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Identified practice gaps and opportunities in anesthesia safety across 14 Arab countries: a multicenter study

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Identified practice gaps and opportunities in anesthesia safety across 14 Arab countries: a multicenter study

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Abstract

Background: Safe anesthesia is fundamental to safe surgery and depends on facility readiness, team behaviors, and consistent adherence to safety standards such as the World Health Organization (WHO) Surgical Safety Checklist. Across the Arab region, variability in workforce capacity, equipment and supplies, and checklist implementation may contribute to uneven safety performance, yet multicountry data describing readiness and routine anesthesia safety practices remain limited. We therefore assessed facility readiness and clinicians' knowledge, attitudes, and self-reported safety practices, and examined how checklist use and perceived barriers relate to these domains across fourteen Arab countries.

Methods: We conducted a multicountry online cross-sectional survey of anesthesia team members working in hospital operating theatres and procedural anesthesia locations across fourteen Arab countries. The survey evaluated facility readiness, knowledge, attitudes, and self-reported safety practices, and captured frequency of surgical safety checklist use and perceived barriers to safe anesthesia practice.

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Results: Overall, facility readiness and participants' knowledge, attitudes, and self-reported safety practices were generally high; however, routine checklist use was not universal. Commonly reported barriers included understaffing and workload pressure, as well as financial constraints affecting equipment and supplies. More frequent checklist use was associated with better safety-related performance across assessed domains, whereas a higher barrier burden was associated with poorer readiness and self-reported practice.

Conclusions: Although anesthesia safety performance was generally favorable across surveyed settings, important implementation and systems gaps remain, particularly in routine checklist use and resource-related constraints. Strengthening workforce capacity, ensuring access to essential equipment and supplies, and embedding meaningful, high-fidelity checklist use may help reduce residual safety gaps and support safer anesthesia care across diverse hospitals in the Arab region.

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Keywords: Anesthesia; patient safety; surgical safety checklist; perioperative safety; intraoperative complications; operating theatres; Arab region

Trial registration: Not applicable. (This study is an observational cross-sectional survey and did not involve prospective assignment to a health-related intervention.)

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Background

Surgical and anesthetic care is delivered at an immense global scale, with hundreds of millions of operations performed each year, making perioperative safety a major public-health priority [1,2]. Despite advances in technique and technology, avoidable postoperative morbidity and mortality remain substantial, and global estimates suggest that postoperative deaths constitute a large share of preventable health loss [3]. These safety gaps disproportionately affect low- and middle-income

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settings, where health systems face greater constraints in workforce, infrastructure, and access to timely, high-quality surgical and anesthesia services [2].

Safe anesthesia is a cornerstone of safe surgery because anesthetic care directly influences airway/ventilation, hemodynamic stability, and early recognition and management of deterioration [4]. International guidance emphasizes that preventable harm is reduced when trained anesthesia personnel remain continuously present, essential drugs and equipment are reliably available, and minimum monitoring standards (e.g., pulse oximetry, blood pressure measurement, ECG as indicated, and CO_2 detection/capnography where appropriate) are consistently applied [5–7]. However, persistent inequities in resources and implementation contribute to ongoing variability in anesthesia-related outcomes across regions and health-system levels [4].

Beyond individual competencies, contemporary patient-safety science highlights the value of system-level interventions that standardize critical steps, strengthen teamwork, and improve communication [8,9]. The WHO Surgical Safety Checklist (SSC) is one of the most widely disseminated perioperative safety tools, structured around “Sign In,” “Time Out,” and “Sign Out,” and has been associated with reductions in perioperative complications and mortality in diverse settings when meaningfully implemented [8,10,11]. Nevertheless, real-world adoption and fidelity are inconsistent, and sustained benefit

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depends on local leadership, team engagement, workflow integration, and continuous quality improvement rather than mere "tick-box" completion [12,13].

In the Arab region, hospitals vary widely in case-mix, staffing models, training pathways, and the availability of essential monitoring and recovery resources, factors that can influence both SSC uptake and broader anesthesia safety practices. Measuring these determinants requires more than counting checklist use; it requires assessing (i) facility readiness (e.g., availability of pulse oximetry, NIBP, ECG, reliable oxygen, suction, capnography/CO_2 detection, and recovery-area resources) and (ii) provider knowledge, attitudes, and routine practices related to international safety standards and checklist behaviors [14]. The WHO Global Patient Safety Action Plan further underscores the need for context-specific measure implementation gaps across countries and care settings [15].

Therefore, we conducted a multi-center cross-sectional study among anesthesia providers in Arab hospitals to evaluate anesthesia safety using a structured instrument specifically designed to capture SSC use, facility readiness, and provider knowledge, attitudes, and practices aligned with international standards. The aim of this study was to estimate the level of anesthesia safety readiness, knowledge, attitudes, and practices among anesthesia providers in Arab hospitals, and to identify modifiable system and workforce factors, particularly Surgical Safety Checklist adoption and perceived barriers, associated with higher anesthesia safety performance.

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Methods

Study design, setting, and study period

We conducted a multi-country, multi-institutional cross-sectional survey assessing anesthesia safety knowledge, attitudes, and practices (KAP), together with perceived facility readiness and barriers to safe anesthesia delivery. Data were collected using an anonymous, self-administered online questionnaire between 31/12/2025 and 15/01/2026 across Arab hospitals in Palestine, Iraq, Libya, Jordan, Egypt, Yemen, Tunisia, Syria, United Arab Emirates, Kingdom of Saudi Arabia, Qatar, Lebanon, Sudan, and Oman. Reporting was guided by established recommendations for cross-sectional studies and internet-based surveys. Participating hospitals are listed in Table 1, including the hospital name, country, and a brief descriptor of institutional scope/type and facility size/level.

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Table 1. Participating hospitals by country, with institutional scope/type and facility size/level

Country	Participating hospital	Institutional scope/type	Facility size/level*
Palestine	An-Najah National University Hospital	University-affiliated general hospital	Tertiary referral center
Palestine	Rafidya Hospital	Government general hospital	Tertiary referral center
Palestine	Palestine Medical Complex	Government medical complex/referral hospital	Tertiary referral center
Palestine	Nasser Medical Complex	Government medical complex/referral hospital	Tertiary referral center
Palestine	Al-Shifa Hospital, Gaza	Government referral hospital	Tertiary referral center
Iraq	Medical City	Government medical complex/teaching referral center	Tertiary referral center
Iraq	Baghdad Teaching Hospital	Government teaching hospital	Tertiary referral center
Iraq	Al-Sadar Teaching Hospital	Government teaching hospital	Tertiary referral center

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Iraq	Al-Hussain Teaching Hospital	Government teaching hospital	Tertiary referral center
Libya	Aljala Hospital, Benghazi	General/teaching hospital	Tertiary referral center
Libya	Benghazi Medical Center	Medical center/referral hospital	Tertiary referral center
Libya	Tripoli Medical Center	Medical center/referral hospital	Tertiary referral center
Jordan	Jordan University Hospital, Amman	University hospital	Tertiary referral center
Jordan	King Hussein Cancer Center, Amman	Specialist cancer center	Tertiary referral center/quaternary
Jordan	King Abdullah University Hospital, Ar Ramtha	University hospital	Tertiary referral center
Egypt	National Health Institute, Cairo	National referral/specialist institute	Tertiary referral center
Yemen	Al-Thawrah Modern General Hospital, Sana'a	Government general/teaching hospital	Tertiary referral center

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Yemen	Al-Sabeen Hospital for Maternity and Childhood, Sana'a	Specialist maternity and children’s hospital	Tertiary referral center
Yemen	Algamhoryah Teaching Hospital, Aden	Government teaching hospital	Tertiary referral center
Tunisia	Children’s Hospital Bechir Hamza, Tunis	Specialist children’s hospital	Tertiary referral center
Tunisia	Charles Nicolle Hospital, Tunis	University/teaching hospital	Tertiary referral center
Tunisia	Military Hospital, Tunis	Military hospital	Tertiary referral center
Tunisia	La Rabta Hospital, Tunis	University/teaching hospital	Tertiary referral center
Tunisia	Habib Thameur Hospital, Tunis	University/teaching hospital	Tertiary referral center
Tunisia	Mongi Slim Hospital, La Marsa	General hospital	Community hospital
Tunisia	Mohamed Kassab Institute of Orthopedic Surgery, Manouba	Orthopedic specialty institute	Tertiary referral center

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Tunisia	Sahloul Hospital, Sousse	University/teaching hospital	Tertiary referral center
Tunisia	Tahar Sfar Hospital, Mahdia	Regional general hospital	Community hospital
Syria	Al-Mowasat University Hospital	University hospital	Tertiary referral center
United Arab Emirates	CMC Hospital, Dubai	Private hospital	Community hospital
Kingdom of Saudi Arabia	King Faisal Specialist Hospital & Research Centre	Specialist academic/referral hospital	Quaternary
Kingdom of Saudi Arabia	King Saud Medical City	Government medical city/referral center	Tertiary referral center
Kingdom of Saudi Arabia	King Abdulaziz Medical City, Riyadh	Academic/government tertiary referral hospital	Tertiary referral center/quaternary
Kingdom of Saudi Arabia	King Abdulaziz Medical City, Jeddah	Academic/government tertiary referral hospital	Tertiary referral center/quaternary

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Kingdom of Saudi Arabia	King Abdulaziz Hospital, Al-Ahsa	Government hospital	Tertiary referral center
Kingdom of Saudi Arabia	Prince Imam Abdulrahman Al Faisal Hospital, Dammam	Government hospital	Tertiary referral center
Kingdom of Saudi Arabia	Prince Mohammed Bin Abdulaziz Hospital, Medina	Government hospital	Tertiary referral center
Kingdom of Saudi Arabia	King Salman Specialized Hospital, Taif	Specialized/government hospital	Tertiary referral center
Kingdom of Saudi Arabia	King Salman bin Abdulaziz Hospital, Riyadh	Government general hospital	Tertiary referral center
Kingdom of Saudi Arabia	Al-Iman General Hospital, Riyadh	Government general hospital	Tertiary referral center
Kingdom of Saudi Arabia	King Khaled Hospital, Al Kharj	Government general hospital	Tertiary referral center

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Kingdom of Saudi Arabia	Al Yamamah Hospital, Riyadh	Specialist maternity/children's hospital	Tertiary referral center
Kingdom of Saudi Arabia	Al-Zulfi General Hospital	Government general hospital	Community hospital
Kingdom of Saudi Arabia	Hotat Sudair Hospital	Government general hospital	Community hospital
Qatar	Naseem Surgical & Medical Centre - C Ring	Private surgical/medical center	Secondary
Qatar	Al-Ahli Hospital	Private general hospital	Community hospital
Qatar	The View Hospital	Private multispecialty hospital	Tertiary referral center
Lebanon	Rosary Hospital, Beirut	Private general hospital	Community hospital
Lebanon	Beirut Governmental Hospital	Government hospital	Tertiary referral center
Lebanon	Hayat Hospital, Beirut	Private general hospital	Community hospital
Sudan	Kassala Teaching Hospital	Teaching hospital	Tertiary referral center

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Sudan	Madani Teaching Hospital	Teaching hospital	Tertiary referral center
Sudan	Sudan Sea Ports Hospital	General hospital	Community hospital
Sudan	Al Naw Teaching Hospital	Teaching hospital	Tertiary referral center
Oman	Sultan Qaboos University Hospital	University hospital	Tertiary referral center

Footnote: * Facility size/level is presented as a broad institutional descriptor to characterize participating centers within this multicountry survey.

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Participants, eligibility criteria, and recruitment

Eligible participants were post graduate and undergraduate anesthesia physicians, technicians and nurses and are currently in clinical practice as members of the anesthesia team (physicians, nurses, and other anesthesia staff) working in operating rooms and/or procedural anesthesia locations in participating countries during the study period. We excluded individuals not in clinical practice and surveys that were incomplete (<80% completion or missing any domain items).

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Recruitment was performed through open regional dissemination of a Google Forms link via email and WhatsApp messages. Participation was voluntary and unrestricted across the region. Because the survey link was disseminated openly (with potential forwarding across networks), a conventional response rate (invitations sent/opened vs completed) could not be robustly calculated. However, the number of submitted responses was continuously observable through the Google Forms interface during data collection.

Survey instrument and content validity

The questionnaire comprised six sections (A-F) and required approximately 8-12 minutes to complete. Section A collected demographic and workplace characteristics (country/city; hospital level; hospital type; main anesthesia setting; professional role; years of experience; weekly caseload; recent patient-safety training; and operating room surgical safety checklist use). Sections B-E evaluated the four main study domains:

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- **Facility readiness** (14 items): availability of essential monitoring/equipment and recovery-area resources.
- **Knowledge** (17 items): statements reflecting international anesthesia safety standards and key elements/timing of checklist-based perioperative safety processes.
- **Attitude** (10 items): perceptions regarding anesthesia safety, guideline adherence, and safety culture.

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- **Practice** (17 items): frequency of checklist-related and safety-related behaviors across peri-induction, intraoperative, and recovery phases.

Section F assessed perceived barriers to safe anesthesia practice using a multiple-response list (participants could select any number of barriers), with optional free-text items for additional barriers and improvement suggestions.

Instrument development was anchored in internationally endorsed frameworks, including the World Health Organization surgical safety checklist implementation guidance and the World Federation of Societies of Anesthesiologists–WHO international standards for safe anesthesia practice [5,16]. The knowledge and attitude content included items adapted from peer-reviewed literature and guideline-based constructs, while other sections were newly developed to capture regionally relevant operational readiness and barriers. Content validity was evaluated by an expert panel (anesthesiology and perioperative safety experts), who reviewed items for relevance, clarity, and coverage. No pilot testing or internal consistency (e.g., Cronbach's alpha) analyses were performed. **The full survey questionnaire is provided in Additional file 1.**

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Data collection and data management

The survey was conducted electronically, preceded by an information sheet and an electronic consent statement. No patient identifiers were collected, and responses were anonymous. To reduce duplicate submissions, the Google Form was configured to limit to one response per participant. Data were stored in a password-protected Google Drive account with access restricted to the research team.

Outcomes, coding, and score construction

Operating room SSC use frequency was assessed on a 5-level ordinal scale (never, rarely, sometimes, often, always) and coded 0–4 for analysis.

For each domain, raw scores were computed by summing item codes based on prespecified rules:

1. **Readiness**: Always available = 2; Sometimes available = 1; Not available = 0; “Don’t know” coded as missing.
2. **Knowledge**: Correct = 1; Incorrect/ “Don’t know” = 0.
3. **Attitude**: Collected on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) and recorded to 0-4 for scoring.

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4. **Practice**: Never = 0; Rarely = 1; Sometimes = 2; Often = 3; Always = 4; "Not applicable" coded as 0.

Raw domain scores were converted to a 0-100 scale by dividing the raw score by the number of items, then multiplying by (100 / maximum possible code) for that domain to facilitate comparability across domains. Domain scores were categorized as poor (<60%), moderate (60% to <80%), and high (>=80%). The barriers variable was operationalized as a count (0-9) reflecting the number of predefined barriers selected; "Other" responses were summarized descriptively.

Statistical analysis

Analyses were performed using IBM SPSS Statistics v31.0. Categorical variables were summarized using frequencies and percentages. As domain scores were non-normally distributed, continuous outcomes were summarized using medians and interquartile ranges (IQR). Group differences in domain scores were assessed using Mann–Whitney U tests for dichotomous predictors and Kruskal–Wallis tests for predictors with more than two categories. Spearman's rank correlation was used to examine intercorrelations between domain scores and associations with the barrier count.

For multivariable analysis, multiple linear regression models were constructed for each domain score (readiness, knowledge, attitude, practice). Predictors demonstrating significant associations in univariate analyses were entered into the corresponding multivariable model. Surgical Safety Checklist (SSC) use frequency was modeled as an ordinal predictor (not

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dichotomized), and barriers were entered as a count variable. For non-dichotomous categorical predictors (e.g., hospital level/type), dummy variables were created with a prespecified reference category. Model diagnostics included multicollinearity assessment; variance inflation factor (VIF) values <5 were considered acceptable. Statistical significance was set at $p < 0.05$ (two-sided).

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Institutional Review Board of An-Najah National University (protocol No. Med. Dec. 2025/73; approved on 30 December 2025). The study was conducted in accordance with the Declaration of Helsinki and its later amendments. Written electronic informed consent was obtained from all participants before they accessed the questionnaire. Participation was voluntary and anonymous, and no identifiable personal data were collected.

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Results

Overall, 604 anesthesia team members participated in the study (Table 2). Most respondents worked in level 3 (tertiary) hospitals (65.9%), and nearly half were based on governmental institutions (49.3%). Hospital types were predominantly governmental (49.3%) or teaching/university (29.1%). The most frequently reported anesthesia settings were the main operating room (89.4%), obstetrics/gynecology (61.3%), and pediatrics (58.3%). Residents/trainees constituted 35.6% of participants; 29.0% reported 4–7 years of anesthesia experience and 60.9% reported >20 cases per week. In the preceding 24 months, 58.6% attended a patient-safety lecture/seminar, and 40.9% reported that the Surgical Safety Checklist (SSC) was always used in their operating room. Distributions of hospital level, main clinical settings, professional roles, recent patient-safety training, and operating-room SSC use are provided in **Figures 1–5**.

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Table 2: Participant demographics and workplace characteristics

Variables	Categories	Frequency	Percentage
Hospital level	Level 1 (district/primary)	75	12.4%
	Level 2 (regional/secondary)	93	15.4%
	Level 3 (tertiary)	398	65.9%
	Not sure	38	6.3%
Hospital type	Governmental	298	49.3%
	Private	89	14.7%
	Teaching/university	176	29.1%
	Military	20	3.3%
	NGO/non-profit	21	3.5%
Main anesthesia setting(s)	Main operating room	540	89.4%
	Obstetrics/gynecology	370	61.3%
	Pediatrics	352	58.3%

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	Endoscopy/GI procedures	322	53.3%
	Cardiac cath. /interventional radiology	208	34.4%
	Radiology/MRI	267	44.2%
Professional role	Consultant anesthesiology	165	27.3%
	Specialist anesthesiology	127	21.0%
	Anesthesia resident / trainee	215	35.6%
	Nurse anesthesia	12	2.0%
	Non-specialist physician anesthetist	2	0.3%
	Anesthesia technician / assistant	83	13.7%
Experience in anesthesia	< 1 year	24	4.0%
	1-3 years	131	21.7%
	4-7 years	175	29.0%
	8-15 years	128	21.2%
	> 15 years	146	24.2%
Average weekly anesthesia cases	0-5 cases	16	2.6%

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	6-10 cases	62	10.3%
	11-20 cases	158	26.2%
	> 20 cases	368	60.9%
Patient-safety training in the last 2 years	Lecture/seminar	354	58.6%
	Hands-on workshop	167	27.6%
	Simulation training	104	17.2%
	Online course	125	20.7%
Does your OR use SSC?	Never	50	8.3%
	Rarely	72	11.9%
	Sometimes	101	16.7%
	Often	134	22.2%
	Always	247	40.9%

Notes: Data are n (%) unless stated otherwise. Abbreviations: OR, operating room; SSC, Surgical Safety Checklist; NGO, non-governmental organization; GI, gastrointestinal; MRI, magnetic resonance imaging.

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Figure 1: Hospital level of participating institutions (n=604)

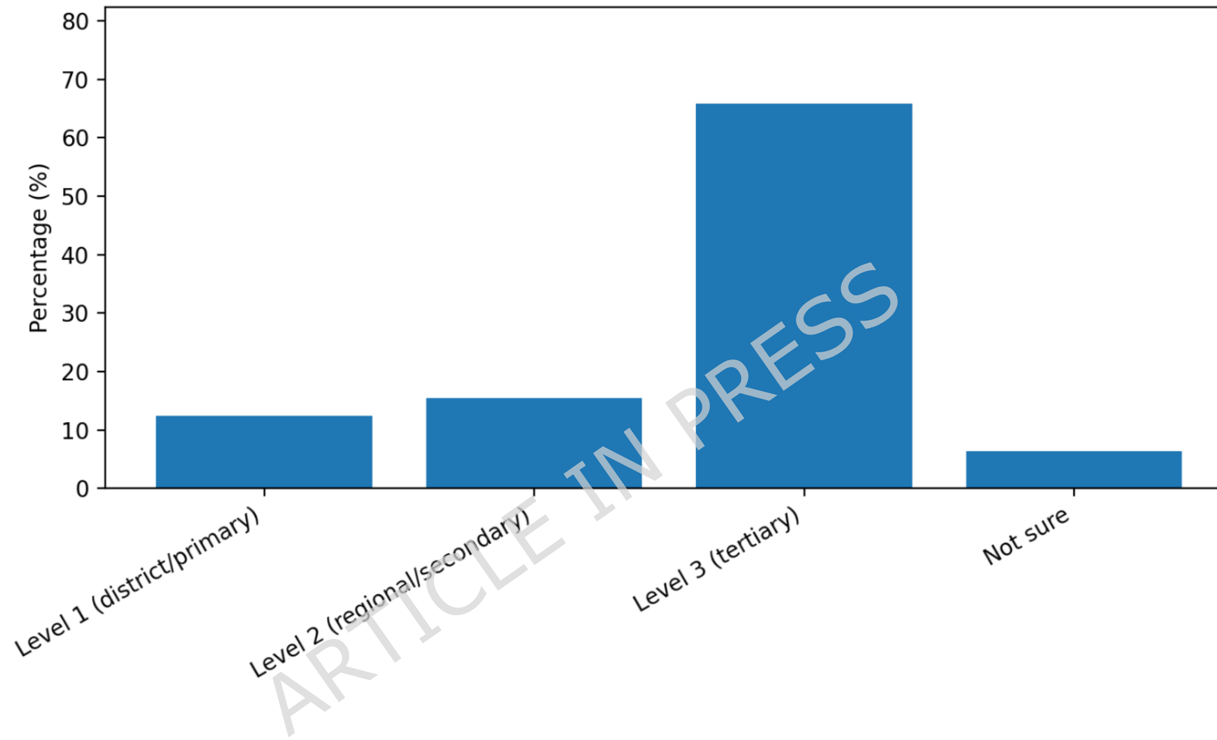

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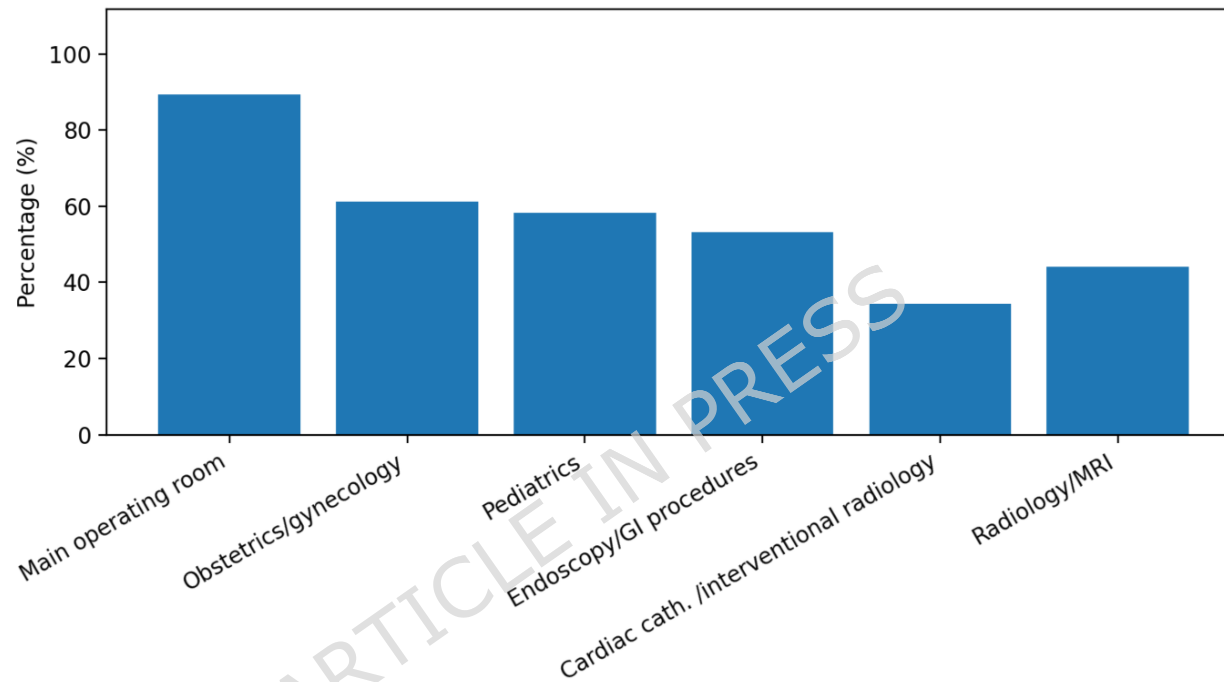
Figure 2: Main anesthesia clinical settings reported by participants (multiple responses; n=604)



Note: Percentages may sum to >100% because multiple settings/training types could be selected

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Figure 3: Professional roles of participants (n=604)

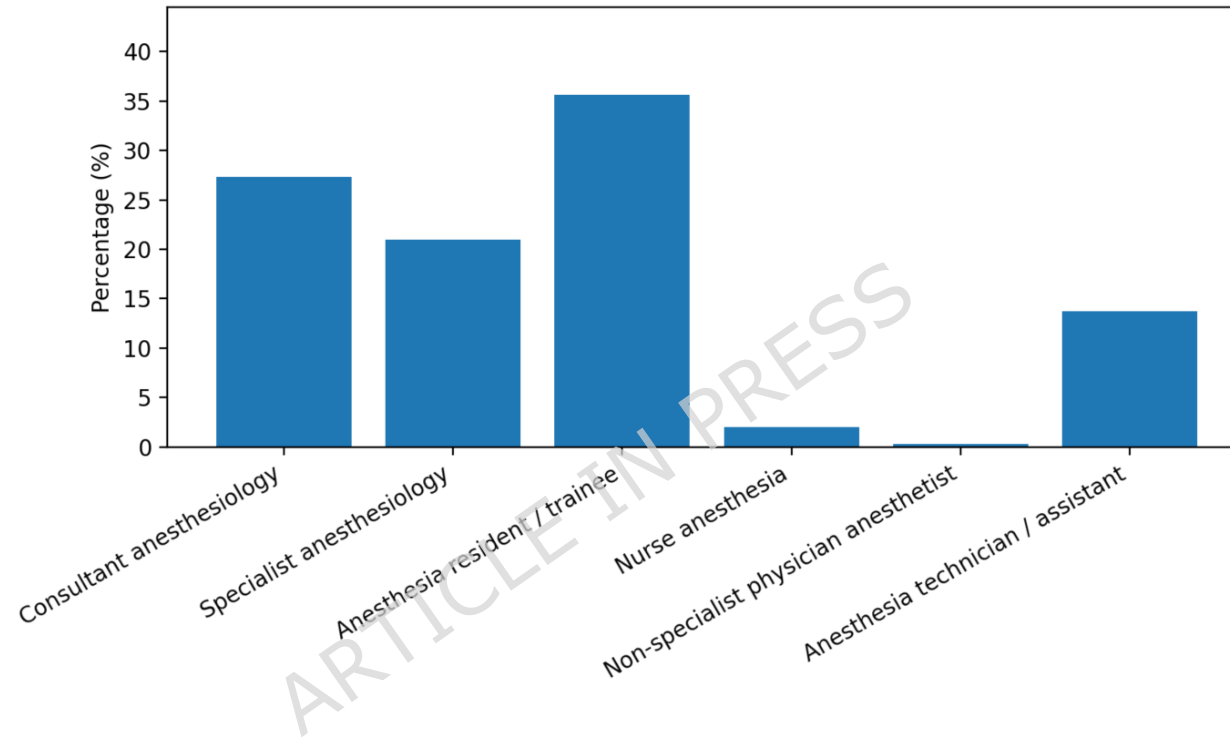
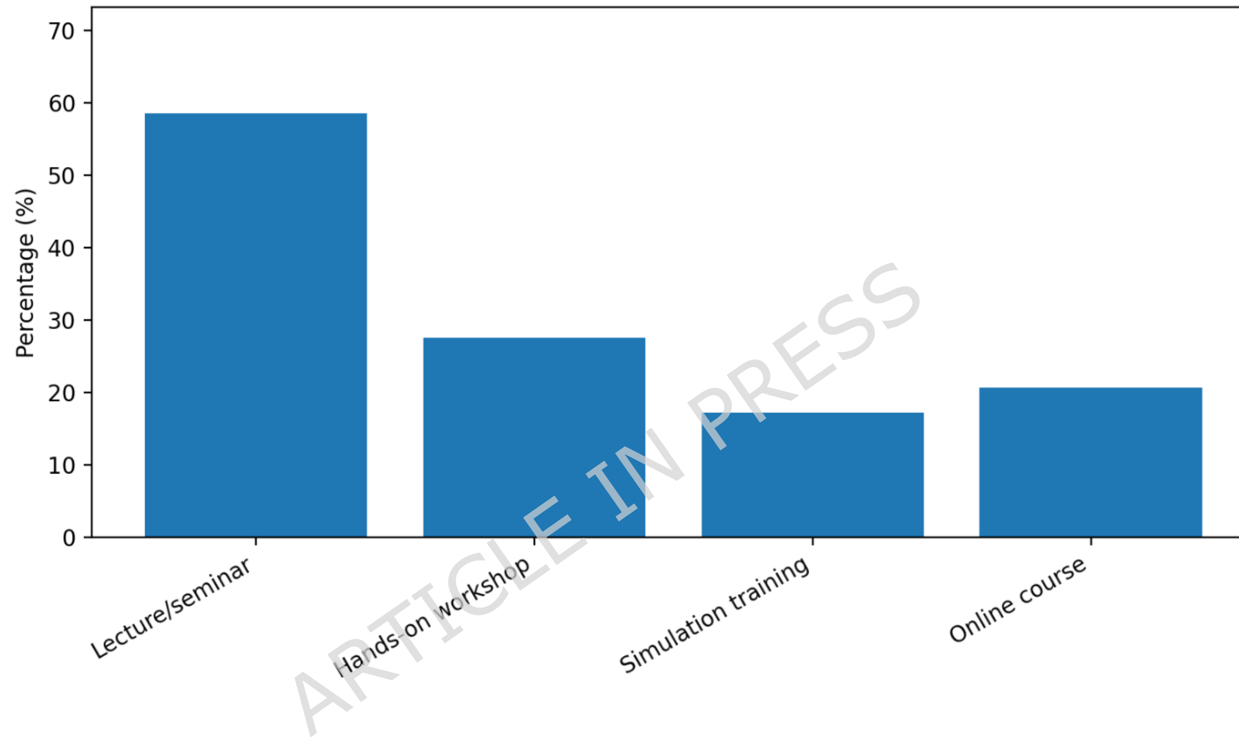


Figure 4: Patient-safety training attended in the last 2 years (multiple responses; n=604)



Note: Percentages may sum to >100% because multiple settings/training types could be selected

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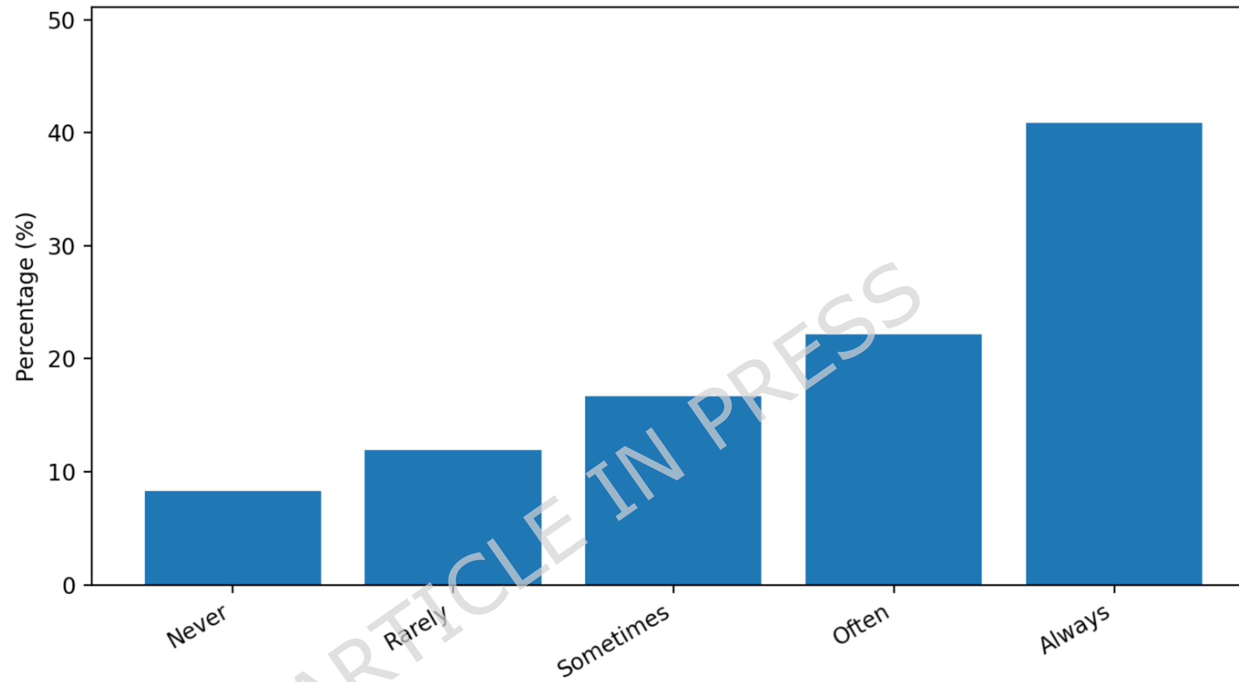
Figure 5: Frequency of Surgical Safety Checklist (SSC) use in the operating room (n=604)



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Median standardized domain scores (0–100) were high (Table 3): readiness 89.29 (IQR 14.29), knowledge 94.12 (IQR 17.65), attitude 85.00 (IQR 22.50), and practice 91.18 (IQR 14.71). High performance (≥80%) was observed in 75.8% for readiness, 76.3% for knowledge, 66.1% for attitude, and 77.8% for practice. Item-level distributions are provided in **Tables 4–7.**

Table 3: Standardized domain scores for anesthesia safety (readiness, knowledge, attitude, and practice)

Domain	Poor		Moderate		High		Mean ± SD	Median (IQR)
	N	%	N	%	N	%		
Readiness	17	2.9%	124	21.3%	442	75.8%	87.38 ± 12.12	89.29 (14.29)
Knowledge	59	9.8%	84	13.9%	461	76.3%	88.10 ± 15.69	94.12 (17.65)

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Attitude	79	13.1%	126	20.9%	399	66.1%	77.92 ±24.69	85.00 (22.50)
Practice	15	2.5%	119	19.7%	470	77.8%	88.31 ± 11.35	91.18 (14.71)

Notes: Scores are scaled 0-100. Poor/moderate/high categories are defined in Methods. Abbreviations: SD, standard deviation; IQR, interquartile range.

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Table 4: Distribution of participants' responses to questions related to facility readiness in terms of equipment and monitoring

Statement	**Always**		**Sometimes**		**Not available**		**Don't know**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Pulse oximeter every anesthetic case	598	99.0%	4	0.7%	2	0.3%	0	0.0%
Audible pulse oximeter tone and alarm	561	92.9%	33	5.5%	7	1.2%	3	0.5%

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NIBP monitor with appropriate cuffs	540	89.4%	57	9.4%	6	1.0%	1	0.2%
ECG monitoring	457	75.7%	134	22.2%	13	2.2%	0	0.0%
CO_2 detection for intubation	363	60.1%	177	29.3%	64	10.6%	0	0.0%
Continuous waveform capnography	374	61.9%	177	29.3%	52	8.6%	1	0.2%
A ventilator disconnection alarm	527	87.3%	54	8.9%	18	3.0%	5	0.8%
Temperature monitoring	154	25.5%	312	51.7%	134	22.2%	4	0.7%
Reliable oxygen source	558	92.4%	35	5.8%	5	0.8%	6	1.0%
Functional suction device at induction	552	91.4%	47	7.8%	3	0.5%	2	0.3%

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Adult and pediatric bag-mask ventilation equipment	559	92.5%	43	7.1%	2	0.3%	0	0.0%
Defibrillator accessible in or near OR	504	83.4%	76	12.6%	20	3.3%	4	0.7%
A designated PACU/recovery room exists	440	72.8%	119	19.7%	45	7.5%	0	0.0%
In recovery: oxygen, suction, and bag-mask ventilation	469	77.6%	106	17.5%	28	4.6%	1	0.2%

Notes: Data are presented as n (%). NIBP = non-invasive blood pressure; ECG = electrocardiogram; CO2 = carbon dioxide; OR = operating room; PACU = post-anesthesia care unit.

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Table 5: Distribution of participants' responses to statements related to knowledge of international anesthesia safety standards

Statement	**True**		**False**		**Don't know**	
	N	**%**	**N**	**%**	**N**	**%**

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One trained and vigilant anesthesia provider should remain continuously present during anesthesia until recovery or transfer of care	596	98.7%	6	1.0%	2	0.3%
Tissue oxygenation should be continuously monitored by both clinical observation and pulse oximetry	585	96.9%	9	1.5%	10	1.7%
Non-invasive blood pressure should usually be measured at least every 5 minutes during anesthesia	573	94.9%	28	4.6%	3	0.5%
If an endotracheal tube is used, correct placement must be verified by auscultation	560	92.7%	42	7.0%	2	0.3%
CO_2 detection is highly recommended to confirm correct placement of an endotracheal tube	563	93.2%	31	5.1%	10	1.7%
Use of a Surgical Safety Checklist (modified locally if needed) is highly recommended by WHO and WFSA	523	86.6%	13	2.2%	68	11.3%
A structured system for handover (transfer of care) at end of anesthesia is part of safe practice standards	556	92.1%	9	1.5%	39	6.5%
All medications should be clearly labeled and dated	596	98.7%	6	1.0%	2	0.3%

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	Patients should be monitored in a designated recovery area until recovery of consciousness	592	98.0%	7	1.2%	5	0.8%
	In recovery, continuous pulse oximetry and intermittent blood pressure monitoring are highly recommended	592	98.0%	7	1.2%	5	0.8%
	The "Sign In" checklist step occurs before induction of anesthesia	529	87.6%	16	2.6%	59	9.8%
	The "Time Out" checklist step occurs before skin incision	422	69.9%	59	9.8%	123	20.4%
	The "Sign Out" checklist step occurs before the patient leaves the operating room	451	74.7%	46	7.6%	107	17.7%
	The "Sign In" includes confirming patient identity, surgical site, procedure, and consent	538	89.1%	12	2.0%	54	8.9%
	The "Sign In" includes confirming anesthesia machine/medication check completion and pulse oximeter functioning	467	77.3%	57	9.4%	80	13.2%
	The "Time Out" includes confirmation of antibiotic prophylaxis within the last 60 minutes (when applicable)	423	70.0%	47	7.8%	134	22.2%

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Statement	N	%	N	%	N	%
The "Sign Out" includes confirming counts, specimen labeling, equipment problems, and recovery management concerns	455	75.3%	24	4.0%	125	20.7%

Notes: Data are presented as n (%). WHO = World Health Organization; WFSA = World Federation of Societies of Anaesthesiologists; SSC = Surgical Safety Checklist.

Table 6: Responses of participants to statements related to their attitudes toward anesthesia safety and guideline adherence

Statement	**Strongly disagree**		**Disagree**		**Neutral**		**Agree**		**Strongly agree**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
1. The WHO Surgical Safety Checklist improves patient safety in my operating rooms	38	6.3%	17	2.8%	56	9.3%	138	22.8%	355	58.8%
2. The "Sign In, Time Out, Sign Out" should be performed even during emergencies when feasible (without delaying life-saving actions)	44	7.3%	30	5.0%	83	13.7%	174	28.8%	273	45.2%
3. Continuous presence of an anesthesia provider is essential for safe anesthesia in all cases	47	7.8%	12	2.0%	31	5.1%	81	13.4%	433	71.7%

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4. Pulse oximetry for every anesthetic case is non-negotiable for patient safety	77	12.7%	23	3.8%	28	4.6%	44	7.3%	432	71.5%
5. CO_2 detection for confirming endotracheal tube placement is essential for safety when intubation is performed	48	7.9%	9	1.5%	55	9.1%	107	17.7%	385	63.7%
6. A structured handover to recovery / ICU staff reduces preventable postoperative complications	45	7.5%	13	2.2%	32	5.3%	133	22.0%	381	63.1%
7. Any team member should be able to speak up and pause the workflow if a key safety step is missed	38	6.3%	20	3.3%	94	15.6%	169	28.0%	283	46.9%
8. If a guideline requirement is not met, the main reason is usually system limitation (equipment / staffing), not lack of provider motivation	45	7.5%	44	7.3%	158	26.2%	168	27.8%	189	31.3%
9. You feel safe to report near misses or safety concerns without fear of punishment	53	8.8%	55	9.1%	108	17.9%	167	27.6%	221	36.6%
10. If the sterility / cleanliness of an LMA or ETT is in doubt, it should not be used	47	7.8%	18	3.0%	49	8.1%	107	17.7%	383	63.4%

Notes: Data are presented as n (%). Response options: strongly disagree, disagree, neutral, agree, strongly agree. WHO = World Health Organization; LMA = laryngeal mask airway; ETT = endotracheal tube; ICU = intensive care unit.

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Table 7: Distribution of participants' responses to statements related to practice of safe anesthesia

Statements	Always		Often		Sometimes		Rarely		Never		N/A	
	N	%	N	%	N	%	N	%	N	%	N	%
1. Before induction ("Sign In"), identity / site / procedure / consent is verbally confirmed with the team/patient	411	68.0%	100	16.6%	61	10.1%	13	2.2%	13	2.2%	6	1.0%
2. Before induction, anesthesia machine and medication check is completed	497	82.3%	83	13.7%	20	3.3%	3	0.5%	1	0.2%	0	0.0%
3. Before induction, pulse oximeter is placed and confirmed to be functioning	557	92.2%	36	6.0%	7	1.2%	1	0.2%	2	0.3%	1	0.2%
4. Before incision ("Time Out"), team members introduce themselves by name and role	204	33.8%	115	19.0%	122	20.2%	86	14.2%	66	10.9%	11	1.8%
5. Before incision, antibiotic prophylaxis timing is confirmed when applicable	298	49.3%	148	24.5%	109	18.0%	34	5.6%	14	2.3%	1	0.2%

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6. Before leaving OR ("Sign Out"), counts / specimen labeling / equipment problems are verbally confirmed with team	325	53.8%	138	22.8%	82	13.6%	28	4.6%	26	4.3%	5	0.8%
7. Before leaving OR, the team discusses key concerns for recovery and postoperative management	273	45.2%	168	27.8%	105	17.4%	41	6.8%	14	2.3%	3	0.5%
8. A trained anesthesia provider remains continuously present with the patient during anesthesia	443	73.3%	107	17.7%	49	8.1%	4	0.7%	0	0.0%	1	0.2%
9. Pulse oximetry is used continuously throughout anesthesia	567	93.9%	17	2.8%	17	2.8%	2	0.3%	1	0.2%	0	0.0%
10. NIBP is measured at least every 5 minutes in stable patients (or more frequently if unstable)	529	87.6%	47	7.8%	23	3.8%	1	0.2%	3	0.5%	1	0.2%
11. If intubation is performed, CO_2 detection is used to confirm tube placement when available	428	70.9%	74	12.3%	58	9.6%	21	3.5%	19	3.1%	4	0.7%
12. When mechanical ventilation is used, a disconnection alarm is active (when available)	505	83.6%	55	9.1%	30	5.0%	7	1.2%	5	0.8%	2	0.3%

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13. Audible alarms (e.g., pulse oximeter tone) are kept ON and audible during cases	530	87.7%	52	8.6%	18	3.0%	3	0.5%	1	0.2%	0	0.0%
14. Medication syringes are labeled (drug name ± concentration) and checked before administration	511	84.6%	76	12.6%	14	2.3%	3	0.5%	0	0.0%	0	0.0%
15. The patient is transferred to a designated recovery area (PACU / recovery) after anesthesia when indicated	442	73.2%	96	15.9%	40	6.6%	10	1.7%	14	2.3%	2	0.3%
16. A structured handover is given to recovery / ICU staff (procedure, anesthetic, events, analgesia, concerns)	377	62.4%	136	22.5%	59	9.8%	15	2.5%	10	1.7%	7	1.2%
17. In recovery, SpO_2 and BP monitoring are used until recovery criteria met (when Equipment / staff allow)	457	75.7%	98	16.2%	38	6.3%	4	0.7%	5	0.8%	2	0.3%

Notes: Data are presented as n (%). N/A = not applicable. OR = operating room; SpO_2 = peripheral oxygen saturation; BP = blood pressure; NIBP = non-invasive blood pressure; CO_2 = carbon dioxide; ICU = intensive care unit; PACU = post-anesthesia care unit.

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The most frequently endorsed barriers to safe anesthesia practice were understaffing, fatigue, and excessive workload (53.8%) and financial constraints limiting equipment/supplies (49.2%) (Table 8). Additional commonly reported barriers included lack of ongoing training/continuing medical education (38.1%) and suboptimal teamwork/communication culture or incomplete SSC adoption (33.4%). Participants endorsed a median of 3 barriers (IQR 1; range 0–9).

Table 8: Reported barriers to safe anesthesia practice

Barriers	**N**	**%**
Lack of monitors (SpO_2, NIBP, ECG, CO_2 detection, capnography)	147	24.3%
Lack of reliable oxygen supply and/or suction	72	11.9%
No designated recovery area or inadequate recovery monitoring	172	28.5%

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Understaffing, fatigue, and excessive workload	325	53.8%
Surgical Safety Checklist not adopted or poor teamwork/communication culture	202	33.4%
Lack of ongoing training/continuing medical education	230	38.1%
Inadequate maintenance and biomedical technical support	184	30.5%
Weak institutional commitment to patient safety	133	22.0%
Financial constraints limiting equipment/supplies	297	49.2%
Number of barriers	**Median 3 (IQR 1), min-max = 0-9**	

Notes: Multiple responses were permitted; percentages reflect respondents selecting each barrier. Abbreviations: SpO2, peripheral oxygen saturation; NIBP, non-invasive blood pressure; ECG, electrocardiogram; CO2, carbon dioxide.

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In univariate analyses, higher readiness, knowledge, attitude, and practice scores were generally observed among respondents working in level 3 hospitals and in non-governmental hospital types, those practicing in pediatrics, endoscopy/GI, cardiac catheterization, or radiology/MRI, those in senior professional roles and with longer experience, respondents who had received patient-safety training, and those reporting more frequent SSC use **(Tables 9–12)**.

Table 9: Relationships between participants' demographics and anesthesia safety readiness scores

Factors	Categories	Median	Q1	Q3	Mean rank	Test statistic	p-value
Hospital level	Level 1	89.29	78.57	92.86	233.91	10.010	0.007
	Level 2	89.29	78.57	96.43	248.64		

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	Level 3		92.86	82.14	96.43	287.56		
Hospital type	Governmental		85.71	75.00	92.86	237.59	80.350	<0.001
	Private		96.43	89.29	96.43	353.16		
	Teaching/university		92.86	82.14	96.43	315.53		
	Non-governmental		100.00	96.43	100.00	448.04		
Main anesthesia setting(s)	Main OR	No	89.29	82.14	96.43	280.23	15854.5	0.550
		Yes	89.29	82.14	96.43	293.45		
	Ob/Gyn	No	89.29	82.14	96.43	288.66	39769.0	0.698

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		Yes	92.86	82.14	96.43	294.16		
	Pediatrics	No	85.71	78.57	96.43	257.77	3306.5	<0.001
		Yes	92.86	82.14	96.43	316.64		
	Endoscopy/GI	No	85.71	78.57	96.43	253.41	31779.0	<0.001
		Yes	92.86	82.14	96.43	325.99		
	Cardiac cath.	No	89.29	78.57	96.43	257.25	24991.0	<0.001
		Yes	96.43	85.71	100.00	358.55		
	Radiology	No	85.71	78.57	92.86	244.40	26454.5	<0.001

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		Yes	96.43	85.71	100.00	351.96		
Professional role	Consultant		96.43	85.71	100.00	349.25	39.510	<0.001
	Specialist		89.29	82.14	96.43	293.96		
	Resident / trainee		85.71	75.00	94.64	239.79		
	Non-specialized		91.07	82.14	96.43	304.30		
Experience in anesthesia	<3 years		85.71	75.00	96.43	245.20	27.036	<0.001
	4-7 years		89.29	78.57	96.43	277.19		
	8-15 years		92.86	82.14	96.43	308.82		

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	> 15 years		92.86	85.71	96.43	342.11		
Weekly anesthesia cases	0-10 cases		85.71	75.00	96.43	252.23	5.382	0.068
	11-20 cases		92.86	78.57	96.43	306.71		
	> 20 cases		89.29	82.14	96.43	293.76		
Patient-safety training	Lecture/seminar	No	89.29	78.57	96.43	270.72	36166.5	0.009
		Yes	92.86	82.14	96.43	307.31		
	Hands-on workshop	No	89.29	78.57	96.43	281.23	29285.5	0.011
		Yes	92.86	82.14	96.43	320.47		

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	Simulation training	No	89.29	78.57	96.43	285.32	20524.5	0.032
		Yes	92.86	85.71	96.43	325.07		
	Online course	No	89.29	78.57	96.43	277.20	21299.0	<0.001
		Yes	94.64	85.71	100.00	347.92		
Does your OR use SSC?	Never		75.00	64.29	85.71	143.37	170.525	<0.001
	Rarely		82.14	75.00	89.29	206.10		
	Sometimes		82.14	75.00	92.86	210.54		
	Often		89.29	78.57	96.43	265.07		

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	Always	96.43	89.29	100.00	392.24		
Adoption of SSC	Adopted	92.86	82.14	96.43	322.71	26043.0	<0.001
	Not adopted	85.71	75.00	92.86	231.37		

Notes: Domain scores are scaled 0-100. Q1/Q3 indicate the 25th/75th percentiles. Group comparisons used Mann-Whitney U tests (two groups) or Kruskal-Wallis tests (>2 groups). OR = operating room; SSC = Surgical Safety Checklist.

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Table 10: Relationships between participants' demographics and anesthesia safety knowledge scores

Factors	**Categories**	**Median**	**Q1**	**Q3**	**Mean rank**	**Test statistic**	**p-value**
Hospital level	Level 1	88.24	76.47	100.00	254.89	4.418	0.110
	Level 2	94.12	76.47	100.00	269.76		

	Level 3		94.12	82.35	100.00	292.10		
Hospital type	Governmental		94.12	76.47	100.00	273.53	22.558	<0.001
	Private		100.00	88.24	100.00	342.63		
	Teaching/university		94.12	82.35	100.00	314.49		
	Non-governmental		100.00	94.12	100.00	374.49		
Main anesthesia setting(s)	Main OR	No	94.12	76.47	100.00	288.84	16405.5	0.490
		Yes	94.12	82.35	100.00	304.12		
	Ob/Gyn	No	94.12	76.47	100.00	286.30	39499.5	0.058

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		Yes	94.12	82.35	100.00	312.74		
	Pediatrics	No	94.12	76.47	100.00	274.40	37271.5	<0.001
		Yes	94.12	82.35	100.00	322.62		
	Endoscopy/GI	No	94.12	76.47	100.00	280.79	39278.5	0.003
		Yes	94.12	82.35	100.00	321.52		
	Cardiac cath.	No	94.12	76.47	100.00	284.62	34103.0	<0.001
		Yes	100.00	88.24	100.00	336.54		
	Radiology	No	94.12	76.47	100.00	282.42	38222.0	<0.001

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		Yes	94.12	88.24	100.00	327.85		
Professional role	Consultant		100.00	88.24	100.00	351.52	27.638	<0.001
	Specialist		94.12	82.35	100.00	302.91		
	Resident / trainee		88.24	70.59	100.00	260.99		
	Non-specialized		94.12	82.35	100.00	310.60		
Experience in anesthesia	<3 years		88.24	70.59	100.00	267.15	22.772	<0.001
	4-7 years		94.12	82.35	100.00	287.35		
	8-15 years		94.12	82.35	100.00	306.19		

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	> 15 years		100.00	88.24	100.00	354.95		
Weekly anesthesia cases	0-10 cases		91.18	70.59	100.00	275.78	3.047	0.218
	11-20 cases		94.12	82.35	100.00	296.75		
	> 20 cases		94.12	82.35	100.00	310.63		
Patient-safety training	Lecture/seminar	No	94.12	76.47	100.00	279.05	38388.0	0.004
		Yes	94.12	82.35	100.00	319.06		
	Hands-on workshop	No	94.12	76.47	100.00	288.66	30442.5	0.001
		Yes	100.00	88.24	100.00	338.71		

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	Simulation training	No	94.12	76.47	100.00	292.55	21023.5	0.001
		Yes	100.00	88.24	100.00	350.35		
	Online course	No	94.12	76.47	100.00	289.47	23698.0	<0.001
		Yes	100.00	88.24	100.00	352.42		
Does your OR use SSC?	Never		85.29	58.82	100.00	223.59	67.801	<0.001
	Rarely		88.24	70.59	100.00	229.07		
	Sometimes		88.24	70.59	100.00	245.44		
	Often		94.12	82.35	100.00	305.13		

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	Always	100.00	88.24	100.00	361.78		
Adoption of SSC	Adopted	94.12	88.24	100.00	327.27	30644.5	<0.001
	Not adopted	88.24	70.59	100.00	253.21		

Notes: Domain scores are scaled 0-100. Q1/Q3 indicate the 25th/75th percentiles. Group comparisons used Mann-Whitney U tests (two groups) or Kruskal-Wallis tests (>2 groups). OR = operating room; SSC = Surgical Safety Checklist.

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Table 11: Relationships between participants' demographics and anesthesia safety attitude scores

Factors	**Categories**	**Median**	**Q1**	**Q3**	**Mean rank**	**Test statistic**	**p-value**
Hospital level	Level 1	82.50	65.00	90.00	236.89	12.584	0.002
	Level 2	82.50	70.00	90.00	254.83		

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	Level 3		87.50	75.00	95.00	298.98		
Hospital type	Governmental		82.50	70.00	92.50	274.39	17.022	<0.001
	Private		87.50	80.00	95.00	321.32		
	Teaching/university		90.00	72.50	95.00	326.66		
	Non-governmental		92.50	80.00	95.00	362.20		
Main anesthesia setting(s)	Main OR	No	85.00	62.50	95.00	288.40	16377.5	0.493
		Yes	85.00	75.00	95.00	304.17		
	Ob/Gyn	No	85.00	67.50	92.50	290.63	40512.5	0.183

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		Yes	85.00	75.00	95.00	310.01		
	Pediatrics	No	82.50	67.50	92.50	274.13	37203.0	<0.001
		Yes	87.50	77.50	95.00	322.81		
	Endoscopy/GI	No	82.50	70.00	92.50	279.38	38882.5	0.002
		Yes	87.50	75.00	95.00	322.75		
	Cardiac cath.	No	85.00	70.00	92.50	285.93	34622.0	0.001
		Yes	87.50	77.50	95.00	334.05		
	Radiology	No	82.50	70.00	92.50	279.89	37370.5	<0.001

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		Yes	87.50	75.00	95.00	331.04		
Professional role	Consultant		90.00	82.50	97.50	364.64	37.158	<0.001
	Specialist		87.50	75.00	92.50	308.53		
	Resident / trainee		82.50	67.50	92.50	278.90		
	Non-specialized		77.50	60.00	90.00	241.21		
Experience in anesthesia	<3 years		85.00	75.00	92.50	295.86	3.922	0.270
	4-7 years		85.00	70.00	92.50	291.76		
	8-15 years		85.00	70.00	95.00	297.18		

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	> 15 years		90.00	75.00	95.00	327.08		
Weekly anesthesia cases	0-10 cases		81.25	62.50	92.50	265.01	6.396	0.041
	11-20 cases		85.00	70.00	92.50	290.72		
	> 20 cases		87.50	75.00	95.00	315.50		
Patient-safety training	Lecture/seminar	No	82.50	67.50	92.50	271.77	36567.0	<0.001
		Yes	87.50	75.00	95.00	324.20		
	Hands-on workshop	No	85.00	72.50	92.50	294.84	33143.0	0.080
		Yes	87.50	75.00	95.00	322.54		

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	Simulation training	No	85.00	70.00	95.00	294.89	22193.5	0.018
		Yes	87.50	77.50	95.00	339.10		
	Online course	No	85.00	70.00	92.50	290.96	24409.0	0.001
		Yes	90.00	80.00	95.00	346.73		
Does your OR use SSC?	Never		82.50	70.00	90.00	260.96	47.768	<0.001
	Rarely		80.00	66.25	90.00	251.35		
	Sometimes		80.00	65.00	87.50	235.48		
	Often		82.50	72.50	95.00	296.84		

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	Always	90.00	80.00	97.50	356.30		
Adoption of SSC	Adopted	87.50	75.00	95.00	324.76	31652.0	<0.001
	Not adopted	80.00	67.50	90.00	258.19		

Notes: Domain scores are scaled 0-100. Q1/Q3 indicate the 25th/75th percentiles. Group comparisons used Mann-Whitney U tests (two groups) or Kruskal-Wallis tests (>2 groups). OR = operating room; SSC = Surgical Safety Checklist.

Table 12: Relationships between participants' demographics and anesthesia safety practice scores

Factors	**Categories**	**Median**	**Q1**	**Q3**	**Mean rank**	**Test statistic**	**p-value**
Hospital level	Level 1	86.76	76.47	94.12	229.23	13.646	0.001
	Level 2	89.71	79.41	95.31	261.19		

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	Level 3		92.65	83.82	98.53	298.94		
Hospital type	Governmental		87.87	77.94	95.59	259.94	38.742	<0.001
	Private		92.65	86.76	98.53	343.99		
	Teaching/university		92.65	85.29	98.53	333.30		
	Non-governmental		94.12	91.18	98.53	389.51		
Main anesthesia setting(s)	Main OR	No	90.44	79.41	97.79	292.66	16650.0	0.632
		Yes	91.18	82.35	97.06	303.67		
	Ob/Gyn	No	91.18	82.35	97.06	304.40	42844.5	0.830

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		Yes	91.18	82.35	97.06	301.30		
	Pediatrics	No	89.71	79.41	97.06	283.17	39481.5	0.021
		Yes	91.18	83.82	98.53	316.34		
	Endoscopy/GI	No	89.71	79.41	95.59	283.03	39911.0	0.010
		Yes	92.65	83.82	98.53	319.55		
	Cardiac cath.	No	89.71	79.41	97.06	283.27	33570.5	<0.001
		Yes	94.12	85.29	98.53	339.10		
	Radiology	No	89.71	79.41	95.59	280.63	37618.5	<0.001

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		Yes	92.65	83.82	98.53	330.11		
Professional role	Consultant		92.65	86.76	98.53	338.82	15.587	0.001
	Specialist		89.71	82.35	95.59	291.48		
	Resident / trainee		88.24	77.94	97.06	272.09		
	Non-specialized		92.65	83.82	100.00	322.55		
Experience in anesthesia	<3 years		88.24	77.94	97.06	273.00	18.058	<0.001
	4-7 years		89.71	80.88	95.59	280.73		
	8-15 years		92.65	84.56	97.06	315.87		

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	> 15 years		94.12	86.76	100.00	348.19		
Weekly anesthesia cases	0-10 cases		86.76	76.47	94.12	261.09	5.308	0.070
	11-20 cases		91.18	82.35	97.06	303.17		
	> 20 cases		91.18	82.35	98.53	310.99		
Patient-safety training	Lecture/seminar	No	88.24	77.94	95.59	270.80	36325.5	<0.001
		Yes	92.65	83.82	98.53	324.89		
	Hands-on workshop	No	89.71	80.88	97.06	287.29	29843.5	<0.001
		Yes	94.12	85.29	98.53	342.30		

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	Simulation training	No	89.71	80.88	97.06	290.57	20033.5	<0.001
		Yes	94.12	87.50	100.00	359.87		
	Online course	No	89.71	80.88	97.06	288.43	23198.5	<0.001
		Yes	94.12	86.76	100.00	356.41		
Does your OR use SSC?	Never		76.47	61.76	86.76	153.79	153.475	<0.001
	Rarely		82.35	75.00	89.71	188.51		
	Sometimes		85.29	77.94	92.65	241.91		
	Often		89.71	83.82	95.59	290.72		

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	Always	95.59	91.18	100.00	397.00		
Adoption of SSC	Adopted	94.12	86.76	98.53	347.43	22539.0	<0.001
	Not adopted	83.82	75.00	91.18	213.08		

Notes: Domain scores are scaled 0-100. Q1/Q3 indicate the 25th/75th percentiles. Group comparisons used Mann-Whitney U tests (two groups) or Kruskal-Wallis tests (>2 groups). OR = operating room; SSC = Surgical Safety Checklist.

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Domain scores were positively inter-correlated (Spearman $r = 0.281–0.518$; all $p < 0.001$), with the strongest association between readiness and practice ($r = 0.518$) (Table 13). A higher barrier count was inversely correlated with readiness ($r = −0.440$), knowledge ($r = −0.243$), attitude ($r = −0.184$), and practice ($r = −0.414$) (all $p < 0.001$).

Table 13: Spearman correlations between domain scores and perceived barriers

Domain	Readiness	Knowledge	Attitude	Practice

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	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**
Readiness	--	--						
Knowledge	0.322	<0.001	--	--				
Attitude	0.281	<0.001	0.357	<0.001	--	--		
Practice	0.518	<0.001	0.472	<0.001	0.374	<0.001	--	--
Barriers	-0.440	<0.001	-0.243	<0.001	-0.184	<0.001	-0.414	<0.001

Notes: r, Spearman correlation coefficient; p values are two-sided.

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In multivariable linear regression, higher readiness was independently associated with teaching/university hospitals (B = 2.577, 95% CI 0.635–4.520; p = 0.009), other hospital types grouped as “others” (B = 4.743, 95% CI 1.325–8.162; p = 0.007), more frequent SSC use (B = 3.252, 95% CI 2.552–3.952; p < 0.001), and practicing in radiology/MRI (B = 3.577, 95%

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CI 1.273–5.882; $p = 0.002$), while a higher perceived barrier count was associated with lower readiness (B = −1.554 per additional barrier, 95% CI −2.094 to −1.014; $p < 0.001$) (Table 14).

Table 14: Multivariable linear regression predictors of anesthesia safety readiness score

Predictors (reference)	**Levels**	**B**	**p-value**	**95% CI**
Intercept		77.857	<0.001	72.828 - 82.886
Hospital level (level 1)	Level 2	-0.614	0.689	-3.629 - 2.401
	Level 3	0.182	0.886	-2.302 - 2.666
Hospital type (governmental)	Private	1.539	0.253	-1.102 - 4.180
	Teaching/university	2.577	0.009	0.635 - 4.520
	Others	4.743	0.007	1.325 - 8.162
Professional role (consultant)	Specialist	-0.049	0.971	-2.674 - 2.577
	Resident/trainee	-2.769	0.059	-5.641 - 0.103
	Non-specialist physician anesthetist	1.594	0.263	-1.198 - 4.386

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Experience (up to 3 years)	4-7 years	0.302	0.797	-2.011 - 2.616
	8-15 years	1.216	0.407	-1.662 - 4.095
	>15 years	1.857	0.230	-1.178 - 4.893
Weekly cases (up to 10 cases)	11-20 cases	1.906	0.192	-0.957 - 4.769
	>20 cases	2.227	0.087	-0.326 - 4.780
Using SSC (not using)		3.252	<0.001	2.552 - 3.952
Settings (not worked at them)	Pediatrics	-0.268	0.795	-2.292 - 1.755
	Endoscopy/GI	-0.999	0.383	-3.249 - 1.251
	Catheterization	1.644	0.143	-0.559 - 3.848
	Radiology	3.577	0.002	1.273 - 5.882
Training (not trained)	Lectures	0.541	0.552	-1.244 - 2.327
	Hand-on workshops	-0.471	0.658	-2.560 - 1.619
	Simulation	0.299	0.803	-2.060 - 2.658
	Online training	0.241	0.827	-1.921 - 2.402
Number of perceived barriers		-1.554	<0.001	-2.094 - -1.014

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Notes: B, unstandardized regression coefficient; CI, confidence interval. Reference categories are shown in parentheses. SSC was modeled as a 5-level ordinal variable (never to always). Barrier count was modeled as a 0-9 count. p values are two-sided. Abbreviations: SSC, Surgical Safety Checklist.

Higher knowledge was associated with more frequent SSC use (B = 2.827, 95% CI 1.815–3.839; $p < 0.001$), whereas residents/trainees had lower knowledge compared with consultants (B = −6.820, 95% CI −11.056 to −2.585; $p = 0.002$) (Table 15). For attitude, non-specialist physician anesthetists had lower scores compared with consultants (B = −12.868, 95% CI −19.371 to −6.365; $p < 0.001$), and more frequent SSC use was associated with higher attitude scores (B = 2.765, 95% CI 1.043–4.487; $p = 0.002$) (Table 16).

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Table 15: Multivariable linear regression predictors of anesthesia safety knowledge score

Predictors (reference)	**Levels**	**B**	**p-value**	**95% CI**
Intercept		79.092	<0.001	72.728 - 85.456
Hospital type (governmental)	Private	1.580	0.400	-2.102 - 5.263

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	Teaching/university	1.615	0.258	-1.187 - 4.417
	Others	2.649	0.303	-2.400 - 7.698
Professional role (consultant)	Specialist	-1.804	0.359	-5.662 - 2.055
	Resident/trainee	-6.820	0.002	-11.056 - -2.585
	Non-specialist physician anesthetist	-2.185	0.282	-6.173 - 1.803
Experience (up to 3 years)	4-7 years	1.219	0.474	-2.124 - 4.562
	8-15 years	0.751	0.723	-3.416 - 4.918
	>15 years	2.399	0.284	-1.994 - 6.793
Using SSC (not using)		2.827	<0.001	1.815 - 3.839
Settings (not worked at them)	Pediatrics	1.957	0.196	-1.011 - 4.925
	Endoscopy/GI	0.996	0.551	-2.285 - 4.278
	Catheterization	1.918	0.238	-1.272 - 5.108
	Radiology	-1.694	0.322	-5.050 - 1.663
Training (not trained)	Lectures	1.972	0.130	-0.585 - 4.529
	Hand-on workshops	-0.204	0.893	-3.185 - 2.776

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	Simulation	2.963	0.089	-0.455 - 6.380
	Online training	1.802	0.256	-1.308 - 4.912
Number of perceived barriers		-0.483	0.224	-1.261 - 0.296

Notes: B, unstandardized regression coefficient; CI, confidence interval. Reference categories are shown in parentheses. SSC was modeled as a 5-level ordinal variable (never to always). Barrier count was modeled as a 0-9 count. p values are two-sided. Abbreviations: SSC, Surgical Safety Checklist.

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Table 16: Multivariable linear regression predictors of anesthesia safety attitude score

Predictors (reference)	**Levels**	**B**	**p-value**	**95% CI**
Intercept		64.988	<0.001	54.245 - 75.730
Hospital level (level 1)	Level 2	0.959	0.799	-6.443 - 8.361
	Level 3	4.804	0.121	-1.264 - 10.872
Hospital type (governmental)	Private	0.137	0.967	-6.372 - 6.646
	Teaching/university	-0.372	0.878	-5.133 - 4.389
	Others	1.778	0.679	-6.656 - 10.212

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Professional role (consultant)	Specialist	-2.626	0.379	-8.488 - 3.235
	Resident/trainee	-5.100	0.053	-10.276 - 0.076
	Non-specialist physician anesthetist	-12.868	<0.001	-19.371 - -6.365
Weekly cases (up to 10 cases)	11-20 cases	-2.566	0.469	-9.521 - 4.389
	>20 cases	0.521	0.869	-5.676 - 6.718
Using SSC (not using)		2.765	0.002	1.043 - 4.487
Settings (not worked at them)	Pediatrics	3.411	0.176	-1.539 - 8.361
	Endoscopy/GI	0.640	0.821	-4.914 - 6.194
	Catheterization	1.773	0.519	-3.626 - 7.172
	Radiology	-2.441	0.395	-8.068 - 3.186
Training (not trained)	Lectures	3.759	0.083	-0.495 - 8.013
	Simulation	4.152	0.139	-1.348 - 9.653
	Online training	1.545	0.557	-3.624 - 6.714
Number of percevied barriers		0.486	0.477	-0.853 - 1.824

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Notes: B, unstandardized regression coefficient; CI, confidence interval. Reference categories are shown in parentheses. SSC was modeled as a 5-level ordinal variable (never to always). Barrier count was modeled as a 0-9 count. p values are two-sided. Abbreviations: SSC, Surgical Safety Checklist.

Better practice was independently associated with working in level 3 (tertiary) hospitals (B = 2.647, 95% CI 0.274–5.020; p = 0.029), teaching/university hospitals (B = 2.185, 95% CI 0.335–4.034; p = 0.021), having >15 years of experience (B = 3.467, 95% CI 0.542–6.391; p = 0.020), and more frequent SSC use (B = 3.475, 95% CI 2.802–4.148; p < 0.001), while a higher perceived barrier count was associated with lower practice (B = −1.341 per additional barrier, 95% CI −1.864 to −0.818; p < 0.001) (Table 17).

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Table 17: Multivariable linear regression predictors of anesthesia safety practice score

Predictors (reference)	**Levels**	**B**	**p-value**	**95% CI**
Intercept		76.171	<0.001	71.703 - 80.640
Hospital level (level 1)	Level 2	1.264	0.390	-1.622 - 4.150

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	Level 3	2.647	0.029	0.274 - 5.020
Hospital type (governmental)	Private	1.260	0.331	-1.283 - 3.803
	Teaching/university	2.185	0.021	0.335 - 4.034
	Others	2.816	0.093	-0.476 - 6.109
Professional role (consultant)	Specialist	1.373	0.288	-1.161 - 3.906
	Resident/trainee	1.166	0.409	-1.605 - 3.938
	Non-specialist physician anesthetist	0.868	0.522	-1.793 - 3.529
Experience (up to 3 years)	4-7 years	1.005	0.372	-1.203 - 3.213
	8-15 years	2.723	0.052	-0.029 - 5.475
	>15 years	3.467	0.020	0.542 - 6.391
Using SSC (not using)		3.475	<0.001	2.802 - 4.148
Settings (not worked at them)	Pediatrics	0.417	0.672	-1.519 - 2.353
	Endoscopy/GI	-0.525	0.634	-2.690 - 1.640
	Catheterization	-0.019	0.986	-2.112 - 2.075
	Radiology	-0.380	0.734	-2.576 - 1.815

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Training (not trained)	Lectures	1.271	0.143	-0.430 - 2.972
	Hand-on workshops	-0.595	0.555	-2.575 - 1.385
	Simulation	1.249	0.274	-0.990 - 3.488
	Online training	0.674	0.518	-1.374 - 2.723
Number of perceived barriers		-1.341	<0.001	-1.864 - -0.818

Notes: B, unstandardized regression coefficient; CI, confidence interval. Reference categories are shown in parentheses. SSC was modeled as a 5-level ordinal variable (never to always). Barrier count was modeled as a 0-9 count. p values are two-sided. Abbreviations: SSC, Surgical Safety Checklist.

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Discussion

This multicountry survey across different Arab countries provides a granular assessment of readiness, knowledge, attitudes, and self-reported safety practices among anesthesia providers, while explicitly modelling how WHO Surgical Safety Checklist (SSC) use frequency and barrier burden relate to these domains. Three findings are particularly salient. First,

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standardized domain performance (0–100) was high overall, readiness 89.29 (IQR 14.29), knowledge 94.12 (IQR 17.65), attitude 85.00 (IQR 22.50), and practice 91.18 (IQR 14.71), yet attitudes remained the comparatively weakest domain (high-category attainment 66.1% vs 75.8–77.8% across the other domains), suggesting that safety culture attributes (e.g., speaking up, psychological safety) may lag behind technical readiness and procedural know-how. Second, routine Surgical Safety Checklist (SSC) use was not universal; only 40.9% of respondents reported "always" using the SSC in their operating room. Third, multivariable analyses demonstrated a coherent implementation–constraint pattern: more frequent SSC use was independently associated with higher readiness, knowledge, attitude, and practice scores, whereas greater barrier burden was associated with lower readiness and practice, indicating that checklist intensity and system constraints jointly shape observed safety behaviors.

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SSC utilization in context and why it matters

The observed SSC utilization gap is clinically meaningful because checklist implementation has repeatedly been linked to improved perioperative outcomes and team processes. In the landmark global evaluation, Alex B. Haynes et al. found that SSC implementation was associated with a reduction in major complications from 11.0% to 7.0% and inpatient mortality from 1.5% to 0.8% [10,17]. A broader evidence base supports these benefits: Jeroen Bergs et al. found in a systematic review and

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meta-analysis that SSC use was associated with lower postoperative complications (e.g., pooled effects around RR ~0.57 for overall complications in several summaries of the evidence) and improved adherence to safety processes [18,19].

Importantly, "having a checklist" is not equivalent to "using it well." [20]. A large systematic review and meta-analysis of SSC completeness reported an overall compliance of around 73% (and consistently lower completion for communication-heavy phases such as time-out and sign-out in many settings) [21]. Our item-level pattern aligns with this implementation reality: technical checks (e.g., anesthesia machine check, patient identification, antibiotic verification) are commonly reported, whereas the teamwork/communication elements, notably "team member introductions during time-out" and some sign-out discussions, show lower "always" performance. This distinction matters because communication steps are central to preventing latent failures and coordination breakdowns, not just equipment-related hazards.

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Readiness gaps: monitoring and recovery capacity

Our readiness findings are reassuring in core areas (e.g., near-universal pulse oximetry availability), yet they also expose high-value gaps that are strongly tied to preventable harm. Temperature monitoring was reported as "always available" in only 25.5%, and waveform capnography availability was ~61.9%, both of which are notable because international anesthesia safety standards emphasize minimum monitoring and the value of capnography for airway safety [5]. The clinical relevance is well-established: Hart et al. highlighted that inadvertent perioperative hypothermia is common and has been

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associated with materially worse outcomes, including reports of a threefold increase in surgical site infection rates in colorectal surgery patients experiencing hypothermia [22]. Consistent with this, National Institute for Health and Care Excellence guidance on inadvertent perioperative hypothermia underscores perioperative temperature measurement/monitoring and active warming strategies as core components of prevention [23]. Together, these points strengthen the interpretation that closing "readiness" gaps (monitoring + recovery infrastructure) is not cosmetic, it is plausibly outcome relevant.

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Determinants: checklist intensity and barrier burden

Our modelling results offer a coherent explanatory framework. SSC use frequency showed a consistent positive association across domains, suggesting that higher implementation intensity may function as a bundled intervention: it standardizes safety tasks, prompts communication, and encourages shared situational awareness. This interpretation is aligned with implementation science evidence. Antoine Fourcade et al. found that adoption barriers often reflect workflow friction, local culture, and perceived redundancy, factors that can attenuate checklist uptake even when staff intellectually agree with the concept [24]. In our data, the most endorsed barriers, understaffing (53.8%), financial constraints (49.2%), and limited training (38.1%), are consistent with a system-constraint model, and the negative association of barrier count with readiness and practice reinforces that resource and process constraints translate into measurable performance

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differences. Bake et al. reported in their systematic review that operating-room safety culture in African hospitals is commonly undermined by communication barriers, hierarchical dynamics, non-punitive error-reporting weaknesses, and resource limitations, supporting the interpretation that durable improvement requires multi-level, context-sensitive strategies rather than checklist adoption alone [25]. Firde further showed that anesthesia medication errors were strongly associated with workflow vulnerabilities, particularly failure to consistently double-check medications before administration and administration of drugs prepared by another provider [26], while Grigg emphasized that improving anesthesia safety requires a human-factors approach that addresses system constraints rather than reliance on individual vigilance alone [27]. Finally, the observed cadre and setting effects (e.g., residents having lower knowledge scores than specialists; tertiary/university settings showing higher readiness and practice) support a plausible gradient in exposure to structured governance, auditing, and standardization, which may be less consistently available in lower-resourced contexts. At the same time, Lynch et al. reported that resident involvement in a large anesthesiology teaching-service cohort was not associated with worse clinically relevant postsurgical outcomes [28], and Hofheins et al. similarly found that supervised resident-delivered procedural anesthesia was associated with a very low adverse-event rate comparable to attending-delivered care [29]. These findings support a balanced interpretation of the resident-versus-specialist differences observed in our survey and suggest that lower knowledge scores among trainees should not automatically be equated with inferior patient safety in appropriately supervised environments.

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Practical implications for perioperative governance

These results point to practical actions that are high-yield and feasible without inflating the manuscript with operational detail. First, targeting SSC implementation quality, not merely presence, should focus on the communication-heavy components (team introductions, explicit shared plan, recovery/hand-off discussions), because these were among the lowest "always" practices. This emphasis on communication is supported by recent perioperative evidence showing that, although overall patient-rated anesthetist communication may appear generally favorable, important deficits can persist in checking patient understanding, encouraging questions, explaining next steps, and involving patients in decision-making, all of which are closely aligned with a stronger safety culture [30]. Second, the consistent association between SSC use and all four domains supports adopting routine SSC use as an institutional minimum standard, with lightweight audit-and-feedback rather than punitive enforcement. Third, because barriers clustered around staffing, resources, and training, implementation strategies should be coupled with targeted capacity support (e.g., short training refreshers, local champions, and simple workflow integration), aligning with guidance from global SSC implementation resources [8,31]. Fourth, given the large readiness gap in temperature monitoring and incomplete capnography availability, investment prioritization can be framed around preventable harm: for example, temperature monitoring and warming pathways, alongside progressive movement toward universal capnography availability where intubation is performed.

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Strengths

Key strengths of this study include its multi-country scope across diverse hospital levels and practice environments, and the use of a structured instrument capturing four complementary domains, facility readiness, knowledge, attitudes, and self-reported safety practices, together with perceived barriers. The analytic approach further strengthens interpretability by modelling SSC use as an ordinal exposure and barrier burden as a dose-dependent count variable, enabling assessment of graded associations rather than relying on dichotomized measures. The internal coherence of the findings across domains (SSC use showing consistent positive associations and barrier burden showing consistent negative associations) supports the face validity and practical relevance of the results.

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Limitations

Several limitations merit consideration. First, the cross-sectional design precludes causal inference; associations between SSC use frequency and higher domain scores may reflect underlying differences in institutional resources, governance, or safety culture rather than checklist use alone. Second, outcomes were self-reported and therefore susceptible to recall and social-desirability bias, potentially inflating estimates of adherence to recommended practices. Third, online dissemination limits the ability to estimate a response denominator and introduces potential selection bias toward participants engaged with patient safety. Finally, SSC “quality of execution” (fidelity, completeness, and team communication behaviors

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during time-out/sign-out) was not directly observed; future work incorporating direct audit or mixed-methods assessment would strengthen causal interpretation and implementation guidance.

Take-home message

Overall, anesthesia providers across the surveyed hospitals demonstrated strong performance across readiness, knowledge, and self-reported practices, with comparatively lower scores in attitudes toward safety. However, performance was not uniform: it showed a clear and coherent pattern in which higher frequency of Surgical Safety Checklist (SSC) use aligned with better scores across domains, while greater perceived barrier burden aligned with lower readiness and practice. These results suggest that perioperative safety is shaped not only by what clinicians know, but also by how reliably safety routines are implemented and how feasible safe practice is within local staffing, training, and resource conditions.

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Recommendations

A dual-track improvement strategy is warranted. First, SSC implementation should be strengthened toward high-fidelity routine use, with explicit attention to communication-critical steps (team introductions, shared plan, and structured sign-out/hand-off) and supported by pragmatic audit-and-feedback rather than punitive approaches. Second, system constraints should be addressed in parallel by prioritizing modifiable barriers, workforce and workload pressures, access to

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essential equipment and supplies, and structured continuing education, while focusing early investments on high-value safety enablers such as consistent temperature monitoring and wider availability of capnography where applicable. Future work should incorporate objective measures of checklist fidelity and prospective designs to identify which implementation and capacity-building interventions yield the most sustainable improvements across hospital levels.

Conclusion

In summary, anesthesia providers across the surveyed Arab region demonstrated high overall knowledge and practice scores; however, routine SSC use and several readiness elements, particularly temperature monitoring and capnography availability, remain incomplete. The consistent positive association between SSC use frequency and all safety domains, alongside the negative impact of barrier burden, highlights a dual mandate for perioperative leaders: strengthen checklist implementation (especially communication steps) while also addressing structural constraints that limit readiness and sustain safe practice.

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List of abbreviations

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- **B**: Unstandardized regression coefficient
- **CI**: Confidence interval
- **CO_2**: Carbon dioxide
- **ECG**: Electrocardiography
- **GI**: Gastrointestinal
- **IQR**: Interquartile range
- **IRB**: Institutional Review Board
- **KAP**: Knowledge, attitudes, and practices
- **MRI**: Magnetic resonance imaging
- **NGO**: Non-governmental organization
- **NIBP**: Non-invasive blood pressure
- **OR**: Operating room
- **SD**: Standard deviation
- **SpO_2**: Peripheral oxygen saturation
- **SSC**: Surgical Safety Checklist
- **WHO**: World Health Organization

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Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Institutional Review Board of An-Najah National University (protocol No. Med. Dec. 2025/73; approved on 30 December 2025). The study was conducted in accordance with the Declaration of Helsinki and its later amendments. Written electronic informed consent was obtained from all participants before they accessed the questionnaire. Participation was voluntary and anonymous, and no identifiable personal data were collected.

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Consent for publication

Not applicable. This manuscript does not contain any identifiable individual person's data, images, or videos.

Availability of data and materials

The de-identified dataset supporting the findings of this study is available from the corresponding author on reasonable request, subject to applicable ethical and legal requirements.

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Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

WS and MM contributed equally to this work. WS, MM, and AAD conceived the study and designed the methodology. WS, MM, AAD, and AH developed the survey instrument and coordinated study implementation. All authors contributed to participant recruitment and/or data acquisition within their respective centers/countries and provided critical intellectual input throughout the project. MM, WS, and AAD performed data cleaning and statistical analyses and interpreted the findings, with input from all authors. MM and WS drafted the manuscript. All authors critically revised the manuscript for important intellectual content, approved the final manuscript, and agreed to be accountable for all aspects of the work.

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Additional files

Additional file 1 (docx): Full survey questionnaire

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