REVIEW & SPECIAL ARTICLE

Risk Management in Anesthesia Practice: A Systematic Review Across the Five Stages of Risk Control

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Risk management is a cornerstone of patient safety in anesthesia, where complex procedures, physiological variability, and time-critical decisions create inherent risks. Effective risk control requires a structured approach that spans all phases of anesthesia care. The present review systematically examined the five stages of risk management, which are risk awareness, risk identification, risk assessment, risk management, and risk evaluation, within anesthesia practice.

A comprehensive literature search was conducted in PubMed, Scopus, and Web of Science for articles published between January 2000 and December 2024, using the keywords "anesthesia", "risk management", "patient safety", and "perioperative". Inclusion criteria were peer-reviewed studies, guidelines, and systematic reviews addressing any stage of anesthesia risk management.

Findings highlight that anesthesia risks arise from human factors, equipment/technical failures, environmental conditions, and hospital system issues. Successful strategies include preoperative briefings, structured checklists, incident reporting, root cause analysis, and implementation of validated risk matrices. Continuous feedback and integration with hospital safety systems enhance sustainability.

For anesthesia providers, applying a stage-based model promotes early hazard recognition, prioritization of high-impact risks, and targeted preventive measures. Embedding these processes into daily practice not only reduces adverse events but also fosters a culture of safety, improving both patient outcomes and team performance.

Keywords: Anesthesia safety; Clinical risk assessment; Patient safety; Perioperative care; Risk management

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Background and importance

Risk management is a critical component of anesthesia practice, where patient safety can be compromised by complex clinical conditions, rapid decision-making, and the high-risk nature of perioperative interventions[1,2]. Anesthesiologists and anesthesia providers must continuously balance therapeutic benefit against potential harm, making structured risk management an essential part of daily practice[3,4].

Global and national incidence of anesthesia-related adverse events

Globally, anesthesia-related mortality has decreased significantly over recent decades, yet adverse events remain a concern[4,5]. The World Health Organization (WHO) estimates that millions of surgical procedures annually are associated with preventable anesthesia-related complications[2,6]. In high-income countries, anesthesia-related mortality is approximately 1 per 100,000 to 200,000 anesthetics, whereas in low- and middle-income countries, rates may be as high as 1 per 300 to 10,000 cases[4]. National registry data consistently show that human factors, equipment malfunction, and system errors contribute significantly to morbidity and mortality in anesthesia practice[7-10].

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Magnitude of preventable incidents

Studies suggest that up to 50% to 70% of anesthesia-related adverse events are preventable through initiative-taking identification of hazards, systematic prevention strategies, and effective response protocols[7,8,11,12]. The WHO Surgical Safety Checklist has demonstrated a reduction in peri-operative complications by up to 36%, underscoring the impact of structured risk management[2,6,13].

Table 1. Preoperative briefing flow[2,6,13,24]

Step	Content	Responsible team member	Purpose
1	Confirm patient identity and procedure	Circulating nurse	Prevent wrong-patient/procedure error
2	Review patient history and comorbidities	Anesthesiologist	Identify anesthesia-specific risks
3	Discuss surgical plan and anticipated challenges	Surgeon	Align team expectations
4	Confirm equipment availability and readiness	Anesthesia tech	Prevent equipment-related delays/failures
5	Review contingency plans for emergencies	Entire team	Ensure coordinated crisis response

Purpose of the review

The present review aimed to provide a comprehensive examination of risk management in anesthesia, addressing all five stages, which are risk awareness, risk identification, risk assessment, risk management, and risk evaluation[1,3,4,14]. Unlike previous literature focusing primarily on escalation control during crises, the present paper presents an integrated model encompassing preventive, corrective, and evaluative measures[7,11,12].

Link to patient safety and quality improvement

By embedding a complete risk management cycle into anesthesia workflows, providers can reduce the frequency and severity of adverse events, enhance communication among perioperative teams, and contribute to a culture of continuous safety improvement[1,2,4,11,12]. Structured risk management promotes initiative-taking hazard recognition, standardized preventive measures, and systematic evaluation, thereby supporting both patient safety and overall quality improvement[6,13].

Conceptual framework

The present review adopted a five-stage risk management framework, widely recognized in healthcare safety science[1,3,4,7,14]:

Risk awareness/situation awareness, which is recognizing contextual factors and early warning signs[7,15,16].

Risk identification, which is detecting hazards through structured observation, incident reporting, and process analysis[8,11,12,17].

Risk assessment, which is evaluating the likelihood and severity of identified risks[18-20].

Risk management, which is implementing prevention strategies, mitigation measures, and escalation control when harm is imminent[2,6,13,14].

Risk evaluation/feedback loop, which is monitoring outcomes, learning from incidents, and refining processes[4,11,12].

Five stages of risk management in anesthesia practice

The five-stage model ensures an initiative-taking, systematic, and iterative approach that addresses both the prevention and management of harm[1,3,4,7,12,14]. Applying it in anesthesia practice provides a clear roadmap for clinical teams, aligning international patient safety goals[2,4,6] and facilitating integration into hospital risk management systems[4,11].

Stage 1: Risk awareness/situation awareness (Table 1)

Risk awareness, often referred to as situation awareness in patient safety literature, is the continuous perception and understanding of the clinical environment, combined with the ability to project future states[7,15,16]. In anesthesia practice, this applies to all perioperative phases. The perioperative phases are described below.

Preoperative: recognizing patient-specific risks such as comorbidities, allergies, and airway difficulties, and procedure-related challenges before anesthesia induction[3,21,22].

Intraoperative: maintaining real-time awareness of physiological parameters, surgical progress, and any deviations from expected trends[15,16,23].

Postoperative: anticipating complications such as airway obstruction, hemodynamic instability, or delayed emergence during transfer and recovery[4,17].

Failure in situation awareness is a leading contributor to critical incidents in anesthesia, as it delays recognition of hazards and limits timely intervention[7,8,17].

Contributing factors

A variety of factors contribute to anesthesia-related risk, including human, equipment, environmental, and hospital/system elements[7-10,15,16]. Those are listed below.

Human factors:

- Fatigue from extended shifts or night duties[7,15]
- Limited clinical experience with complex

cases[7,16]

• Communication gaps between anesthesia, surgical, and nursing teams[11,24,25]

Equipment factors:

• Malfunctioning monitors or ventilators[14,23]

• Inadequate preventive maintenance schedules[4]

Environmental factors:

• Excessive background noise making alarms[26]

• Poor lighting or cluttered workspace[26]

Hospital/system factors:

• Inadequate staffing ratios in the operating room[4,9]

• Weak institutional safety culture that discourages speaking up[12]

• The surgical, anesthesia, and nursing teams covering patient details, anticipated risks, and equipment.

Practical tools for enhancing risk awareness

Pre-anesthesia briefing: A structured discussion among readiness and contingency plans[2,24].

Cognitive aids: Crisis checklists and emergency algorithms to reinforce correct actions during rare but high-risk events, ensuring critical steps are not overlooked[6,13,17].

Stage 2: Risk identification (Figure 1)

Risk identification uses historical data and real-time surveillance to detect threats before they escalate[1,7].

Sources of information

Effective risk identification in anesthesia relies on gathering data from multiple sources to ensure both retrospective learning and prospective hazard detection. The sources are listed below.

1. Past incident reports. An analysis of critical incident reporting systems reveals common patterns and recurring hazards, such as medication errors, airway difficulties, and equipment failures[12,27].

2. Morbidity and mortality reviews. A structured review of perioperative complications to extract lessons learned and identify modifiable causes[10].

3. Root cause analysis. A systematic process to uncover underlying system and process failures that contribute to adverse events[7].

4. Failure mode and effects analysis. An initiative-taking tool for mapping anesthesia workflows, identifying potential failure points, and ranking them by severity and likelihood[4,28].

5. Patient safety goals and sentinel event alerts. National and institutional safety alerts highlight high-priority risks requiring urgent mitigation[24,25].

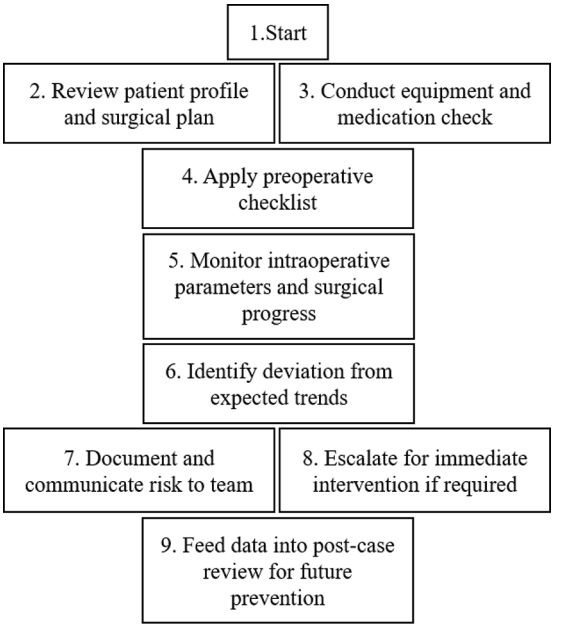

Figure 1. Flowchart for identifying risks in anesthesia workflow[7,10-12,26-34].

Methods for real-time identification

In addition to retrospective reviews, anesthesia practice requires active, real-time identification methods to promptly capture emerging risks:

• Direct observation. On-the-spot detection of hazards during anesthesia care (e.g., incorrect drug labeling, disconnected monitoring cables)[26,29,30].

• Checklists. Structured prompts ensuring that no safety-critical step is overlooked, enhancing consistency and reducing human error[2,6,13,31-33].

• Monitoring data trends. Continuous tracking of vital signs and ventilator parameters to identify early warning signs before clinical deterioration[23,34].

Stage 3. Risk assessment (Table 2, 3)

Risk assessment determines the likelihood that an identified hazard will occur and the severity of its potential impact. This step prioritizes which risks require immediate intervention and which can be managed with routine safeguards[1,4,7,28].

Frameworks

1. Risk matrix (Probability × Impact). A two-dimensional grid categorizing risks into low, moderate, high, and critical levels[1,28].

2. Hazard scoring systems. A numerical scales such as 1 to 5 for probability and 1 to 5 for severity, used to generate a composite risk score[4,18,19].

Case examples

• Airway difficulty risk: Probability to

Table 2. Risk matrix (Probability × Impact)[1,4,18,28]

Risk event	Probability	Impact severity	Risk level	Action priority
Difficult airway	Medium	High	High	Prepare advanced airway equipment, alert senior staff
Allergic reaction to drug	Low	High	Medium	Verify allergy history, prepare emergency drugs
Ventilator malfunction	Low	Critical	High	Check backup equipment before induction
Hypotension during induction	High	Moderate	High	Prepare vasopressors, adjust induction dose
Line disconnection	Medium	Moderate	Medium	Secure connections, continuous monitoring

Table 3. Example hazard scoring system[1,4,18,28]

Probability	Severity				
	Rare (1)	Unlikely (2)	Possible (3)	Likely (4)	Almost certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Insignificant (1)	1	2	3	4	5

Moderate, based on Mallampati score, body mass index, and neck mobility; Impact to High, based on potential for hypoxia and failed intubation[3,8]

- Allergic reaction risk: Probability to Low based on history of drug allergies negative; Impact to High as anaphylaxis possible if occurs[9]
- Hemodynamic instability risk: Probability to High based on severe cardiac disease; Impact to High with risk of cardiac arrest[10,20]

Stage 4: Risk management (Figure 2)

Risk management in anesthesia focuses on prevention, mitigation, and escalation control. Once risks are identified and assessed, interventions are applied to reduce the probability of occurrence and limit the severity of consequences[1,2,4].

Prevention strategies

Standardized protocols: Adherence to WHO Surgical Safety Checklist, local anesthesia guidelines, and medication labeling standards[2,6,13,14,29].

Pre-anesthesia preparation: Confirming patient data, verifying equipment readiness, and preparing emergency drugs before induction[3,14,23].

Staff education and simulation training: Enhancing skills for high-risk scenarios such as difficult airway management or malignant hyperthermia[3,8,24,25].

Mitigation strategies

Redundancy in critical systems: Backup monitoring, spare airway devices, and duplicate power supply[4,23,26].

Real-time decision support: Use of cognitive aids such as crisis management checklists, and electronic reminders to prevent omissions[11,17,31].

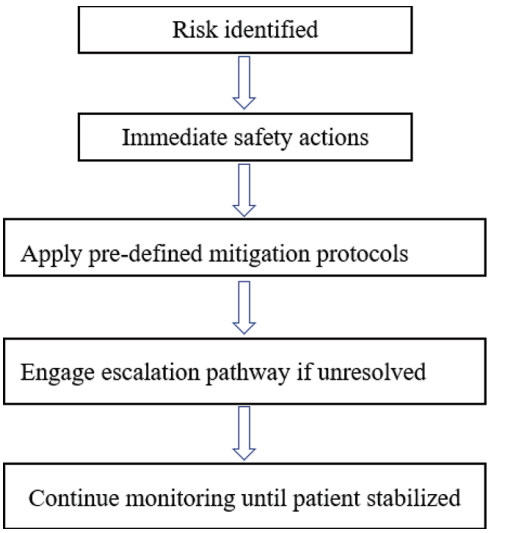

Figure 2. Example anesthesia risk management flow[1,2,4,6,13,14,23-25,29,31].

Escalation control

Clear communication protocols. Use of closed-loop communication during emergencies[7,24,25].

Early activation of support systems. Immediate call for senior anesthesiologist or code team when early warning signs appear[4,10].

Stage 5: Risk evaluation/feedback loop (Table 4, 5)

Risk evaluation ensures that implemented risk controls are effective and continuously improved. It closes the risk management loop by feeding lessons learned into future practice[1,4,7].

Post-event evaluation

Incident debriefings. Conducted immediately after a critical event to review actions taken, identify gaps, and reinforce effective strategies[24,25].

Performance audits. Comparing compliance with safety protocols against benchmarks[6,13,23].

Feedback systems

Reporting into national/institutional databases. Contributing to anesthesia quality registries to track

Table 4. Evaluation metrics for anesthesia risk control[6,11-13,23-25,35,36]

Measures	Metric	Definition	Example Application
Incident recurrence rate	Frequency of a specific adverse event	Number of times a particular adverse event reoccurs within a given period	Reduction in wrong-drug administration cases by 30% over 6 months following protocol changes
Compliance rate with checklist	Percentage adherence to WHO checklist	Proportion of cases in which all steps of the WHO surgical safety checklist are completed	Achieving 95% compliance in completing the pre-induction checklist before anesthesia
Time-to-intervention	Time from risk detection to corrective action	Duration between identifying a critical incident and implementing corrective measures	Relieving airway obstruction within 60 seconds from detection in simulated and real cases
Staff confidence score	Self-rated preparedness	Average score from staff surveys rating their readiness to handle anesthesia-related risks	Improvement in average confidence score from 3.5/5 to 4.7/5 after simulation-based training

WHO=World Health Organization

Table 5. Anesthesia risks across five stages

Stage	Common risks	Contributing factors	Strategies/tools
Risk awareness[7,15,16,24]	Misidentification, overlooked hazards	Fatigue, noise, poor communication	Pre-operative briefing, cognitive aids
Risk identification[7,10-12,27,28]	Undetected airway difficulty, adverse drug reaction	Lack of prior incident analysis, poor monitoring	RCA, FMEA, real-time checklists
Risk assessment[1,3,4,18-20]	Misjudged risk severity	Inexperience, incomplete data	Risk matrix, hazard scoring
Risk management[2,6,13,14,23-25,29,31]	Escalation of hypotension, anaphylaxis	Protocol non-adherence, equipment failure	Prevention protocols, mitigation plans, escalation control
Risk evaluation/feedback[4,10-12,23,35,36]	Recurrent events, gaps in learning	Weak feedback systems, low compliance	Debriefing, audits, M&M review, database reporting

RCA=root cause analysis; FMEA=failure mode and effects analysis; M&M=morbidity and mortality

trends over time[8-10,12].

Regular morbidity and mortality meetings. Converting experiences into policy or protocol updates[10,35,36].

Continuous improvement

Incorporating new evidence into guidelines(3,21,22).

Updating simulation training scenarios based on emerging risks[3,8,24].

Sharing success stories and near-miss analyses to strengthen safety culture[11,12,31,32].

Conclusion

Implementing the five-stage risk management framework enables anesthesia teams to embed an initiative-taking hazard detection, structured responses, and continuous learning into daily practice, to reduce adverse events, strengthen safety culture, and improve patient outcomes. Aligning anesthesia risk management with the hospital's overall safety program ensures that policies, reporting systems, and resources reinforce one another. A balanced approach that combines systemic accountability, designing error-resistant processes, with individual accountability for protocol adherence, competence, and near-miss reporting fosters a fair, effective safety culture. Achieving this culture requires visible leadership commitment, transparent and blame-free reporting, and ongoing training through regular drills, workshops, and protocol updates.

What is already known about this topic?

Anesthesia practice is inherently associated with risks, including complications such as respiratory depression, cardiovascular instability, and adverse drug reactions. Effective risk management is essential to enhance patient safety, improve clinical outcomes, and mitigate legal and ethical challenges. Advances in technology, techniques, and protocols have significantly transformed anesthesia practice, requiring stringent safety standards and initiative-taking strategies to address risks. Human factors such as communication breakdowns, fatigue, and distractions, along with technical factors like equipment reliability and medication errors, can contribute to adverse events. The evolving role of technology, including electronic health records and automated drug delivery systems, has facilitated improved patient monitoring, risk assessment, and communication within anesthesia teams. Collaborative teamwork and structured communication are critical in preventing errors and optimizing anesthesia care.

What does this study add?

This review provides a comprehensive analysis

of risk management strategies in anesthesia, emphasizing their importance in mitigating patient harm and enhancing outcomes. It highlights practical approaches, such as preoperative assessments, tailored anesthesia plans, and vigilant monitoring, to address patient-specific risks. The role of technology is explored in depth, highlighting its impact on improving precision, safety, and decision-making. This article underscores the significance of interdisciplinary collaboration, team communication, and standardized protocols in minimizing risks. It also addresses the ethical and legal dimensions of inadequate risk management, offering insights into how an initiative-taking and multidisciplinary approach can foster a culture of safety in anesthesia practice.

Conflicts of interest

The authors declare no conflict of interest.

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