

Anesthesia Equipment-Related Errors in the Operating Room: Incidence Rate and Management Methods

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Background:

Equipment-related errors in the operating room (OR) are a common source of perioperative disruption, posing significant threats to patient safety, surgical efficiency, and healthcare resources. These errors, ranging from device malfunctions to setup failures, are often preventable and underreported. This systematic review aimed to synthesize evidence on the incidence, causes, and management strategies of equipment-related errors in the OR.

Methods:

A systematic search was conducted in PubMed using MeSH terms and keywords related to "operating room", "equipment failure", and "surgical errors". Inclusion criteria were original studies (clinical trials and cohort studies) reporting quantitative data on the incidence or prevention of equipment-related OR errors. Two independent reviewers screened titles, abstracts, and full texts. Data were extracted using a standardized form, and risk of bias was assessed using appropriate tools based on study design.

Results:

Twelve studies met the inclusion criteria, including 7 cohort studies and 5 clinical trials, conducted across North America, Europe, Asia, and the Middle East. Reported incidence of equipment-related errors ranged from 5% to 21% per surgical procedure. The most common errors involved anesthesia machines, surgical instruments, and monitoring devices. Eight studies found that implementing structured interventions—particularly preoperative checklists—reduced the occurrence and recurrence of equipment errors by 30% to 60%. Secondary outcomes included surgical delays, cancellations and increased staff stress.

Conclusions:

Equipment-related errors in the OR are frequent and largely preventable. Structured safety protocols, staff training, and system-level monitoring significantly reduce their incidence. To improve surgical safety, healthcare systems should prioritize checklist adherence, reporting mechanisms, and human-centered equipment design.

Keywords: *Operating room, Equipment failure, Patient safety, Surgical errors, Checklists, Error prevention.*

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Introduction

Equipment-related errors in the operating room (OR) are a significant concern worldwide, contributing substantially to surgical complications and patient morbidity. A systematic review encompassing 28 studies found that equipment failures accounted for a median of 23.5% of total errors during surgical procedures, with a median of 0.9 equipment problems per procedure (interquartile range [IQR] 0.3–3.6) [1]. These failures often lead to increased operative times, delayed procedures, and, in some cases, patient harm.

The nature of equipment-related errors varies, with common issues including unavailability of necessary devices (37.3%), incorrect configuration or settings (43.4%), and direct malfunctions (33.5%) [1]. A study analyzing 911 surgeries reported 148 equipment-related incidents, with 68% occurring during surgery and 32% during the preparation phase [2]. These incidents resulted in approximately 29 hours and 45 minutes of additional work and over 12 hours of operational delays. While not all equipment failures result in direct patient harm, the indirect consequences can be significant. Extended anesthesia times, increased risk of infection, and heightened stress levels among surgical teams are notable concerns. In a study focusing on cardiac surgeries, equipment failures occurred in 92% of cases, leading to the cancellation of four operations [3]. Such high incidence rates underscore the critical need for effective management strategies. Implementing systematic checks and protocols has proven effective in reducing equipment-related errors. Studies have shown that the use of preoperative checklists can reduce equipment errors by an average of 48.6%, with some studies reporting reductions up to 60.7% when specific equipment checklists are employed [1]. These

measures not only enhance patient safety but also improve overall surgical efficiency. In Saudi Arabia, equipment-related errors are a notable issue within the healthcare system. A review of medical litigation cases revealed that 20.4% of errors occurred in the operating room, making it the most common location for such incidents [4]. Additionally, a study analyzing surgical cancellations in Makkah region hospitals found that 20.03% were due to facility-related issues, including equipment failures [5]. These findings highlight the prevalence and impact of equipment-related errors in the region.

Several systemic and human factors contribute to the occurrence of equipment-related errors. Inadequate training on complex anesthesia and surgical machines, lack of maintenance schedules, insufficient preoperative checks, and limited availability of backup devices all play roles in increasing vulnerability to such incidents [6]. Furthermore, the absence of formalized protocols for device inspection or incident reporting creates a feedback gap that perpetuates recurring errors. Interaction between healthcare staff and equipment can be compromised by poor ergonomic design, non-standardized interfaces, and ambiguous alarm systems. A study revealed that 39% of equipment-related incidents were linked to user confusion or incorrect usage, rather than mechanical failure alone [7]. Such interface issues are particularly dangerous in high-stakes settings like the OR, where split-second decisions are often required under stress. Breakdowns in communication among surgical teams have been associated with nearly 43% of equipment-related errors [8]. The lack of coordinated preoperative briefing or checklist execution may result in the wrong equipment being prepared or not functioning at critical

moments. Multidisciplinary briefings and rehearsals before complex procedures have shown to significantly reduce such failures and improve team responsiveness during equipment emergencies. Implementing systematic checks and protocols has proven effective in reducing equipment-related errors. Studies have shown that the use of preoperative checklists can reduce equipment errors by an average of 48.6%, with some studies reporting reductions up to 60.7% when specific equipment checklists are employed [1].

These measures not only enhance patient safety but also improve overall surgical efficiency. The World Health Organization (WHO) has emphasized the importance of surgical safety checklists in reducing perioperative complications. The implementation of the WHO Surgical Safety Checklist has been associated with a significant decrease in both complication rates (from 11.0% to 7.0%) and mortality rates (from 1.5% to 0.8%) across diverse healthcare settings [6]. These findings support the adoption of standardized protocols to mitigate equipment-related errors [9-12].

Despite the recognized impact of equipment-related errors in the operating room, there is a lack of comprehensive data synthesizing their incidence, causes, and management strategies, particularly within the context of Saudi Arabia. Given the significant proportion of surgical errors attributed to equipment failures and the potential for adverse patient outcomes, a systematic review is essential to identify patterns, assess current mitigation strategies, and recommend best practices tailored to the regional healthcare setting.

Methods

The systematic review was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. We began the literature search using the PubMed database on May 3, 2025, targeting original research articles, systematic reviews, and observational studies that reported the incidence, types, and management of equipment-related errors in the operating room. No restrictions were placed on the year of publication to ensure a comprehensive historical view of the issue. The search was limited to studies published in English. The detailed search strategy involved combining Medical Subject Headings (MeSH) and free-text terms related to equipment errors and operating room incidents. The final search string used in PubMed was as follows: ("Operating Room"[Mesh] OR "Surgical Procedures, Operative"[Mesh] OR "Operating Room" OR "Surgical Suite") AND ("Equipment and Supplies, Health,

Hospital"[Mesh] OR "Equipment Failure"[Mesh] OR "Technology Failure" OR "Device Failure" OR "Equipment Malfunction" OR "Anesthesia Machine Error" OR "Surgical Equipment Error") AND ("Incidence" OR "Prevalence" OR "Risk Factors" OR "Management" OR "Checklist" OR "Prevention" OR "Surgical Safety"). Filters were applied to include only human studies and exclude commentaries, editorials, and narrative reviews. All retrieved articles were exported into EndNote 20 for reference management and duplicate removal. The study selection process was performed in two stages. First, two independent reviewers screened the titles and abstracts to assess eligibility based on predefined inclusion criteria: (1) studies reporting quantitative data on equipment-related errors in operating rooms; (2) studies describing incidence, causes, contributing factors, or management strategies; and (3) studies conducted in hospital-based surgical or anesthetic settings. Exclusion criteria included studies not involving human subjects, reports focused solely on non-operative settings, or studies not published in English. Discrepancies between reviewers were resolved through discussion and consensus with a third senior reviewer.

In the second stage, full-text articles were retrieved and assessed independently by the same two reviewers for final inclusion. Each full-text was examined to confirm relevance to the primary objective of the review. If the eligibility of an article remained uncertain, the reviewers contacted the corresponding author for clarification or excluded the study if key information was missing or unclear. A PRISMA flow diagram was constructed to illustrate the screening process and reasons for exclusion at each stage.

Data extraction was performed using a standardized Excel sheet developed for the review. Extracted information included study title, year of publication, country, study design, sample size, surgical specialty, setting (e.g., academic hospital, private hospital), types of equipment-related errors identified, numerical findings (e.g., incidence rates, proportions, odds ratios), associated outcomes (e.g., delays, cancellations, patient harm), and strategies for error mitigation or prevention. Data extraction was conducted independently by two reviewers, with a third reviewer verifying the consistency and accuracy of the data entries. Any discrepancies were resolved through consensus. To assess the methodological quality and risk of bias of the included studies, different tools were used depending on the study design. Observational studies were assessed using the Newcastle–Ottawa Scale (NOS), which evaluates three broad perspectives: selection of study groups, comparability of groups, and the ascertainment of either

the exposure or outcome. Cross-sectional studies were evaluated using the AXIS tool, which includes 20 items to assess internal validity, study design, reporting clarity, and potential conflicts of interest. Systematic reviews, if included in the synthesis, were appraised using AMSTAR 2, which focuses on the methodological rigor of review articles.

Risk of bias assessment was conducted independently by two reviewers. Each included study was categorized as low, moderate, or high risk of bias based on the scoring of the appropriate tool. Results of the assessment were tabulated and discussed to determine their impact on the overall strength of the evidence. Studies with high risk of bias were not excluded, but sensitivity analyses were planned to explore the impact of excluding such studies in the synthesis phase, should their influence be significant. This rigorous methodological approach ensured transparency, reproducibility, and quality control throughout the review process.

Results

The literature search identified a total of 1,287 articles through PubMed. After removing 242 duplicates, 1,045 articles were screened by title and abstract. Of these, 963 were excluded for not addressing intraoperative equipment errors or lacking primary data. The full texts of 82 articles were reviewed in detail, and 70 were excluded for reasons including commentary format, irrelevant focus, or insufficient methodological detail. Ultimately, 12 studies met the inclusion criteria and were included in the final review. These consisted of 7 cohort studies and 5 randomized controlled trials, published between 2009 and 2024. The PRISMA flow diagram (not shown here) outlines the study selection process and reasons for exclusion. The 12 included studies were conducted across a diverse range of settings including tertiary academic hospitals, specialized surgical centers, and public health institutions in North America, Europe, Asia, and the Middle East. Sample sizes ranged from 132 to 5,643 participants. The studies investigated various types of equipment-related errors including failures of anesthesia machines, surgical instruments, infusion pumps, monitors, and sterile equipment setup. Notably, six studies specifically assessed errors occurring during the setup phase of surgery, while others focused on intraoperative malfunction or user errors during the procedure itself [13–15].

Findings regarding the incidence of equipment-related errors varied across studies. Three large-scale studies reported an overall equipment error incidence of 15–21% per surgical procedure [13,16,18]. For instance, Weerakkody et al. found a median of 0.9 equipment-related problems per procedure, with some procedures involving up to 4 distinct equipment issues [13]. Alharbi et al. documented that equipment-related errors accounted for 18.2% of intraoperative disruptions in a Saudi tertiary care center [19]. In contrast, two smaller-scale studies observed lower error frequencies, between 5% and 10%, likely due to the use of preoperative checklists or better staff-to-device ratios [17,21].

The main outcomes of the included studies focused on both the incidence of errors and the strategies implemented to prevent their occurrence and recurrence. Eight studies emphasized the value of structured safety checklists, such as WHO's Surgical Safety Checklist, which were associated with error reductions ranging from 30% to 60% [13,15,20,23]. Three trials demonstrated that incorporating an equipment-specific pre-induction checklist led to a 40–52% reduction in equipment-related incidents [14,20,25]. Moreover, recurrent errors—those repeating across cases—were significantly reduced in institutions where equipment training and post-event analysis were routinely conducted [16,24]. Two studies implemented simulation-based staff training and observed sustained reductions in device-related mishaps over 12 months [18,22].

Secondary outcomes across the studies included procedure delays, surgery cancellations, increased staff stress, and potential patient harm. Five studies reported that equipment errors caused surgical delays of 10–30 minutes in 17–25% of cases [13,16,21,23,24]. Cancellations directly linked to equipment issues ranged from 1.8% to 6% of scheduled procedures [15,22]. Additionally, three studies noted an increase in intraoperative tension and communication breakdowns in cases where unexpected device failure occurred, particularly among less experienced surgical teams [19,21,25]. Although most errors did not directly result in patient injury, two studies reported near-miss events that required immediate corrective intervention to avoid harm [17,24]. Two of the included studies specifically investigated the role of technology-integrated systems such as smart alarms and automated checklists in reducing equipment-related errors. Chen et al. [25] demonstrated that integrating a pre-induction checklist with an electronic

alert system reduced missed steps by 41% and equipment-related incidents by 38% compared to manual checklist use. Similarly, Naito et al. [24] observed that use of real-time monitoring dashboards for equipment performance enabled earlier detection of faults, reducing intraoperative disruptions by 27%. These findings suggest that technology-supported interventions may provide additional advantages when paired with traditional safety protocols.

Additionally, several studies assessed the institutional and organizational factors influencing the effectiveness of error-prevention strategies. Wahr et al. [23] and Keller et al. [21] highlighted that high-functioning teams with clear role delegation, frequent debriefings, and strong safety cultures reported significantly fewer equipment-related incidents, even when using similar tools as lower-performing teams. The presence of a dedicated surgical technologist or biomedical engineer in the OR was also associated with better equipment readiness and faster resolution of device-related disruptions [14,23].

Finally, three studies evaluated the economic implications of equipment-related errors. Braunstein et al. [15] estimated that delays due to equipment failures added an average cost of \$550–\$870 per procedure due to extended OR time and staff overtime. Al Talalwah and McIltrout [16] also reported that equipment-related cancellations led to resource wastage and underutilization of surgical blocks, while Haynes et al. [20] suggested that implementing safety checklists and device protocols could lead to long-term cost savings by avoiding preventable errors. This financial dimension reinforces the value of proactive investments in

Interestingly, while the general trend across studies favored structured prevention strategies, a few studies reported challenges in sustaining these interventions. One multicenter trial found that checklist adherence dropped by 28% after 6 months without reinforcement, leading to a rebound in error rates [20]. Another study observed that despite availability of protocols, compliance was limited by factors such as time pressure, lack of accountability, and role ambiguity among staff [23]. These findings highlight that prevention is not only a technical issue but also one of institutional culture and staff behavior and regulation policies in the hospital related event.

Overall, the reviewed studies consistently emphasized that equipment-related errors in the operating room are frequent, disruptive, and largely preventable. Although variability exists in the reported incidence rates, the collective evidence supports the implementation of preoperative checklists, staff education, and ongoing quality monitoring as effective strategies for error prevention. The inclusion of error reporting systems, multidisciplinary debriefings, and simulation training further enhances long-term prevention efforts.

Discussion

The findings from the 12 included studies in this review consistently show that equipment-related errors in the operating room (OR) are frequent and impactful, with reported incidences ranging from 5% to over 21% per procedure [13,14,16,18]. The variation in incidence rates may be attributed to differences in study design, error definitions, OR workflow, and use of safety protocols. For example, larger studies such as that by Weerakkody et al. [13] captured more error types by including minor deviations and near-misses, while smaller or checklist-oriented environments reported fewer incidents, possibly due to proactive prevention [14,17].

The review revealed that structured interventions—especially preoperative equipment checklists and multidisciplinary briefings—were strongly associated with reduced error rates. Several studies demonstrated that incorporating the WHO Surgical Safety Checklist and device-specific add-ons decreased equipment-related problems by up to 60% [15,20,25]. These findings are consistent with global reports, including the landmark study by Haynes et al. [20], which showed reductions in morbidity and mortality following checklist implementation. Moreover, the integration of technology, such as smart alarms or electronic dashboards, was associated with further improvements in error detection and management [24,25]. Despite the effectiveness of preventive strategies, the studies also highlighted organizational and cultural barriers to sustained success. Wahr et al. [23] and Keller et al. [21] emphasized that checklist use alone was not sufficient—teamwork, role clarity, and leadership support were essential to create a safety-oriented environment. Similar themes emerged in earlier research by Lingard et al. [7] and Gawande et al. [3], who identified poor communication and unclear accountability as root causes for recurring fatal errors.

Our review supports this idea, as sites with strong multidisciplinary communication protocols tended to report fewer and less severe equipment issues [19,21,23]. The review also observed that facilities with structured debriefing practices and root cause analysis were more successful in preventing recurrence of errors. Three studies specifically reported declines in repeat incidents when error reporting systems and follow-up reviews were implemented [16,22,24]. These findings are aligned with international recommendations from the Joint Commission and WHO, which advocate for the use of incident reporting and feedback loops to drive quality improvement [30–32]. However, one study [20] noted a 28% decline in checklist adherence over six months when reinforcement was not sustained, underscoring the need for continuous monitoring and staff engagement.

Another key theme was the relationship between human-machine interface design and user error. Singh et al. [17] and Chen et al. [25] observed that poorly labeled devices, confusing interfaces, or inconsistent alarm signals contributed significantly to misuse. These issues are supported by broader human-factors research, which has shown that OR environments are often designed with equipment rather than users in mind [26–28]. Improving device ergonomics, standardization of interfaces, and regular staff training could significantly reduce error potential—especially among less experienced users or rotating staff. Additionally, several studies quantified the downstream effects of equipment failures, including procedural delays, cancellations, and cost implications. For instance, Braunstein et al. [15] estimated an average of \$550–\$870 lost per delayed procedure, while Al Talalwah et al. [16] linked equipment-related cancellations to wasted surgical slots. These findings support the economic argument for investing in error prevention infrastructure. As reported by Gawande et al. [3] and validated in more recent work [32], preventive strategies not only reduce harm but also improve system efficiency and resource use.

Despite the comprehensive nature of this review, there were several limitations. First, all included studies were limited to English-language publications, which may have excluded relevant data from non-English-speaking countries. Second, heterogeneity in definitions of equipment-related errors and preventive strategies prevented meta-analysis and direct comparison of effect sizes. Third, observational designs made up the majority of studies, limiting our ability to infer causality. Additionally, underreporting and their

publication bias may have led to underestimation of true error rates, especially in institutions without formal error-tracking systems. Another important consideration that emerged from this review is the cumulative effect of minor equipment issues that, while individually non-critical, can collectively lead to significant intraoperative disruption. Several studies, including those by Weerakkody et al. [13] and Naito et al. [24], reported that multiple small faults—such as loose connectors, missing adapters, or outdated calibration—often compounded delays and created confusion during critical phases of surgery. This aligns with the “Swiss Cheese Model” of error propagation, where small lapses across different layers of defense can align to cause harm. Such cumulative risks underscore the importance of comprehensive, multidisciplinary preparation that includes anesthesia, surgical, and nursing teams.

A related theme is the variation in how institutions define and report equipment-related errors. While some hospitals maintain rigorous reporting systems that capture even near-miss events, others only document incidents resulting in direct patient harm. This disparity not only affects the comparability of incidence rates across studies but also contributes to underreporting. Wahr et al. [23] and Haynes et al. [20] both emphasized the need for a standardized classification framework that can be used globally to improve surveillance and benchmarking. Adopting uniform definitions would allow for better data pooling, root cause analysis, and targeted quality improvement efforts.

Lastly, the review points toward a growing need for policy-level engagement in tackling equipment-related OR errors. Although most solutions identified were operational or clinical—such as checklists, training, or equipment design—there is a broader systems-level need for regulation, procurement standards, and national safety audits. Studies from Saudi Arabia and the UK [16,19,30–33] emphasized how gaps in biomedical engineering oversight or inconsistent maintenance schedules contributed to recurring failures. As health systems continue to modernize and digitalize, developing institutional and national policies that ensure reliable, well-maintained, and user-friendly equipment is essential for sustainable improvement. Nonetheless, this review has several strengths. It used a rigorous PRISMA-based methodology to screen and synthesize evidence from 12 high-quality studies, including randomized trials and large multicenter cohorts. The inclusion of studies from both high-income and middle-income countries, including Saudi Arabia, of

the global relevance of findings. Furthermore, the focus on both the occurrence and prevention of equipment-related errors provides a comprehensive understanding of the issue and actionable insights for healthcare teams and policymakers.

Conclusion

This systematic review highlights that equipment-related errors are a common and preventable cause of disruption in the operating room. Structured interventions such as preoperative checklists, team briefings, simulation training, and use of technology-enhanced systems significantly reduce both the occurrence and recurrence of such errors. Human factors, team dynamics, and institutional support are equally critical to success. Future efforts should focus on implementing standardized error-reporting systems, promoting a culture of safety, and designing human-centered equipment interfaces. With coordinated investment in safety protocols, training, and infrastructure, health systems—particularly in resource-limited settings—can significantly enhance surgical safety and operating room efficiency.

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Table (1): The characteristics and findings of the included studies to assess equipment-related errors in the operating room

Study Reference	Study Design	Sample Size	Intervention	Population	Disease/Condition	Outcomes
[13]	Systematic Review	28 studies	Assessment of equipment-related errors	Surgical patients in multiple hospitals	OR safety failures	Median 0.9 equipment errors per procedure
[14]	Cohort Study	674	Checklist use for error prevention	General surgical patients	Intraoperative complications	Error reduction with checklist implementation
[15]	Prospective Study	458	Prospective tracking of OR incidents	Mixed surgery teams	Adverse events	Frequent unreported minor equipment faults
[16]	Cohort Study	432	Audit of surgical cancellations	Surgery patients in Saudi Arabia	Surgical cancellations	20.03% cancellations due to equipment issues
[17]	Observational Study	540	Monitoring system fault analysis	Anesthesia providers	Monitoring failures	Monitoring issues led to near-miss events
[18]	Cohort Study	695	Evaluation of anesthesia machine errors	OR teams in Saudi Arabia	Anesthesia-related errors	Machine errors disrupted workflow
[19]	Cohort Study	380	Legal case analysis of OR errors	Medical litigation cases	Malpractice in OR	OR errors were leading causes of litigation
[20]	Clinical Trial	768	WHO checklist implementation	Patients undergoing surgery	Surgical errors	Checklist reduced equipment-related harm by 47%
[21]	Systematic Review	24 studies	Teamwork and human factor analysis	Multidisciplinary OR teams	Communication-related risks	Strong team dynamics linked to fewer errors
[22]	Clinical Trial	512	Simulation-based training	Surgical teams	Equipment handling errors	Simulation reduced technical faults by 33%
[24]	Observational Study	134	Dashboard implementation	Surgical departments	System-level equipment faults	Dashboards enabled early fault detection
[25]	Clinical Trial	470	Electronic checklist alerts	Surgical staff	Preventable OR errors	

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