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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 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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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 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

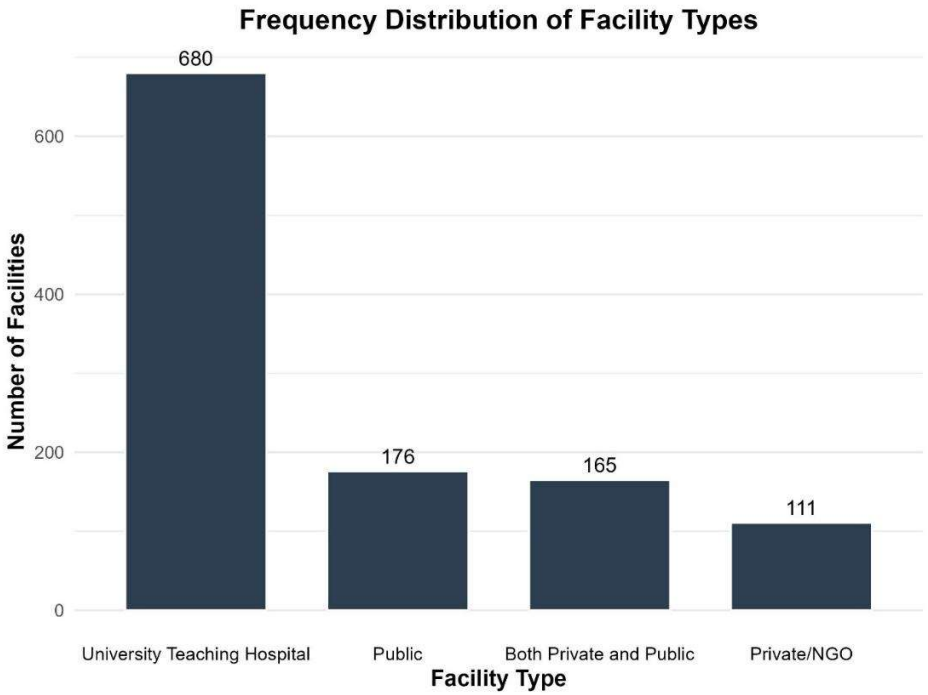
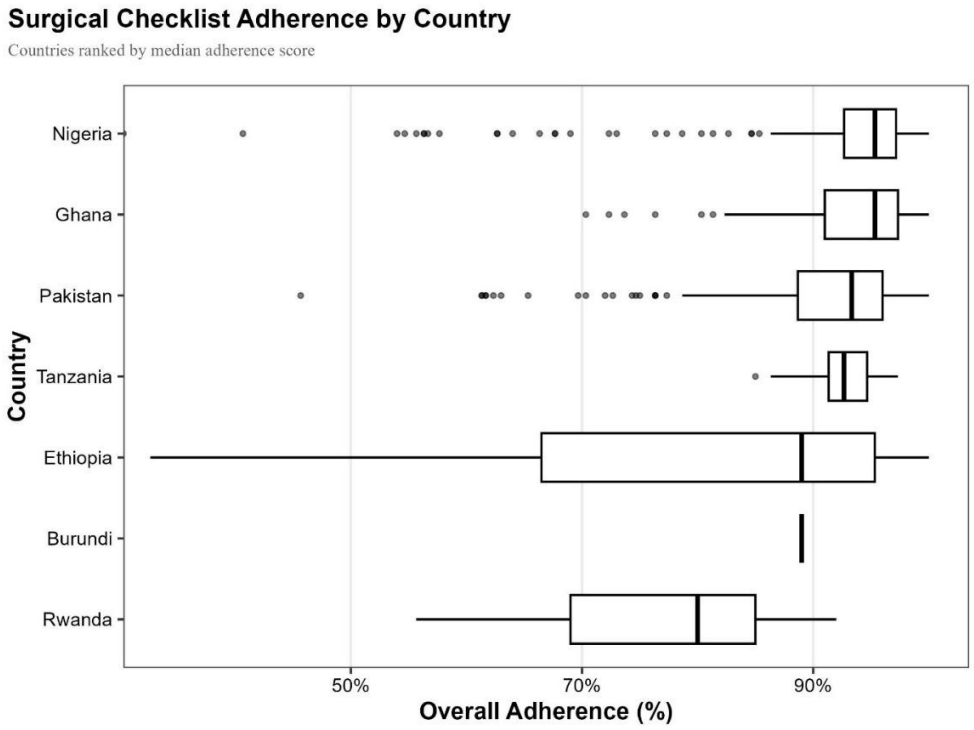
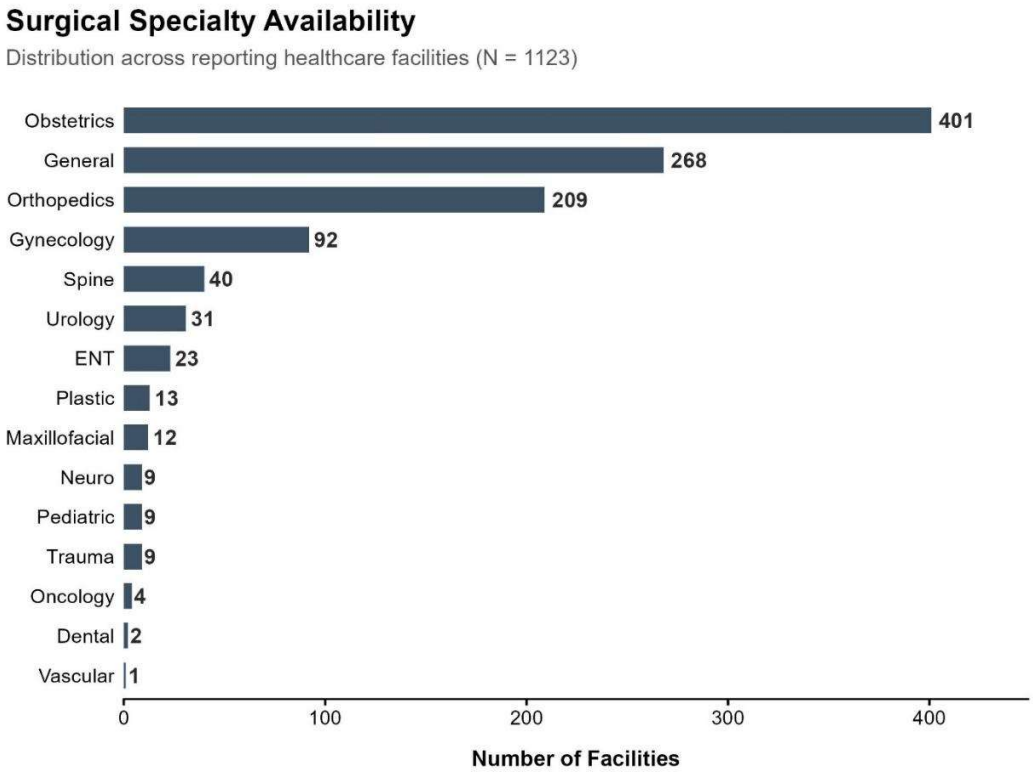


Figure 4. Variation in Checklist Adherence Across Countries



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.

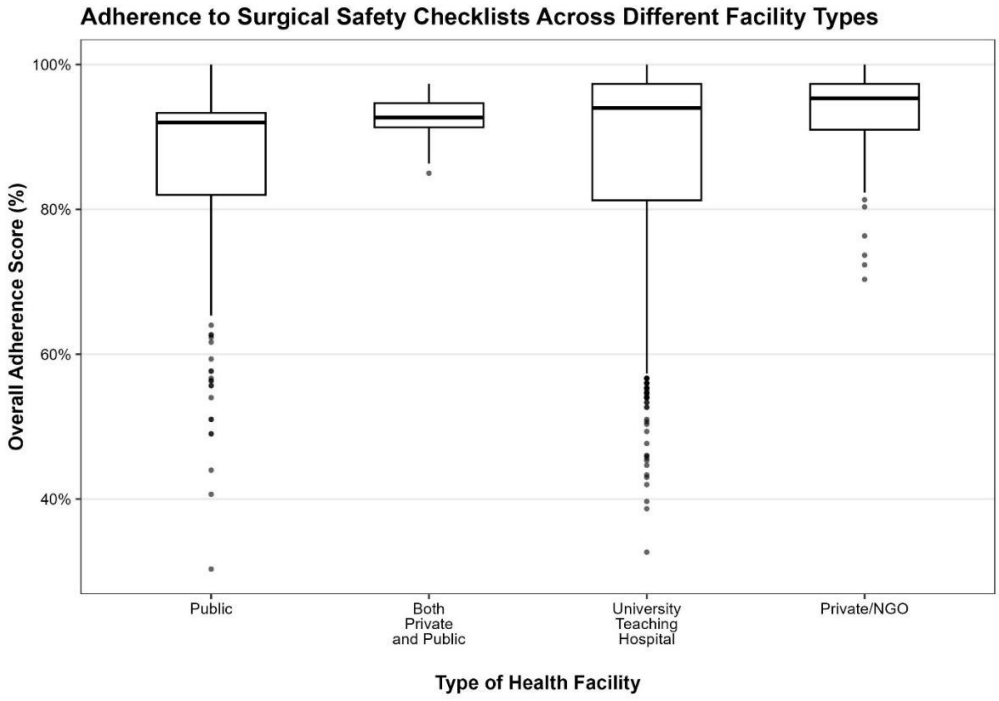
Table 2. Surgical Safety Checklist Non-Adherence by Phase

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

Phase	Safety Item	Non-Adherence Rate (%)
	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.

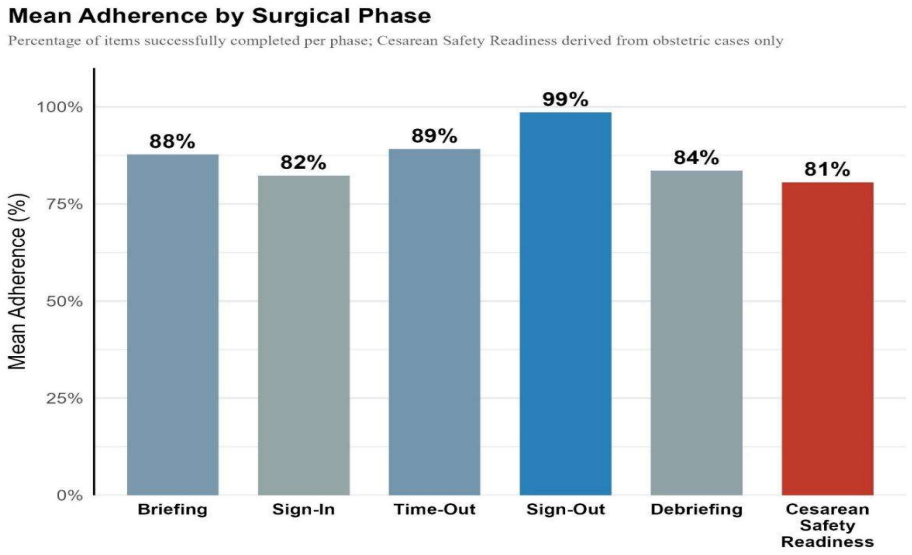
Table 4. Bivariate Analysis of Adverse Events Prevented

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 procepp

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 $n \geq 30$ 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

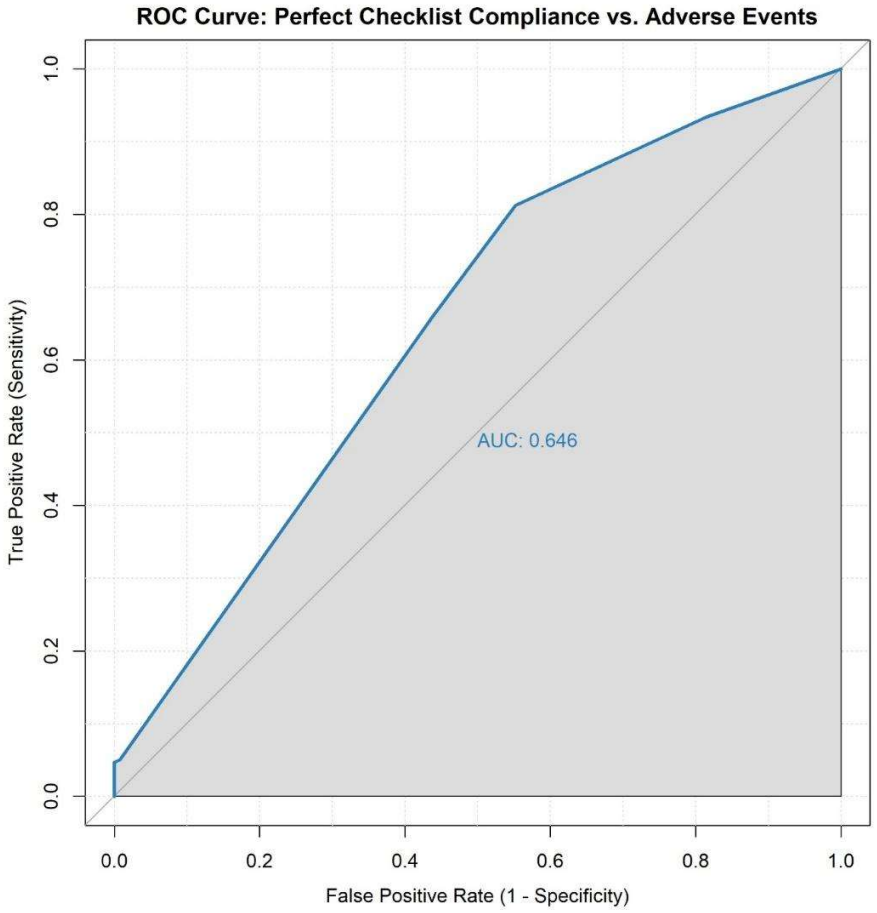
[1]OR = Odds Ratio, CI = Confidence Interval

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.

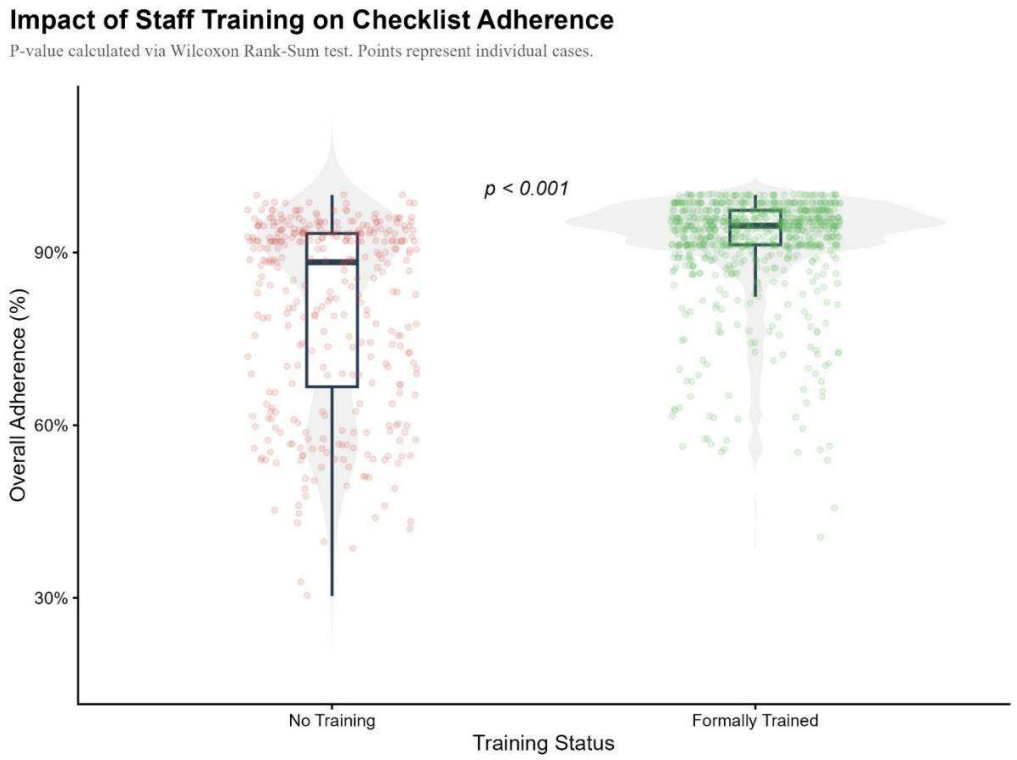
Table 10. Completion of Essential Cesarean Safety Measures

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%)

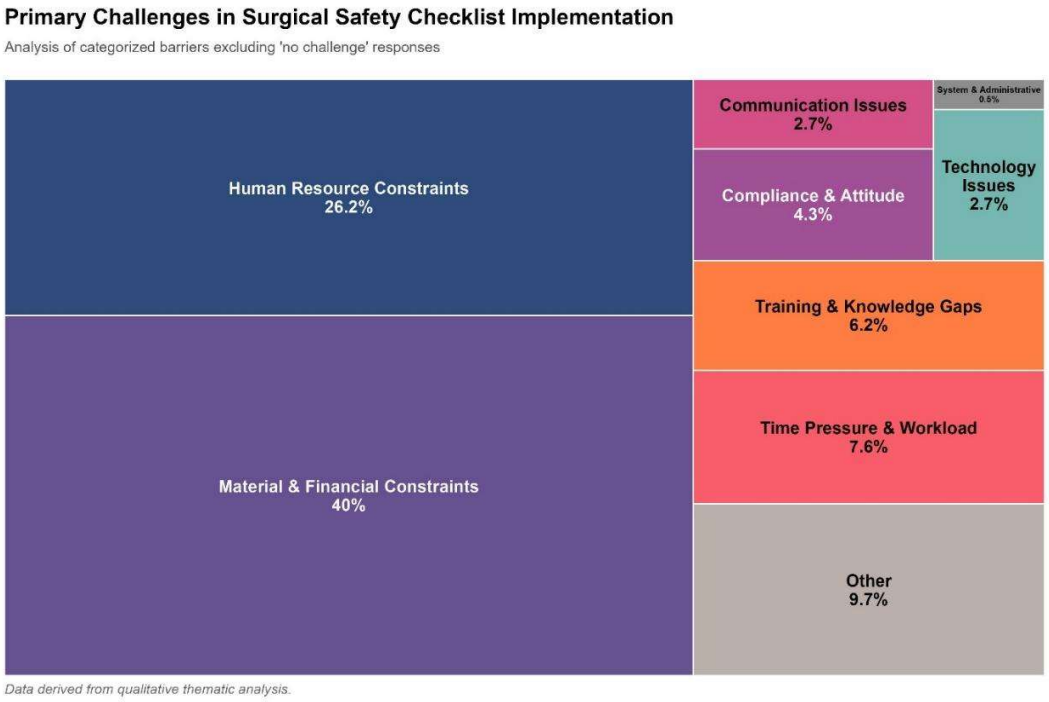
[1]n (%)

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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