormality was conduction abnormalities, which were followed by arrhythmias. A documented cardiac history, diabetes mellitus, and getting older were all independently linked to aberrant ECG results.

ECG anomalies were very common, but they had little effect on the course of surgery. Procedural delays, cancellations, and general pathway disruption were rare, even though aberrant ECG readings sometimes led to referral for additional anesthetic assessment. These results imply that although ECG anomalies are frequently found during preoperative evaluation for cataract surgery, many of them do not eventually lead to patient pathways that are clinically meaningful.

Comparison with Existing Literature

The audit's conclusions are mostly in line with other research on the function of ECG testing in low-risk surgical groups. With a very low frequency of serious perioperative cardiovascular problems, cataract surgery is generally acknowledged as a low-risk technique. As a result, there has been much discussion over the usefulness of routine preoperative investigations in this context (National Institute for Health and Care Excellence (NICE), 2016; Fleisher et al., 2024).

Comprehensive preoperative review did not significantly improve perioperative or postoperative unfavourable outcomes despite lengthening waiting periods for surgery, according to Lira et al. (2016), who assessed the effect of outpatient preoperative evaluation among cataract surgery patients. In a similar vein, while aberrant ECG results were prevalent in the current audit, their impact on the course of surgery was minimal, with relatively few patients incurring delays or cancellations. All of these results point to the possibility that systematic detection of ECG abnormalities may not always result in significant improvements in perioperative outcomes for patients having low-risk ocular procedures.

Previous research also supports the prevalence of ECG abnormalities found in this audit. According to Prakash et al. (2019), aberrant ECG results are common during regular preoperative evaluation, especially in individuals with chronic medical problems and older adults. Age-related circulatory alterations and the rising burden of chronic disease within aging surgical populations are probably responsible for the prevalence of conduction abnormalities and arrhythmias seen in this study.

The audit's findings of an independent association between increasing age and abnormal ECG findings are consistent with research showing that conduction system disease, atrial arrhythmias, and structural cardiac abnormalities are becoming more common in older adults (Fleisher et al., 2024). Similarly, considering the established link between diabetes and

accelerated atherosclerosis, autonomic dysfunction, myocardial fibrosis, & increased cardiovascular morbidity, the linkage between diabetes mellitus and ECG abnormalities is medically reasonable.

The best independent predictor of abnormal ECG results was a recorded cardiac history. This finding supports the importance of focused cardiovascular evaluation in individuals with established heart disease receiving preoperative evaluation & is consistent with previous research (Fleisher et al., 2024).

Clinical Actions Following ECG Findings

One of the most notable findings of this audit was the high frequency of referral for further anaesthetic review. Almost 89% of patients underwent referral following ECG assessment, and referral rates approached 100% among patients with abnormal ECG findings.

This result emphasizes how ECG results have a major impact on perioperative choices made throughout the preoperative evaluation process. Nevertheless, relatively few patients reported procedural interruption, and just one patient needed further evaluation despite the large number of referrals made. This implies that many findings may ultimately have limited clinical implications in the setting of low-risk ocular surgery, even if ECG abnormalities often prompt additional investigation.

These findings raise important questions about striking a balance between patient safety and healthcare efficiency. Excessive reliance on ECG abnormalities alone may raise clinician workload and healthcare utilization, even though referral mechanisms are crucial for identifying patients who need optimization or specialist assessment. Similar issues have been brought to light in studies looking at low-value preoperative testing, where abnormal results often led to further investigations without appreciable benefits in patient outcomes (Ganguli et al., 2019).

Therefore, rather than relying solely on ECG abnormalities as referral triggers, future pathway refinement may benefit from risk-stratified approaches that account for patient comorbidities, functional status & overall perioperative risk, in addition to ECG findings.

Impact on Patient Pathways

Evaluating the impact of ECG results on patient flow & surgical progression was one of the audit's main goals. While abnormal ECG results often led to referrals, planned care was rarely disrupted.

Less than 3% of the sample population, or just seven patients, had any kind of route disturbance. Additionally, there was no statistically significant correlation seen between the aggregate route disruption outcome, procedural delay, or cancellation and ECG classification.

These results imply that many ECG abnormalities found during preoperative evaluation might not be clinically severe enough to change the planned course of surgery. In cataract surgery, when operational and anesthetic risks are often minimal, this fact is especially pertinent (Lira et al., 2016).

The results also support mounting worries over low-value preoperative testing. ECG testing prior to cataract surgery often results in downstream healthcare utilization, such as further cardiac investigations and specialist consultations, without clear evidence of improved outcomes, as Ganguli et al. (2019) showed. The low percentage of pathway interruption found indicates that more investigation into the clinical utility and cost-effectiveness of routine ECG testing in low-risk ocular surgery is necessary, even if the current audit did not explicitly assess economic consequences.

CLINICAL IMPLICATIONS

The audit's conclusions have a number of significant ramifications for clinical practice and service provision.

First, patients receiving preoperative evaluation for cataract surgery frequently had aberrant ECG results, especially older adults and those with diabetes mellitus or established cardiovascular disease. These patient populations might require closer cardiovascular assessment and risk stratification during preoperative evaluation.

Second, despite the high frequency of ECG abnormalities, clinically notable outcomes were unusual. This result corresponds with current guidelines that recommend selective ECG testing rather than regular screening in low-risk surgical groups (NICE, 2016; Fleisher et al., 2024).

Third, the audit identifies a need to improve preoperative assessment routes by strengthening risk-based decision-making and providing more precise referral criteria. Without jeopardizing patient safety, more judicious use of ECG testing may minimize healthcare utilization, increase efficiency, cut down on needless referrals, and promote waiting-list reduction programs.

Lastly, the results highlight how crucial it is to match local practice with evidence-based guidelines in order to guarantee that preoperative investigations offer significant therapeutic value while preventing needless strain on patients and healthcare systems (NICE, 2016).

STRENGTHS AND LIMITATIONS

Strengths

This study has several significant advantages. To minimize selection bias and provide a representative representation of standard clinical practice, the audit included all eligible consecutive patients undergoing preoperative assessment during the research period. Internal consistency was improved and procedural heterogeneity was decreased by using a homogeneous patient population for unilateral cataract surgery.

To provide a thorough evaluation of the practical impact of ECG findings within a real-world preoperative screening service, the study assessed the entire pathway from ECG detection through following clinical actions and patient pathway outcomes.

Additionally, the use of multivariable logistic regression analysis allowed for the accounting of potential confounding variables while identifying independent predictors of aberrant ECG findings.

Limitations

There are a few restrictions to be aware of. First, the audit's retrospective design makes it more difficult to determine the causal connections between ECG results and clinical outcomes. The correctness and completeness of the current documentation were crucial because the study depended on clinical data that was routinely obtained.

Second, this audit was carried out at a single site with a particular set of ophthalmic surgeons. As a result, conclusions could not apply to higher-risk surgical specialties, other companies, or healthcare systems.

Third, postoperative results outside of the direct preoperative pathway were not assessed. As a result, it was unable to ascertain if aberrant ECG results were linked to later perioperative or postoperative problems.

Lastly, statistical power for analyses incorporating pathway disruption outcomes was constrained by the comparatively modest number of delays and cancellations.

FUTURE RESEARCH AND SERVICE IMPROVEMENT

Future studies should use prospective multicenter designs to investigate the clinical value and cost-effectiveness of ECG testing in low-risk surgical groups. The evidence foundation in favor of preoperative ECG use might be strengthened by more research looking at postoperative outcomes linked to particular ECG abnormalities.

The results of this audit could help the local service reassess its existing ECG utilization patterns, improve referral pipelines, and create risk-based evaluation protocols. These programs might increase productivity while upholding strict perioperative safety regulations.

CONCLUSION

This retrospective clinical audit showed that nearly half of the study population had aberrant ECG results during preoperative evaluation for unilateral cataract surgery. The most common ECG abnormalities were conduction

abnormalities and arrhythmias; pre-existing cardiac illness, diabetes mellitus, and advanced age were all independently linked to an increased risk of abnormal ECG findings.

ECG anomalies were relatively common, although they had little effect on patient trajectories. Procedural delays, cancellations, and general route interruption were rare, even though aberrant ECG readings commonly led to referral for additional anesthetic assessment. These results imply that in low-risk ocular surgery, many ECG abnormalities found during preoperative evaluation would not be clinically important enough to change the intended surgical pathway.

The results corroborate current research that favours the use of selective, risk-based ECGs over routine monitoring for all patients having low-risk operations. Optimizing the use of ECG in preoperative assessment services may increase productivity, cut down on pointless tests and referrals, promote evidence-based clinical decision-making, and help make better use of healthcare resources while preserving patient safety.

To assess the clinical value and cost-effectiveness of ECG testing in low-risk surgical populations and to guide the creation of future guidelines, further prospective and multicentre studies are advised.

Study Running Title

PRE-ECG: Preoperative ECG Findings in Cataract Surgery

Conflict of Interest

The authors declare that they have no competing interests, financial or non-financial, related to this study.

Ethical Statement

The PRE-ECG Study was conducted as a retrospective clinical audit in accordance with institutional clinical audit and service evaluation procedures.

The project was classified as a clinical audit rather than a human subjects study; hence formal research ethics committee approval was not required. Before the study began, all relevant institutional audit and governance norms were met.

Before analysis, all data were anonymised, and no personally identifiable patient information was collected, saved, or shared. Data handling techniques followed local confidentiality standards and applicable data protection legislation, such as the General Data Protection Regulation (GDPR).

Authors' Contributions

Prof. Adebusola Adenike Owokole

- Conceived and designed the audit.
- Led project development, oversight and manuscript preparation.
- Coordinated data collection, review, and final manuscript approval.

Dr. Alazar Menbere Haile

- Developed the statistical analysis plan.
- Performed data analysis and interpretation.
- Contributed to methodological development and critical review of the manuscript.

Dr. Joshua Olaopin

- Supported data transcription and dataset development.
- Assisted with data verification and quality assurance processes.
- Contributed to manuscript review and approval.

All authors reviewed, revised, and approved the final manuscript prior to submission.

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Data Availability Statement

The datasets generated and analysed during the current study are not publicly available due to institutional data protection and confidentiality requirements but may be available upon reasonable request from the corresponding author, subject to institutional governance approval.

Use of Artificial Intelligence

Artificial intelligence-assisted tools were used to support manuscript drafting, language refinement, and formatting. All content was reviewed, verified, and approved by the authors, who accept full responsibility for the accuracy and integrity of the manuscript.

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Mucinous Appendiceal Adenocarcinoma Mimicking a Bladder Tumor: A Case Report

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ABSTRACT

Background: Appendiceal mucinous adenocarcinoma is a rare malignancy with nonspecific clinical manifestations, making early diagnosis challenging. Most localized tumors are diagnosed incidentally following appendectomy, whereas advanced disease may present with fistula formation or involvement of adjacent organs.

Case Presentation: A 56-year-old nonsmoking male with no significant comorbidities presented with dysuria, gross hematuria with passage of amorphous clots for six months, and pneumaturia for three months. He denied abdominal pain, melena, or bowel obstruction symptoms.

Clinical Findings and Investigations: Urinalysis revealed numerous red blood cells and pus cells, while urine culture grew Escherichia coli. Ultrasonography demonstrated a solid mass along the right lateral bladder wall with extravesical extension. Following treatment of urinary tract infection, cystoscopy revealed a mucin-covered tumor involving the right lateral and anterior bladder walls with evidence of fistula formation. Histopathological examination of cystoscopy biopsy demonstrated mucinous adenocarcinoma of appendiceal origin. Colonoscopy was unremarkable. Contrast-enhanced CT of the chest, abdomen, and pelvis showed a 6.3 × 4.7 cm heterogeneous mass involving the right lateral and anterior bladder walls with both endophytic and exophytic components and loss of fat planes with an adjacent ileal loop.

Intervention and Outcome: Exploratory laparotomy revealed an appendiceal tumor encasing the ileum and infiltrating the urinary bladder, forming a complex fistulizing mass. En bloc appendectomy, partial cystectomy, and ileal resection with primary anastomosis were performed. Histopathology confirmed pT4bN0M0 mucinous adenocarcinoma arising in a tubulovillous adenoma, with direct invasion of the bladder detrusor muscle and ileum. Surgical margins were negative. Follow-up imaging at three months showed no evidence of recurrence.

Conclusion: Appendiceal mucinous adenocarcinoma may rarely present with urological symptoms due to fistula formation and adjacent organ invasion. A multidisciplinary approach is essential for accurate diagnosis and optimal management in such complex cases.

Keywords: *Appendiceal Mucinous Adenocarcinoma; Hematuria; Pneumaturia; Fistula, Urinary Bladder Invasion.*

INTRODUCTION

Appendiceal mucinous adenocarcinoma is a rare malignancy, accounting for less than 1% of all gastrointestinal cancers. Its incidence is approximately 0.12 per 1,000,000 population per year, and it is incidentally identified in nearly 0.2% of appendectomy specimens, with less than half recognized intraoperatively (1). Clinical presentation is often nonspecific, leading to delayed or incidental diagnosis following appendectomy.

Appendiceal mucinous adenocarcinoma rarely invades the urinary bladder, and fistula formation is exceptionally uncommon, with only a few cases reported in the literature (2). We report a rare case of appendiceal mucinous adenocarcinoma presenting as a presumed bladder tumor with ileal invasion and enterovesical fistula formation.

This report highlights the diagnostic challenges associated with this unusual presentation and emphasizes the importance of considering appendiceal malignancy in the differential diagnosis of complex pelvic masses. It also underscores key aspects of intraoperative decision-making, multidisciplinary management, and postoperative surveillance.

CASE PRESENTATION

A 56-year-old nonsmoking male with no significant comorbidities presented with dysuria, gross hematuria with passage of amorphous clots for six months, and pneumaturia for three months. He denied any history of melena, abdominal pain, or bowel obstruction. On physical examination, the patient appeared lean and pale but was comfortable at rest and fully oriented to time, place, and person. His blood pressure was 130/70 mmHg, pulse rate was 72 beats/minute, and body temperature was 98.4°F. Digital rectal examination revealed a moderately enlarged, firm, and non-tender prostate. The remainder of the general physical and systemic examinations was unremarkable.

Laboratory investigations revealed numerous red blood cells and pus cells on urinalysis, while urine culture demonstrated growth of Escherichia coli. Initial ultrasonography of the abdomen and pelvis showed a solid lesion arising from the right lateral wall of the urinary bladder with extension into the extravesical region. Following treatment of the urinary tract infection, cystoscopy was performed, which revealed a solid growth involving the right lateral and anterior walls of the urinary bladder (Figure 1). The lesion was covered with mucinous deposits, and communication with the extravesical space was visualized, suggesting fistula formation. Cold-cup biopsies were obtained, and histopathological examination demonstrated mucinous adenocarcinoma consistent with appendiceal origin. Colonoscopy was subsequently performed to exclude a primary colorectal malignancy; however, no abnormalities were identified. Contrast-enhanced computed tomography (CT) of the chest, abdomen, and pelvis demonstrated a 6.3 × 4.7 cm lobulated, heterogeneously enhancing lesion involving the right lateral and anterior walls of the urinary bladder, with both exophytic and endophytic components (Figure 2). The exophytic component exhibited loss of the intervening fat plane with an adjacent loop of small bowel, raising suspicion of direct invasion.

The case was discussed in a multidisciplinary tumor board meeting. Based on the available clinical, radiological, and histopathological findings, the differential diagnosis included mucinous adenocarcinoma of the urinary bladder invading the small bowel or, alternatively, a gastrointestinal primary tumor invading the bladder. Consequently, en bloc radical cystectomy with small bowel resection, mesenteric excision, and ileal conduit diversion was planned based on presumed diagnosis. During exploratory laparotomy, the tip of the appendix was found to harbor a tumor encasing the ileum and directly infiltrating the urinary bladder, forming a complex mass. The appendix was collapsed and difficult to distinguish from the adjacent ileum due to fistulous communication with both the ileum and urinary bladder. No gross peritoneal deposits, pseudomyxoma peritonei, or mesenteric involvement were identified (Figure 3A & Figure 3B). An en bloc resection comprising appendectomy, segmental ileal resection with its mesentery, and partial cystectomy was performed, followed by primary bladder closure and ileo-ileal anastomosis. The postoperative course was uneventful, with no fever, sepsis, or requirement for blood transfusion. The patient was discharged on postoperative day six in stable condition. Histopathological examination of the resected specimen revealed pT4bN0M0 mucinous adenocarcinoma arising from the appendix on a background of tubulovillous adenoma, with direct invasion of the bladder detrusor muscle and trans-serosal involvement of the ileum. All surgical margins were free of tumor (Figure 4). Follow-up CT imaging of the abdomen and pelvis at three months demonstrated no evidence of local recurrence or metastatic disease. The patient was subsequently referred to medical oncology for further management and surveillance.

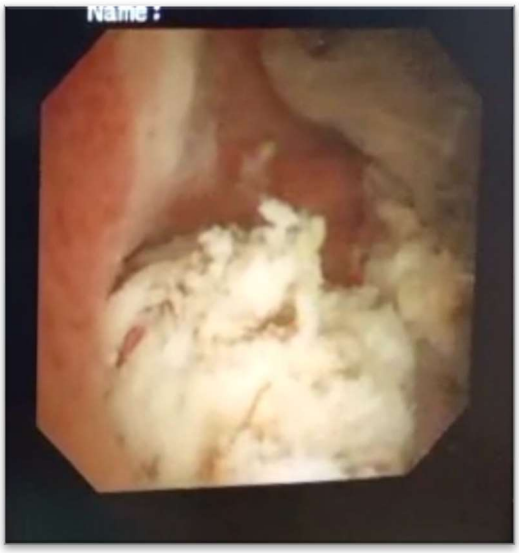


Figure 1: Cystocopic appearance of a solid growth on the right lateral and anterior wall of urinary bladder

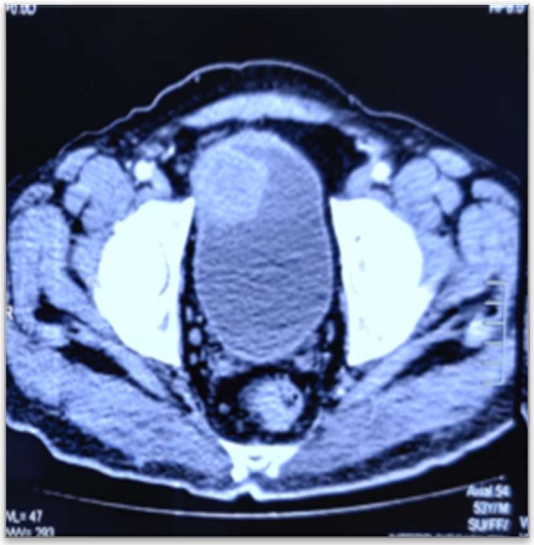
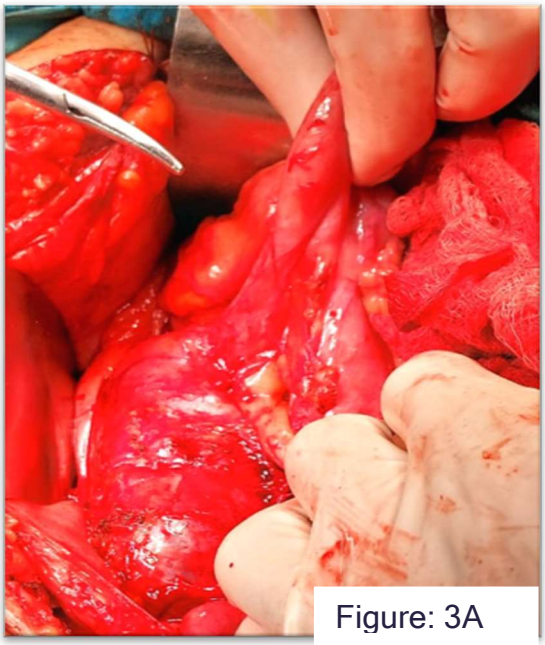


Figure 2: A 6.3 cm x 4.7 cm lobulated heterogeneously enhancing lesion arising from the right lateral wall and anterior wall of urinary bladder having exophytic and endophytic components.



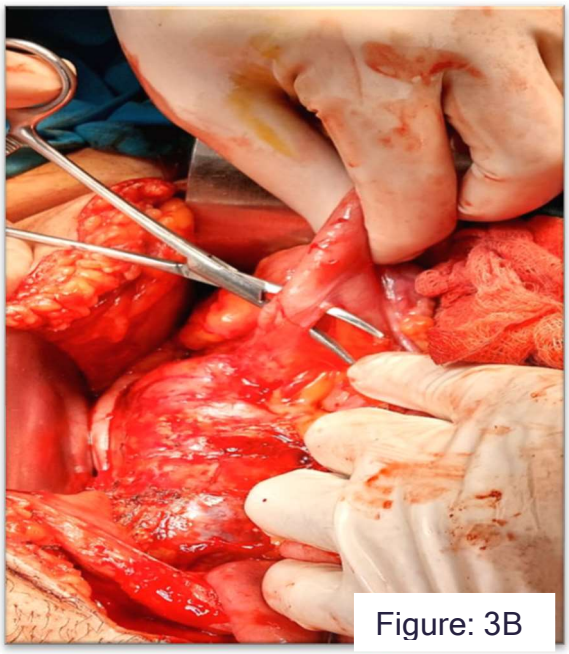


Figure 3A & Figure 3B: The gross intra operative view showing a mass like structure encasing ileum, appendix and invading urinary bladder.

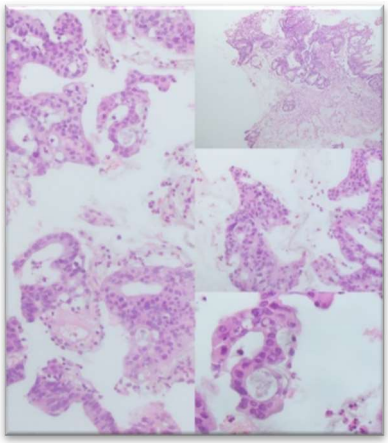


Figure 4: Shows histopathological assessment using hematoxylin and eosin staining with x100 and x400 magnification. The findings are consistent with mucinous adenocarcinoma of appendix, showing infiltrating glands with abundant mucin.

DISCUSSION

Mucinous adenocarcinoma of the appendix is a rare malignancy with nonspecific clinical manifestations, making early diagnosis challenging. Most patients present with symptoms mimicking more common gastrointestinal or genitourinary conditions, and diagnosis is frequently established at surgery or on final histopathology when the disease is already locally advanced (3).

The present case highlights an unusual presentation of appendiceal mucinous adenocarcinoma with hematuria, pneumaturia, and bladder wall involvement, closely resembling a primary bladder malignancy. Preoperative cystoscopy demonstrated a bladder mass with fistulous communication, while biopsy revealed mucinous adenocarcinoma. Combined with CT findings showing a bladder lesion with adjacent small bowel involvement, the initial working diagnosis favored an advanced bladder tumor invading the bowel.

Urachal carcinoma was also considered in the differential diagnosis because of its mucin-producing nature and tendency to involve the bladder; however, this entity accounts for less than 2% of all bladder cancers. Unlike urothelial carcinoma, the standard treatment for localized urachal carcinoma is partial cystectomy with en bloc resection of the urachus rather than radical cystectomy. Contrast-enhanced CT is the primary imaging modality for the evaluation of appendiceal neoplasms. Findings such as appendiceal dilatation, mural thickening, soft tissue masses, and mural calcifications may raise suspicion for a mucinous neoplasm (4). In patients presenting with appendiceal mucocele and acute appendicitis, CT findings including cystic appendiceal dilatation, mural calcification, or luminal dilatation greater than 13 mm have demonstrated good diagnostic performance. However, these characteristic features were absent in our patient because the appendiceal tumor had fistulized into both the ileum and urinary bladder, allowing continuous drainage of mucin and preventing the development of a distended mucus-filled appendix.

Magnetic resonance imaging (MRI) may provide additional information regarding the site of origin, local invasion, and peritoneal disease burden. Diffusion-weighted MRI has been reported to improve the detection of small-volume peritoneal metastases, while MRI may outperform CT in assessing tumor extent and small bowel involvement in selected patients (5,6). In retrospect, preoperative MRI may have helped better delineate the appendiceal origin of the tumor and aided operative planning.

A key learning point from this case is the importance of intraoperative vigilance. During exploration, the appendiceal tumor was found to encase the ileum and infiltrate the urinary bladder, forming a complex mass. The appendix was collapsed and difficult to identify because of fistulous communication with both organs. Consequently, the typical appearance of a mucin-filled appendix was absent, and the appendiceal origin was not apparent preoperatively. In such circumstances, surgeons should maintain a high index of suspicion for an appendiceal primary when encountering mucinous tumors involving the bowel and urinary bladder. Intraoperative frozen-section analysis may be helpful, as confirmation of the tumor origin could influence the extent of oncological resection.

Appendiceal adenocarcinomas commonly spread through the terminal ileal and cecal lymphatic pathways. When the diagnosis is established preoperatively, right hemicolectomy with en bloc mesenteric lymphadenectomy remains the standard oncological treatment for non-metastatic disease. Reported survival outcomes are superior following right hemicolectomy compared with appendicectomy alone (7,8). Although limitations are inherent in rare and diagnostically

challenging cases, the absence of preoperative MRI and intraoperative frozen-section analysis in our patient may have influenced the optimal surgical strategy.

This case illustrates the diagnostic complexity of appendiceal mucinous adenocarcinoma presenting as a bladder mass with enterovesical fistula. Awareness of this rare presentation, multidisciplinary evaluation, and careful intraoperative assessment are essential to achieve accurate diagnosis and appropriate management.

CONCLUSION

Appendiceal mucinous adenocarcinoma invading both the ileum and urinary bladder with fistula formation is an exceptionally rare presentation and poses significant diagnostic challenges. Owing to its nonspecific clinical and radiological features, accurate preoperative diagnosis may be difficult, often resulting in diagnosis at an advanced stage. A high index of suspicion, careful intraoperative assessment, and the judicious use of frozen-section analysis are essential for appropriate surgical management. Close multidisciplinary collaboration among radiologists, pathologists, surgeons, and oncologists is critical to achieving optimal oncological and functional outcomes.

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ETHICAL APPROVAL
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DECLARATION OF COMPETING INTEREST
The authors have no conflicts of interest to disclose in relation to this work.

CONSENT
Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available on request.

AUTHORSHIP
MK and AH drafted the manuscript; RAK supervised the study; NK critically reviewed the manuscript. All authors reviewed and approved the final manuscript.

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Advancing Sterile Processing Through Governance Intelligence: The G-SSIF Framework for Improving CSSD Coordination, Productivity, and Patient Safety

(TORG-NZ Global CSSD Best Practice Essay Competition 2026 - First Place Winner)

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ABSTRACT

Sterilization of reusable medical devices is essential to prevention and safe surgical care. Despite strong technical standards, variability in sterile processing performance persists across healthcare systems. While core sterilization practices are often consistent, gaps remain in coordination-related areas such as workflow alignment, service delivery, and workforce capability. These gaps lead to delays, instrument unavailability, and increased patient risk. This essay examines sterile processing through a patient safety and system performance lens, arguing that technical compliance alone does not ensure safe outcomes. The Gacias Sterilization Systems Intelligence Framework (G-SSIF) is introduced as a governance model integrating system capability, operational performance, coordination, and AI-enabled intelligence. The conceptual framework supports alignment between CSSD and surgical demand, improving on-time procedure starts, reducing case delays, and strengthening perioperative performance. Strengthening coordination in sterile processing is a practical and scalable pathway to safer surgical care.

Keywords: *Central Sterile Services Department (CSSD); Sterile Processing; Surgical Patient Safety; Healthcare Governance; Perioperative Performance*

Competition Recognition:
This article was selected as the First Place Winner of The Operating Room Global New Zealand (TORG-NZ) CSSD Best Practice Essay Competition 2026 and subsequently underwent editorial review prior to publication in The Operating Room Global Journal (TORGJ).

MAIN TEXT

Sterile processing plays a direct role in surgical patient safety, yet many failures are not caused by lack of knowledge or equipment. Instead, they occur when systems do not work together. This essay addresses the role of CSSD in surgical patient safety by examining breakdowns in coordination, communication, and workflow alignment. In practice, instruments may meet sterilization standards but still arrive late or incomplete. When this happens, procedures are delayed, teams are disrupted, and patient risk increases. These are system failures, not technical failures.

Sterilization of reusable medical devices remains a cornerstone of infection prevention and control and safe surgical care. Healthcare-associated infections continue to contribute to prolonged hospital stays, increased costs, and avoidable complications (World Health Organization, 2016). While CSSD ensures instrument sterility, compliance alone does not guarantee reliable service delivery.

Sterile processing is not only a technical function, but a system-dependent service. It requires alignment between CSSD and clinical demand to support safe surgery, consistent perioperative performance, and surgical throughput.

Reframing the Problem: Beyond Technical Compliance

Traditional sterilization management focuses on technical parameters, equipment validation, and environmental control. These remain essential, but they do not explain why delays and disruptions persist. In many facilities, technical performance is stable. Variation occurs in coordination areas such as workflow standardization, service interfaces, sterile storage, and workforce training. These gaps affect how CSSD connects with clinical services.

CSSD operates as a bridge between reprocessing and patient care. When coordination fails, the impact reaches the operating room. Improving outcomes requires a shift from compliance alone to system alignment and governance.

Demonstrating the Patient Safety Gap

A common operating room situation illustrates the issue. The case is scheduled, the patient is prepared, and the instruments have completed the sterilization cycle. However, one required set is missing or incomplete. The team is forced to wait. The delay increases anesthesia exposure, raises the risk of infection, and disrupts workflow. The sterilization process was completed correctly. The failure occurred in coordination. Patient safety depends on both sterility and availability. Systems that focus only on technical compliance fail to address this gap.

The G-SSIF Framework: A Governance Intelligence Approach

The Gacias Sterilization Systems Intelligence Framework (G-SSIF) addresses these system-level challenges by examining how sterile processing performs within the wider healthcare system rather than as an isolated technical function. The G-SSIF is presented as a conceptual governance framework developed from systems thinking concepts, observations from sterile processing operations, and practical quality improvement experience. While elements of the framework have been applied in operational improvement initiatives, the framework itself has not yet undergone formal validation. Future research is needed to assess its reliability, applicability, and effectiveness across diverse healthcare settings.

The framework is structured around three core intelligence domains: Capability Intelligence, Operational Intelligence, and Governance & Partnership Intelligence. Capability Intelligence encompasses workforce competency, equipment adequacy, and compliance maturity. Operational Intelligence focuses on workflow efficiency, productivity, cost, and performance. Governance & Partnership Intelligence addresses coordination through vendor capability evaluation, service-level agreements, regulatory alignment, and system integration. These domains are supported by an outer layer of AI-Enabled Systems Intelligence and connected through strategic decision pathways that guide organizational decision-making and service delivery models.

At its core, the framework is designed to support healthcare organizations in evaluating and selecting appropriate service models, including in-house, centralized, hybrid, and outsourced approaches. By integrating operational data with governance and performance considerations, it provides a structured basis for planning, coordination, and resource optimization. The AI-enabled intelligence layer further enhances this capability through applications such as demand forecasting based on surgical schedules, predictive maintenance of sterilization equipment, automated compliance monitoring, and centralized coordination of instrument inventory across multiple facilities.

This approach moves beyond individual processes to focus on overall system performance, recognizing that effective coordination plays a critical role in supporting patient safety outcomes.

Figure 1. The Gacias Sterilization Systems Intelligence Framework (G-SSIF)
A governance model integrating system capability, operational performance, coordination, and AI-enabled intelligence to support decision-making and patient safety
Source: Author's original work.

As shown in Figure 1, the framework integrates capability, operations, governance, partnerships, and AI-enabled intelligence within a single system, enabling leaders to align CSSD performance with surgical demand and support more informed decision-making.

What Makes G-SSIF Different

Most CSSD models focus on compliance and internal control. While these elements remain essential, they do not fully reflect how sterile processing systems function under real world operational conditions.

Existing sterilization frameworks and standards, such as AAMI ST79, primarily address technical compliance, sterilization processes, and quality assurance. Similarly, governance and quality improvement models generally concentrate on organizational performance and process optimization. Building on these established perspectives, the G-SSIF brings together system capability, operational performance, governance coordination, and emerging systems intelligence within a unified sterile processing governance framework.

Rather than viewing sterile processing as a collection of discrete activities, the G-SSIF highlights coordination, connectivity, and system integration. It positions CSSD within a continuous operational workflow that is closely linked to clinical demand and surgical services. This approach supports decision-making informed by operational trends and interdependencies across the system, rather than by isolated events or individual performance measures. By adopting this broader perspective, the G-SSIF recognizes CSSD as an integrated service that contributes directly to overall healthcare system performance.

Practical Application in Sterile Processing Systems

The framework can be applied through structured and consistent actions. Implementation begins by aligning CSSD processes with clinical demand. In practice, this involves tracking instrument readiness at the point of use, aligning sterilization cycles with operating room schedules, and maintaining regular coordination between CSSD and surgical teams. Reducing variation in tray configuration and reviewing delays helps identify recurring issues. Regular review of operational data also supports proactive decision-making by enabling leaders to identify performance trends, allocate resources more effectively, and address potential service disruptions before they affect patient care. When CSSD output is aligned with surgical scheduling, instrument-related delays decrease, improving on-time procedure starts and reducing case delay frequency, supporting workflow stability and patient safety.

Global Relevance and Low-Resource Application

The framework applies across different healthcare settings. In low-resource environments, improving coordination often has greater impact than increasing equipment. Hospitals may face limits in staffing or infrastructure, yet improvements in communication, workflow design, and targeted workforce training can enhance performance without major cost. This enables shared learning and more consistent practice across healthcare systems.

Contribution to Patient Safety

Sterile processing supports every surgical procedure. When it functions well, it is often unnoticed. When it fails, the impact is immediate. Patient safety depends on reliable access to complete and sterile instruments. Delays increase exposure time and disrupt care delivery. Inconsistent supply creates avoidable risk. By improving coordination and aligning CSSD with clinical demand, the G-SSIF framework strengthens service reliability and supports safer surgical outcomes.

Implications for Leadership and System Integration

For healthcare leaders, sterile processing performance reflects how well systems function together. The G-SSIF framework supports decision-making by linking CSSD operations with surgical demand, resource planning, and service reliability

The framework also supports workforce development. By defining capability, coordination, and performance expectations, it guides targeted training and continuous improvement within CSSD teams, enabling shared learning, professional collaboration, and consistent practice across institutions.

Strengthening CSSD at this level improves not only internal workflow but also overall perioperative performance, supporting safer and more efficient surgical systems.

CONCLUSION

Sterile processing is a system-critical service that directly affects surgical outcomes. When coordination fails, patient safety is compromised even when sterilization standards are met. Improving CSSD performance requires better alignment between processes, people, and clinical demand. The Gacias Sterilization Systems Intelligence Framework provides a structured approach to achieve this. By strengthening coordination and system performance, it supports more reliable service delivery, reduces delays, and contributes to safer patient care.

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CONFLICT OF INTEREST

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Improving Sterilisation Safety in Low-Resource Settings Through Structured Monitoring and Practical System Improvements

(TORG-NZ Global CSSD Best Practice Essay Competition 2026 – Second Place Winner)

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ABSTRACT

Sterilisation safety is a critical component of infection prevention and surgical patient safety. In many low-resource healthcare settings, challenges arise not solely from limited infrastructure but from inconsistent monitoring, inadequate staff training, and weak process control. This article explores practical approaches to strengthening sterilisation safety through structured monitoring systems, standard operating procedures, competency-based training, and continuous quality improvement initiatives. Evidence from the literature demonstrates that interventions such as routine use of sterilisation indicators, standardised load-release procedures, and regular audits can significantly improve sterility assurance without substantial financial investment. While digital monitoring tools may enhance performance, practical paper-based systems remain effective where technological resources are limited. Strengthening process control and accountability can improve sterilisation reliability, reduce preventable infections, and support safer surgical care in resource-constrained environments.

Keywords: *Sterilisation Safety; Central Sterile Services Department (CSSD); Sterility Assurance; Process Monitoring; Surgical Patient Safety.*

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MAIN TEXT

Safe sterilization is fundamental to patient safety and the prevention of surgical site infections. In many low-resource healthcare settings, however, deficiencies in sterilization safety arise not primarily from inadequate equipment but from inconsistent monitoring, insufficient staff training, and weak process control. Strengthening these operational elements can substantially improve sterility assurance without requiring significant financial investment [1,2].

Reliable sterilization extends beyond completing an autoclave cycle; it requires systematic verification that critical parameters have been achieved before instruments are released for clinical use [3]. Physical parameters, chemical indicators, and biological indicators each play complementary roles in confirming process effectiveness, with biological indicators providing the highest level of routine sterility assurance when used according to established standards. Nevertheless, their implementation remains inconsistent in many resource-constrained facilities because of financial limitations and the absence of structured policies [4].

An illustrative example highlights the importance of process oversight. Recurrent wet packs following steam sterilization may indicate inadequate drying times or inappropriate loading practices [5]. Rather than requiring new equipment, corrective actions such as restoring recommended drying parameters, retraining personnel, and introducing standardized load-release checklists can effectively eliminate these events while reinforcing accountability and compliance [6].

Equally important is the adoption of practical standard operating procedures that govern every stage of instrument reprocessing, from cleaning and inspection to packaging, sterilization, and release [7]. Regular competency assessments and internal audits ensure that staff understand not only how procedures are performed but also why adherence is essential for patient safety [8].

Digital logbooks and performance dashboards offer additional opportunities to strengthen quality monitoring by tracking sterilization cycles, indicator compliance, and equipment performance [9]. However, their implementation may be constrained by unreliable electricity, limited information technology infrastructure, financial barriers, or insufficient staff training. In such circumstances, well-maintained paper-based records and manually updated audit systems remain practical and effective alternatives until digital solutions become sustainable [10].

Ultimately, improving sterilization safety in low-resource settings depends less on sophisticated technology than on disciplined monitoring, standardized procedures, and a culture of accountability [7]. By emphasizing consistent process control and continuous quality improvement, healthcare facilities can enhance sterility assurance, reduce preventable infections, and strengthen confidence across the entire surgical pathway [10].

CONCLUSION

Improving sterilisation safety in low-resource settings depends on consistent monitoring, standardised procedures, staff competency, and a culture of accountability. These improvements do not necessarily require sophisticated technology or major financial investment; rather, they rely on disciplined process control and continuous quality improvement. By strengthening sterilisation systems and adherence to established standards, healthcare facilities can enhance sterility assurance, reduce preventable infections, and improve patient outcomes. CSSD professionals play a central role in sustaining these improvements through ongoing monitoring, adherence to best practices, and commitment to quality and patient safety.

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The Role of Physiology Knowledge in Improving Sterilization Outcomes

(TORG-NZ Global CSSD Best Practice Essay Competition 2026 - Third Place Winner)

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ABSTRACT

Sterilization remains a critical component of infection prevention and patient safety in surgical care. Despite advancements in sterile processing systems, surgical site infections (SSIs) continue to pose a significant global health burden, particularly in low-resource settings. This commentary examines the role of physiology knowledge in improving sterilization outcomes by linking biological principles to clinical practice. It highlights how an understanding of infection dynamics, immune responses, and systemic complications can enhance adherence to sterilization protocols and reduce preventable harm. It further examines existing gaps in sterilization practices and proposes practical, low-cost strategies for integrating physiology-based training into Central Sterile Department (CSSD) operations. By bridging the gap between scientific knowledge and routine practice, this approach supports improved patient outcomes and aligns with global efforts to strengthen surgical safety and infection prevention.

Keywords: *Sterilization; Surgical Wound Infection; Infection Control; Decontamination; Patient Safety.*

Competition Recognition:
This article was selected as the Third Place Winner of The Operating Room Global New Zealand (TORG-NZ) CSSD Best Practice Essay Competition 2026 and subsequently underwent editorial review prior to publication in The Operating Room Global Journal (TORGJ).

MAIN TEXT

Every surgical procedure begins long before the first incision, with the assurance that every instrument is free from harmful microorganisms. Sterilization, a core function of the Central Sterile Services Department (CSSD), plays a critical role in safeguarding patient health and preventing infections. However, beyond protocols and equipment, a deeper understanding of human physiology is essential for improving sterilization outcomes and ensuring effective patient care.

Surgical site infections remain a major global health challenge. According to WHO's Global Guidelines for the Prevention of Surgical Site Infection, approximately 2–5% of patients undergoing inpatient surgery worldwide acquire an SSI, with significantly higher rates in low- and middle-income countries (LMICs) where infection prevalence may exceed 10% (1). In LMICs specifically, 11% of patients who undergo surgery are infected during the process (2).

The WHO 2024 Global Report on Infection Prevention and Control estimates that on average, 7% of patients in high-income countries and 15% in LMICs acquire at least one healthcare-associated infection (HAI) during their hospital stay. Patients in LMICs have up to 20 times higher risk of acquiring infections during healthcare delivery than those in high-income countries (3).

In Africa, SSI rates reach levels significantly higher than global averages. The GlobalSurg Collaborative reported that SSI incidence more than doubled from high-income countries (7.4%) to middle-income countries (14.4%) to low-income countries (20.0%), with one in three patients from LMICs suffering an SSI in the most contaminated procedures (4). In Africa specifically, up to 20% of women who have a caesarean section contract a wound infection (5). Approximately one in ten patients undergoing surgery in low-resource settings is at risk of acquiring an infection (5).

Physiology and Infection Dynamics

Physiology, the study of how the human body functions, provides essential insight into how infections occur, spread, and affect body systems. During surgical procedures, the body's primary defense (the skin) is intentionally breached, exposing internal tissues to potential microbial invasion. Once pathogens gain access, they proliferate rapidly in nutrient-rich environments such as blood and interstitial fluids. This invasion initiates complex physiological responses including inflammation, immune activation, and metabolic stress. While these responses are protective, they can cause tissue damage, delayed wound healing, and severe systemic complications such as sepsis (6).

From a physiological standpoint, even minimal contamination of surgical instruments can disrupt the body's internal balance, particularly in patients with weakened immune systems or underlying health conditions. Understanding these processes transforms sterilization from a routine technical procedure into a critical, life-preserving intervention. This perspective highlights how foundational biomedical knowledge directly influences clinical outcomes beyond theoretical learning and reinforces the importance of strict adherence to sterilization protocols.

Gaps in CSSD Operational Practices

Despite the importance of sterilization, significant gaps persist in practice, especially in resource-limited environments. CSSD units face challenges including inadequate infrastructure, outdated equipment, and insufficient personnel training. According to the Central Sterile Services Department Guidelines issued by Namibia's Ministry of Health and Social Services, inadequate decontamination of reusable medical devices continues to lead to HAIs across many settings (7).

The CSSD decontamination life cycle illustrates the critical nature of each step. The cycle begins when dirty medical devices are brought to the CSSD, then cleaned, disinfected, inspected, packed, sterilized, transported, stored, used, and transported back to the CSSD. Each step is crucial, an error during any stage may lead to huge costs, serious suffering, and endangerment of patient and healthcare worker lives.

Key CSSD operational requirements include:

CSSD Area	Ventilation (ACH)	Pressure	Temperature
Dirty area	10–20	Negative	18–20°C
IAP area	10–20	Positive	18–23°C
Sterile store	10–20	Positive	15–25°C

Table 1. Key CSSD operational requirements. Adapted from the Namibia CSSD Guidelines (7).

The workflow must be unidirectional from dirty to clean, with physical barriers separating these areas. Steam sterilization is the preferred method for sterilizing critical medical devices, requiring saturated steam under pressure at 121°C or above. Quality assurance through biological indicators, chemical indicators, and Bowie-Dick tests must be performed continuously to validate sterilization effectiveness (8, 7).

In parts of Africa, approximately one in ten patients undergoing surgery is at risk of acquiring an infection (5). These challenges are not solely technical but influenced by human factors: fatigue, inconsistent protocol adherence, and limited awareness of physiological consequences of sterilization failure.

A critical issue underlying these gaps is the disconnect between routine sterilization practices and the biological impact of their failure. When sterile processing is perceived merely as a procedural task rather than a determinant of patient survival, compliance diminishes and errors go unnoticed. Addressing this requires integrating physiological understanding into the

core of sterilization training and practice. When healthcare workers appreciate how microbial contamination can trigger inflammatory cascades, immune dysfunction, or life-threatening complications such as sepsis, the importance of strict adherence to sterilization protocols becomes more evident and personally meaningful.

Integrating Physiology into CSSD Practice

Integrating physiology into sterilization practices offers a practical and impactful strategy for improving outcomes. Training should move beyond procedural instruction to include clear explanations of biological consequences of inadequate sterilization. This fosters informed responsibility, where actions are guided not only by protocols but by understanding their clinical implications.

CSSD staff qualifications and training requirements, per the Namibia CSSD Guidelines (7):

- Entry-level operators: High school completion certificate
- Nurses: Basic CSSD course (6 months)
- Supervisors: Basic CSSD course plus 2 years' experience
- Managers: Advanced CSSD course plus 5 years' experience

All CSSD staff must receive comprehensive training on decontamination processes, IPC principles, and understanding risks related to their work. Continuous education and periodic competency assessments are essential.
Case-based learning, examining real clinical scenarios through a physiological perspective, can strengthen this connection by illustrating how sterilization lapses translate into adverse patient outcomes.

Practical and scalable innovations can enhance physiology knowledge application within sterile processing systems. Low-cost interventions include:

- Visual checklists emphasizing infection risks
- Peer-led microtraining sessions
- Continuous professional education
- Mobile-based learning platforms for ongoing training

These approaches are especially relevant in LMICs, where resource constraints require adaptable, sustainable solutions.
AORN's updated Guideline for Sterilization provides perioperative nurses with guidance for processing, transporting, and storing reusable medical devices, emphasizing selection of processing methods and quality assurance (9). AAMI ST77 standards establish weight limits of 25 pounds for instrument sets and provide comprehensive sterilization container specifications (10). AAMI ST58 and ST41 guidelines govern gas plasma and ethylene oxide sterilizer conformity, respectively (11).

Global Impact and Collective Commitment

Beyond technical improvement, strengthening sterilization practices contributes to a broader global movement toward safer surgical systems. Knowledge sharing among healthcare professionals, continuous education, and recognition of sterile processing as critical to patient care are essential for driving long-term progress.

When healthcare systems invest in sterile processing personnel development and encourage best practice exchange across regions, impact extends beyond individual institutions to the global healthcare community. Such efforts improve technical outcomes and reinforce collective commitment to patient safety and quality care.

CONCLUSION

Ultimately, sterilization is not merely a technical process, but a critical safeguard grounded in human physiology principles. Understanding how infections affect the body transforms sterile processing into a vital component of safe surgical care. As healthcare systems address the SSI burden, particularly in resource-limited environments, integrating physiological knowledge into sterilization practices presents a practical, sustainable solution.

By bridging the gap between science and application, healthcare professionals can improve sterilization outcomes, enhance patient safety, and uphold the fundamental right of every patient to receive carefree from preventable harm.

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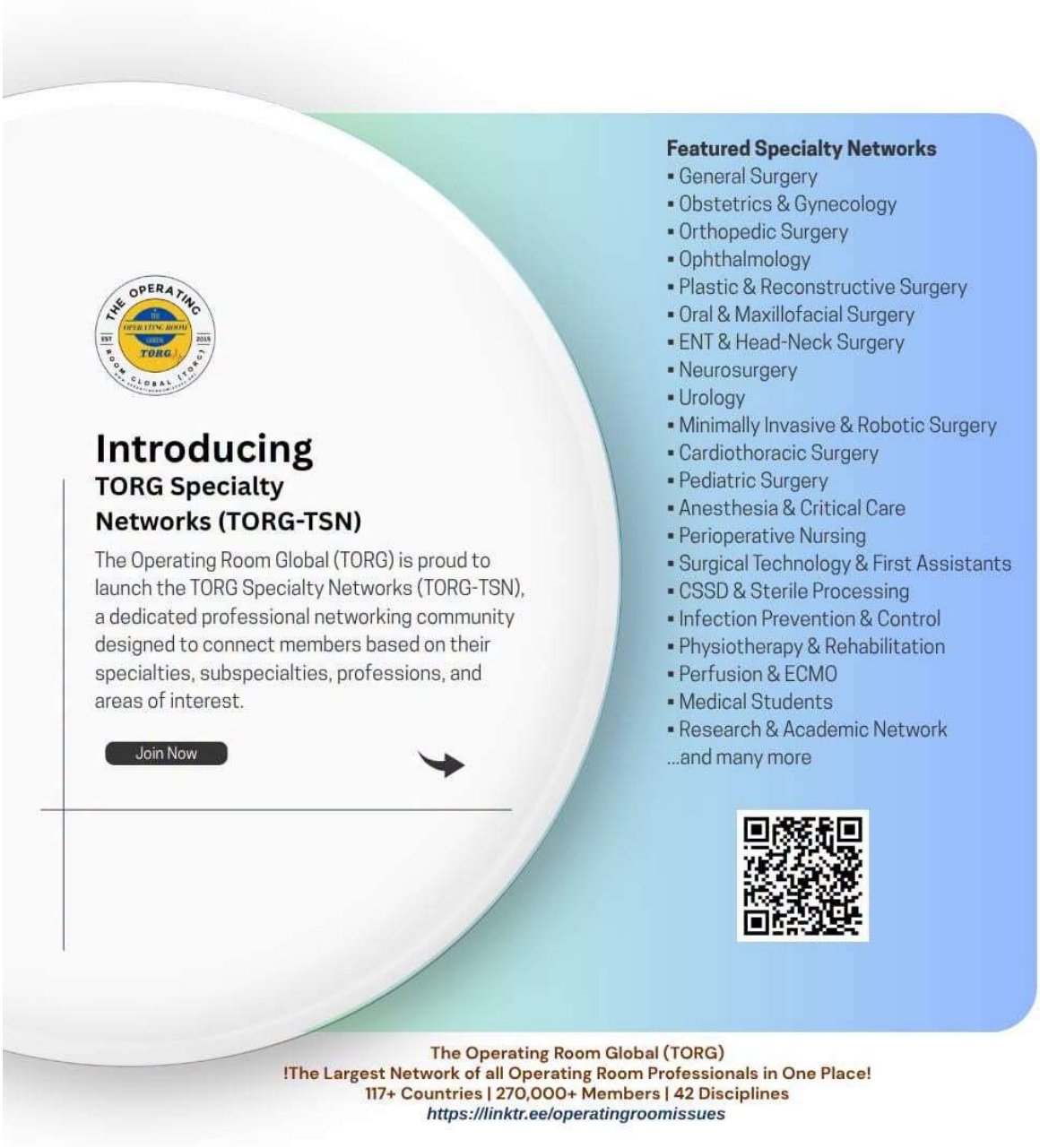
Introducing the TORG Specialty Networks Community (TORG-TSN)



As our global membership continues to grow, The Operating Room Global (TORG) is pleased to launch the *TORG Specialty Networks Community (TORG-TSN). This new initiative provides dedicated spaces for professionals to connect, collaborate, learn, share experiences, participate in research, discuss cases, and engage in specialty-focused educational activities with colleagues from around the world.

Members are encouraged to join one or more specialty groups relevant to their profession, specialty, subspecialty, or area of interest. Whether you are a surgeon, anesthesia provider, perioperative nurse, surgical technologist, infection prevention specialist, perfusionist, physiotherapist, researcher, student, or another member of the surgical and perioperative workforce, there is a network for you.

Join the community and become part of a more focused, collaborative, and connected global professional network. Together, we continue to strengthen collaboration, education, innovation, research, and patient care across the global surgical community.

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