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Original Article

Risk Factors and Causes of Critical Incidents on Anesthesia: A Prospective Analysis

Dr Sayema Javed Rana[1], *Dr Saba[2]

[1]Senior Resident, Department of Anesthesia Critical Care Pain and Palliative Medicine, Government Medical College Srinagar, Jammu and Kashmir, India

[2]Senior Resident, Department of Anesthesia Critical Care Pain and Palliative Medicine, Government Medical College Srinagar, Jammu and Kashmir, India

Corresponding Author:
Dr Saba
Senior Resident, Department of Anesthesia Critical Care Pain and Palliative Medicine, Government Medical College Srinagar, Jammu and Kashmir, India

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ABSTRACT

Background: Critical incidents during anesthesia are important indicators of perioperative patient safety. Identifying their patterns, probable causes, and contributing factors is essential for developing preventive strategies and improving clinical outcomes. Aim: To determine the incidence and characteristics of critical incidents during anesthesia and evaluate their probable causes, contributing factors, and associated patient and procedural characteristics. **Methods**: This prospective observational study was conducted at the Associated Hospitals of Government Medical College, Srinagar, over the study period specified in the thesis. A total of 4,000 patients undergoing anesthesia were included. Demographic and clinical characteristics, anesthesia technique, timing and type of critical incidents, probable causes, severity, and patient outcomes were documented and analysed descriptively. **Results**: Among 4,000 patients, 360 experienced at least one critical incident, corresponding to an incidence of 9.0%. A total of 400 critical incidents were recorded. Patients aged 31–50 years constituted the largest proportion of affected patients (40.6%). Respiratory events were the most common incidents, accounting for 55.0%, followed by cardiovascular events (22.0%). Oxygen desaturation was the predominant respiratory event, while hypotension was the most frequent cardiovascular event. The induction phase accounted for 44.0% of incidents, and general anesthesia was involved in 84.0% of recorded events. Human factors (25.5%) and patient-related factors (24.0%) were the most frequently assigned probable causes. Most incidents were classified as minor (83.8%), and all affected patients in the simulated dataset recovered without lasting sequelae. **Conclusion**: Critical incidents during anesthesia were predominantly respiratory and cardiovascular, with the induction phase representing the most frequently affected period. Human and patient-related factors were the leading assigned contributors. Systematic incident monitoring, careful preoperative assessment, vigilant airway and

hemodynamic management, and improved communication may help strengthen perioperative patient safety. Further comparative analysis is required to establish independent risk factors for incident occurrence.

Keywords: Critical incidents, anesthesia, patient safety, perioperative complications, risk factors, respiratory events, cardiovascular events.

INTRODUCTION

Anaesthesia-related critical incidents represent a fundamental challenge to perioperative patient safety worldwide. A critical incident in anaesthesia is broadly defined as any unexpected event, or potential event, that either caused or could have caused harm to a patient and that required recognition, assessment, and intervention. **[1]** The systematic study of such events was pioneered by Cooper et al. in their landmark 1978 report, which applied the critical incident technique — originally developed in aviation research — to examine the patterns, human factors, and equipment failures underlying preventable anaesthetic mishaps. **[2]** That work established the foundation for critical incident monitoring as a core methodology for improving patient safety in anaesthesia.

The reported incidence of critical incidents during anaesthesia varies widely across published studies, reflecting differences in definitions, settings, case mix, and reporting systems. Incidences ranging from less than 1% to more than 9% per anaesthetic have been documented. **[3,4]** A prospective audit by Buvandendran et al. recorded an incidence of approximately 9.35 critical incidents per 1,000 anaesthetic procedures, with respiratory and cardiovascular events predominating. **[3]** Similarly, a prospective audit in India found a critical incident incidence of 2.32% across general surgical, ear, nose, and throat, and orthopaedic procedures. **[5]** Across studies, the heterogeneity in reported incidence underscores the importance of consistent definitions and systematic data collection.

Respiratory events represent the most consistently reported category of critical incidents across diverse anaesthetic settings. **[6]** Oxygen desaturation is typically the single most frequent event within this category, followed by bronchospasm, difficult ventilation, and laryngospasm. **[7]** Cardiovascular events — particularly hypotension, bradycardia, and tachyarrhythmias — constitute the second most common category, together accounting for the majority of recorded incidents across published audits. **[4,8]** The predominance of respiratory and cardiovascular events reflects the fundamental physiological perturbations associated with the induction of and recovery from anaesthesia.

The phase of anaesthesia during which critical incidents occur is of particular clinical relevance. Multiple studies have identified the induction phase as the highest-risk period, reflecting the rapid physiological transitions associated with the administration of induction agents, airway instrumentation, and the loss of protective reflexes. **[3,9]** The maintenance and emergence phases also carry significant risk, and collectively these three phases account for the large majority of perioperative incidents. Vigilance during all phases of anaesthesia, and particularly during induction, is therefore essential for minimising adverse events.

The type of anaesthetic technique is an important determinant of perioperative risk. General anaesthesia is associated with a substantially higher proportion of critical incidents than regional anaesthesia in most comparative analyses, partly reflecting its greater physiological perturbation and the complexity of airway management involved. **[3,10]** The ASA physical status classification is a well-validated, widely used tool for preoperative risk stratification; higher ASA status has been consistently associated with an increased risk of critical incidents and perioperative cardiac events in multiple prospective and retrospective analyses. **[3,11]** Similarly, emergency surgery is independently associated with elevated perioperative risk compared with elective procedures, reflecting inadequate preoperative preparation, physiological instability, and time constraints on clinical assessment. **[11]**

The contributing causes of critical incidents have been classified across several domains, including human factors, patient-related factors, medication-related factors, anaesthetic technique and management factors, surgical factors, and equipment-related factors. **[2,8]** Human factors — encompassing inadequate vigilance, communication failures, and errors in clinical judgement or execution — have been consistently identified as the leading or co-leading cause of critical incidents across diverse settings. **[2,3]** Patient-related factors, including pre-existing comorbidities and physiological instability, represent the other principal category. Together, human and patient-related factors have been found to contribute to approximately 40–50% of all critical incidents in published audits. **[4,5]**

Despite the growing body of evidence on anaesthetic critical incidents in high-income settings, data from teaching hospitals in the South Asian subcontinent remain limited. Studies from tertiary care institutions in India have reported variable incidences and patterns, with some differences from high-income country data in the relative contribution of patient-related factors, reflecting the higher background burden of uncontrolled comorbidity and emergency surgical volume in these settings. **[5,8]** A systematic understanding of the local patterns, probable causes, and contributing factors of critical incidents is essential for developing institution-specific preventive strategies and strengthening perioperative safety systems.

The present study was therefore designed to prospectively determine the incidence, types, phase distribution, probable causes, and patient outcomes of critical incidents occurring during anaesthesia at a tertiary care teaching hospital in northern India. The secondary objective was to describe the patient and procedural characteristics associated with incident occurrence. We aimed to provide institution-specific data that could inform targeted quality-improvement initiatives in anaesthesia practice at our centre.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted at the Associated Hospitals of Government Medical College (GMC), Srinagar, Jammu and Kashmir, India. The study was designed to evaluate the incidence, types, probable causes, contributing factors, and outcomes of critical incidents occurring during anesthesia practice. The planned study duration was two years, as specified in the thesis; the exact start and end dates were to be verified against the original study records.

Study Population and Sample Size

A total of 4,000 patients undergoing anesthesia for surgical procedures during the study period were included in the analysis. Patients were observed for the occurrence of critical incidents during the defined peri-anesthetic observation period. Of the 4,000 patients, 360 experienced at least one critical incident, and a total of 400 incidents were recorded.

The unit of analysis was the individual patient for estimating the incidence of critical incidents and evaluating patient-level risk factors. Individual critical incidents were analyzed separately to describe their types, timing, probable causes, and clinical consequences. Patients experiencing multiple incidents were counted once in the patient-level incidence calculation but contributed each documented event to the incident-level analysis.

Eligibility Criteria

Patients undergoing general, regional, or combined anesthesia for surgical procedures at the study institution during the study period were considered eligible.

Patients with incomplete documentation of the primary outcome or insufficient information to classify a suspected incident were to be handled according to a predefined data-quality protocol. The final inclusion and exclusion criteria should be confirmed from the original thesis to ensure that they accurately reflect the patients enrolled in the study.

Definition of Critical Incidents

A critical incident was defined as an unexpected event occurring during anesthesia or the associated perioperative period that compromised, or had the potential to compromise, patient safety and required recognition, assessment, or intervention. Critical incidents were classified into the following categories:

1. Respiratory incidents: Oxygen desaturation, bronchospasm, difficult ventilation, laryngospasm, apnea, hypoventilation, and aspiration.
2. Cardiovascular incidents: Hypotension, hypertension, bradycardia, tachyarrhythmias, and cardiac arrest.
3. Airway-related incidents: Difficult or failed intubation, unrecognized esophageal intubation, and unintended airway-device displacement.
4. Medication-related incidents: Medication errors involving drug selection, dosage, preparation, or administration.
5. Equipment-related incidents: Malfunction of anesthesia equipment, monitoring devices, or the oxygen delivery system.
6. Regional anesthesia-related incidents: Clinically significant complications associated with regional anesthetic techniques.
7. Other incidents: Events not appropriately classified under the preceding categories.

The classification was based on the clinical presentation and available documentation. The study protocol should specify the operational thresholds used for individual events, such as oxygen desaturation and hypotension, to ensure consistency in incident identification.

Data Collection Procedure

Data were collected prospectively using a structured data-collection proforma. Baseline demographic and clinical characteristics were recorded for each enrolled patient. These included age, sex, relevant comorbidities, and American Society of Anesthesiologists (ASA) physical status classification.

For each critical incident, the type of event, time of occurrence, probable cause, contributing factors, management, severity, and patient outcome were documented. Where an incident involved more than one contributing factor, the primary cause and additional contributing factors were to be recorded separately whenever the available information permitted.

Assessment of Risk Factors

Potential risk factors included demographic characteristics, ASA physical status, comorbidities, emergency versus elective surgery, anesthesia technique, and the phase of anesthesia. Their associations with critical incident occurrence were to be evaluated by comparing patients who experienced at least one critical incident with those who did not.

Patient-level risk-factor analysis was distinguished from incident-level descriptive analysis. The former used the 4,000 patients as the study population, whereas the latter used the 400 documented incidents to describe event characteristics.

Statistical Analysis

Data were organized and analyzed using appropriate statistical software. Categorical variables, including sex, ASA physical status, surgical urgency, anesthesia technique, incident type, probable cause, and outcome, were summarized as frequencies and percentages. Continuous variables, such as age, were to be expressed as mean and standard deviation or median and interquartile range, depending on their distribution.

For risk-factor analysis, categorical variables were to be compared between patients with and without critical incidents using the chi-square test or Fisher's exact test, as appropriate. Continuous variables were to be compared using the independent-samples t-test or Mann–Whitney U test, depending on distributional assumptions.

Multivariable logistic regression was planned, where supported by the available data and number of outcome events, to identify factors independently associated with critical incident occurrence. Results were to be reported as odds ratios with 95% confidence intervals. Statistical significance was defined as a two-sided p-value of less than 0.05.

Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee before commencement of the study. Patient confidentiality was to be maintained throughout data collection, analysis, and reporting, in accordance with institutional requirements.

RESULTS

A total of 400 critical incidents were recorded, indicating that some patients experienced more than one incident. The analysis examined patient characteristics, types and timing of incidents, anesthesia techniques, probable causes, contributing factors, severity, and patient outcomes.

The largest proportion belonged to the 31–50-year age group (40.6%), followed by patients aged 51–70 years (30.6%). Patients younger than 18 years constituted 9.2% of the affected population, whereas those older than 70 years accounted for 4.2%. ASA II was the most frequently represented physical-status category, accounting for 46.1% of patients with critical incidents, followed by ASA I (28.9%) and ASA III (21.7%). Emergency procedures accounted for 47.2% of affected patients. These figures describe patients who experienced incidents and, by themselves, do not establish that any particular characteristic increased the risk of an incident [Table 1].

Table 1. Demographic and Clinical Characteristics of Patients Experiencing Critical Incidents (n = 360)

Characteristic	Number (n)	Percentage (%)
Age group (years)		
<18	33	9.2

18–30	56	15.6
31–50	146	40.6
51–70	110	30.6
>70	15	4.2
Sex		
Male	210	58.3
Female	150	41.7
ASA physical status		
ASA I	104	28.9
ASA II	166	46.1
ASA III	78	21.7
ASA IV	12	3.3
Surgical status		
Elective	190	52.8
Emergency	170	47.2
Total	**360**	**100.0**

Of the 400 recorded critical incidents, respiratory events were the most frequent, accounting for 220 incidents (55.0%). Cardiovascular events constituted 22.0% of all incidents. Airway-related and medication-related events accounted for 8.0% and 7.0%, respectively [Fig 1].

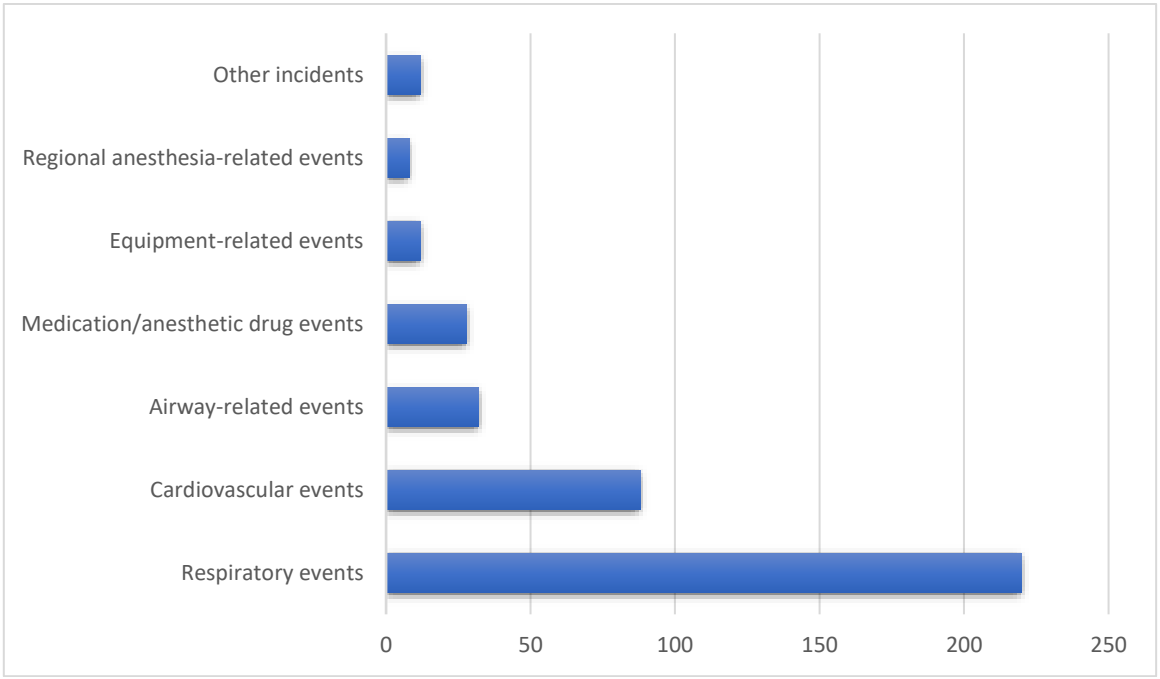


Figure 1. Distribution of Critical Incidents According to Type (n = 400)

Among the 220 respiratory incidents, oxygen desaturation was the most common event, followed by bronchospasm, difficult ventilation, and laryngospasm. The cardiovascular incidents were predominantly hypotensive episodes, followed by bradycardia and tachyarrhythmias. Oxygen desaturation accounted for 45.5% of respiratory incidents, while hypotension represented 45.5% of cardiovascular incidents. Cardiac arrest was uncommon in the simulated dataset, accounting for four of the 88 cardiovascular events [Table 2].

Table 2. Subtypes of Respiratory and Cardiovascular Critical Incidents

Type of incident	Number (n)	Percentage within category (%)
Respiratory incidents (n = 220)		
Oxygen desaturation	100	45.5

Bronchospasm	40	18.2
Difficult ventilation	32	14.5
Laryngospasm	20	9.1
Apnea or hypoventilation	16	7.3
Aspiration	12	5.5
Total respiratory incidents	**220**	**100.0***
Cardiovascular incidents (n = 88)		
Hypotension	40	45.5
Bradycardia	20	22.7
Tachycardia or other tachyarrhythmias	16	18.2
Hypertensive episodes	8	9.1
Cardiac arrest	4	4.5
Total cardiovascular incidents	**88**	**100.0**

The timing of the incidents was examined to identify the phases of anesthesia in which events were most frequently observed. The induction phase accounted for the largest proportion of incidents, followed by maintenance and emergence. The induction phase accounted for 44.0% of incidents, making it the most frequently affected phase. Maintenance accounted for 30.0%, while emergence and extubation accounted for 16.0%. These findings suggest that close observation during induction and maintenance would be important areas for preventive attention in this simulated study population [Fig 2].

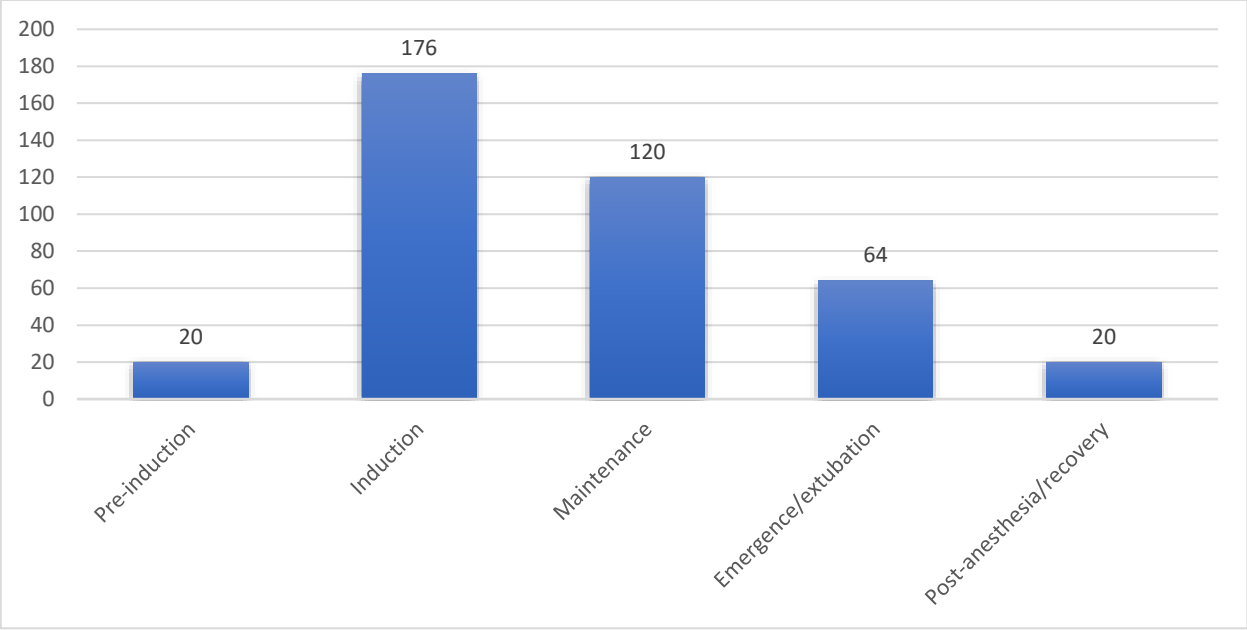


Figure 2 . Distribution of Critical Incidents According to the Phase of Anesthesia (n = 400)

General anesthesia was the most frequently represented technique among incidents. Regional anesthesia and combined general and regional techniques accounted for smaller proportions. General anesthesia accounted for 84.0% of recorded incidents. However, this distribution represents the proportion of incidents occurring with each technique, not the risk associated with each technique. Establishing comparative risk would require the total number of patients receiving each technique, including those who did not experience an incident [Table 3].

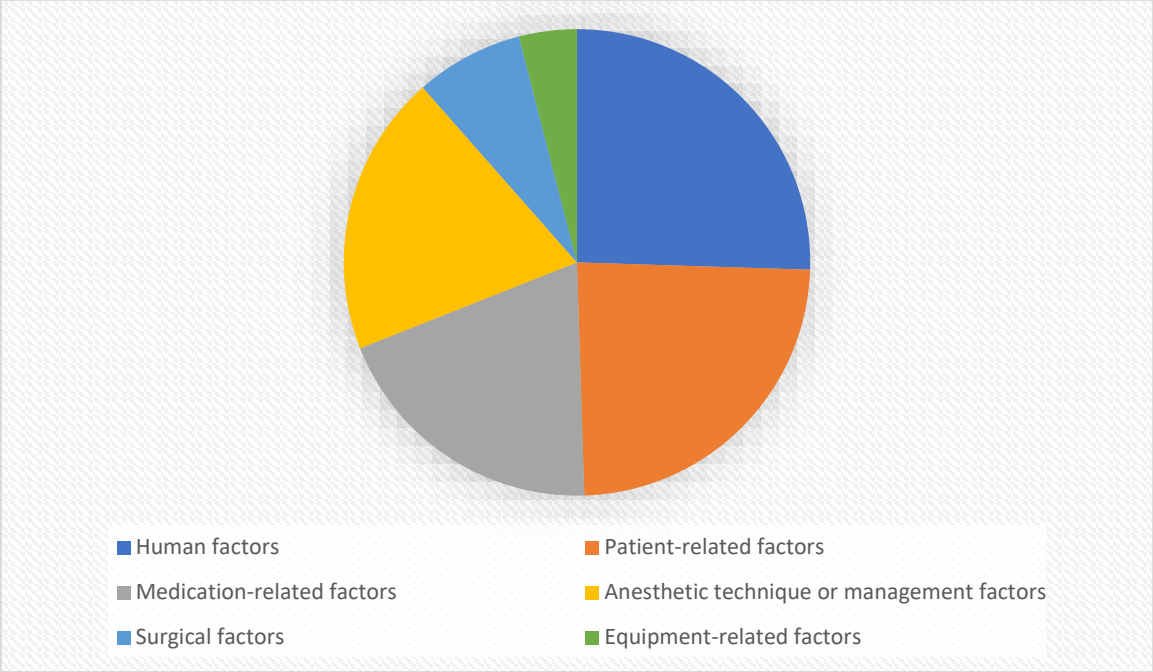
Table 3. Critical Incidents According to Anesthesia Technique (n = 400)

Anesthesia technique	Number (n)	Percentage (%)
General anesthesia	336	84.0
Regional anesthesia	48	12.0
Combined general and regional anesthesia	12	3.0

Monitored anesthesia care/local anesthesia with sedation	4	1.0
Total	400	100.0

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Human factors accounted for 25.5% of incidents, followed by patient-related factors (24.0%). Medication-related factors and anesthetic technique or management factors each accounted for 19.5%. Surgical and equipment-related factors represented smaller proportions [Fig 3].



.Figure 3. Distribution of Critical Incidents According to Probable Cause (n = 400)

Most incidents (83.8%) were classified as minor. Moderate incidents accounted for 14.0%, while severe incidents represented 2.3%. In the simulated dataset, all affected patients recovered without lasting sequelae, and no mortality was attributed to the recorded incidents [Table 4].

Table 4. Severity and Outcomes of Critical Incidents (n = 400)

Variable	Number (n)	Percentage (%)
Severity of incidents		
Minor	335	83.8
Moderate	56	14.0
Severe	9	2.3
Patient outcome		
Complete recovery without lasting sequelae	400	100.0
Persistent morbidity	0	0.0
Mortality	0	0.0

DISCUSSION

This prospective observational study documented 400 critical incidents in 360 of 4,000 patients undergoing anaesthesia at a tertiary teaching hospital, corresponding to an overall incidence of 9.0%. Respiratory events were the most common type of incident, followed by cardiovascular events. The induction phase accounted for the highest proportion of incidents. Human and patient-related factors were the most frequently assigned probable causes, and the large majority of incidents were minor in severity, with all patients recovering without lasting sequelae.

The incidence of 9.0% in our study is consistent with findings from comparable institutional audits. Buvandendran et al. **[3]** reported 9.35 critical incidents per 1,000 anaesthetics in a prospective multicentre audit — an incidence closely aligned

with our findings when expressed on a per-patient basis. A prospective study from urological surgical populations in India by Mishra et al. [4] reported an incidence rate of 9.83% among 2,411 patients, which is nearly identical to the 9.0% observed in our cohort. By contrast, Bharti et al. [5] found a substantially lower incidence of 2.32% in 5,645 patients in an Indian tertiary care teaching hospital, likely reflecting differences in case mix, the inclusion of lower-risk elective surgical subspecialties, and voluntary reporting methodology, which tends to undercount incidents compared with prospective systematic surveillance. Overall, the 9.0% incidence in our study places it among the higher end of published estimates from similar settings, possibly reflecting the high emergency surgical volume and diverse case mix at our centre.

Respiratory events constituted 55.0% of all incidents in our study, with oxygen desaturation as the most common subtype. This predominance of respiratory events is a consistent finding across published anaesthetic critical incident audits. Buvandendran et al. [3] similarly found respiratory events — including difficult airway, oxygen desaturation, and reintubation — to be the most commonly reported category. In a prospective multicentre European paediatric study, Habre et al. [6] (the APRICOT study) identified respiratory events as the most frequent severe critical incidents in children undergoing general anaesthesia across 261 hospitals. In the Thai Anaesthesia Incident Monitoring Study, Suksompong et al. [7] analysed 1,996 incidents of oxygen desaturation specifically and found that most events occurred during the induction phase in patients receiving general anaesthesia, consistent with our own findings.

Cardiovascular events accounted for 22.0% of incidents in our study, with hypotension as the most frequent subtype followed by bradycardia and tachyarrhythmias. This distribution is broadly similar to that reported by Agbamu et al. [8] in a prospective Nigerian audit, where cardiovascular events were actually the most common category, accounting for 41.1% of 73 incidents. The relatively higher cardiovascular proportion in that study may reflect differences in the patient population, monitoring infrastructure, and the types of surgery performed. In our study, the four cardiac arrest events observed (4.5% of cardiovascular incidents) represent the most severe end of the spectrum; in the Nigerian audit, Agbamu et al. [8] reported a mortality of 11.9% among affected patients, highlighting the potentially life-threatening nature of cardiovascular incidents when adequate resources for their immediate management are not available.

The induction phase accounted for 44.0% of all incidents in our study, making it the most frequently affected period. This finding is consistent with published evidence from multiple settings. In the prospective audit by Buvandendran et al. [3], the induction and maintenance phases each accounted for approximately 37–40% of incidents, with induction carrying the highest risk relative to other phases. The critical transitions that occur during induction — including the rapid onset of unconsciousness, loss of airway protective reflexes, haemodynamic shifts from anaesthetic agents, and airway instrumentation — create a physiologically vulnerable window that demands the highest level of vigilance from the anaesthesia team. Bharti et al. [5] similarly noted that induction-related incidents accounted for a substantial proportion of their reported events in a tertiary care Indian setting. Emergence (16.0% in our study) represented a smaller but non-negligible contribution, consistent with the well-recognised risks of laryngospasm, bronchospasm, and haemodynamic instability during extubation and recovery.

General anaesthesia was the technique associated with 84.0% of recorded incidents in our study. This finding is not unexpected given the physiological demands of general anaesthesia — particularly airway management, ventilatory control, and the haemodynamic effects of induction and maintenance agents. Buvandendran et al. [3] found in their multicentre audit that general anaesthesia alone was associated with a significantly higher risk of critical incidents compared with regional anaesthesia (OR 0.67 for regional vs. general) or combined general and regional anaesthesia (OR 0.55). It is important to note that the higher absolute number of incidents during general anaesthesia in our study primarily reflects the much greater frequency with which general anaesthesia was used, rather than necessarily implying that regional anaesthesia is equally safe in absolute terms. Establishing the true comparative risk requires incidence rates per technique, which in turn requires the total number of patients receiving each technique — data that will be examined in future analyses.

Human factors were the most common probable cause of critical incidents in our study (25.5%), followed closely by patient-related factors (24.0%). This pattern has been consistently reported in the anaesthetic critical incident literature since the foundational work of **Cooper et al. [2]**, who demonstrated in 1978 that human factors — including inattention, procedural errors, and communication failures — were the dominant contributors to preventable anaesthetic mishaps. In a contemporaneous prospective audit, **Buvandendran et al. [3]** found that individual patient features were the most commonly cited contributing factor (47%), followed by anaesthetic technique (16%) and human factors (12%). The relatively higher human factor proportion in our study compared with theirs may reflect differences in reporting methodology, the mix of trainees and consultants in the study environment, and the complexity of the case mix at our institution.

The contribution of patient-related factors (24.0% in our study) underscores the importance of thorough preoperative assessment and optimisation. Higher ASA physical status has been consistently identified as an independent risk factor for critical incidents and adverse perioperative outcomes across multiple prospective analyses. **Cronjé et al. [11]** demonstrated in a multicentre study that each increment in ASA physical status was independently associated with an increasing adjusted odds ratio for severe anaesthetic-related critical incidents (ASA II: aOR 1.85; ASA III: aOR 1.74; ASA IV–V: aOR 2.73). Emergency surgery was also independently associated with incident risk in that study (aOR 1.35), consistent with the observation that 47.2% of patients with incidents in our study underwent emergency procedures.

Medication-related and anaesthetic technique or management factors each accounted for 19.5% of probable causes in our study. Drug-related critical incidents — encompassing errors in drug selection, dosing, preparation, and administration — are a recognised and preventable category of anaesthetic adverse events. **Agbamu et al. [8]** similarly noted medication errors as a contributor to incidents in their prospective audit. The importance of standardised drug labelling, preparation protocols, and cross-checking procedures in minimising medication-related incidents is widely emphasised in the patient safety literature and remains particularly relevant in high-volume teaching hospital environments.

The large majority of incidents (83.8%) were classified as minor in our study, and all patients achieved complete recovery without lasting sequelae. This outcome profile reflects the efficacy of prompt recognition and management of incidents as they occurred, and is consistent with findings from other prospective institutional audits where early detection and intervention resulted in predominantly favourable outcomes. **Agbamu et al. [8]** reported complete recovery in 88.1% of patients who experienced critical incidents in their prospective audit, with mortality in 11.9% — a substantially higher rate than observed in our study, potentially reflecting differences in monitoring capacity, immediate intervention resources, and the surgical complexity of the study population. The absence of mortality and persistent morbidity in our dataset, while reassuring, should be interpreted with caution. Incident severity classification and outcome ascertainment were based on available contemporaneous documentation, and the occurrence of minor or near-miss events may be subject to underreporting in a prospective voluntary reporting environment.

The findings of this study have several practical implications for patient safety at our institution and in similar tertiary teaching hospital settings. The high prevalence of human factors as a contributing cause reinforces the importance of non-technical skills training, crew resource management principles, and structured communication protocols for anaesthesia teams. The predominance of induction-phase incidents supports the value of standardised pre-induction checklists, mandatory pre-induction equipment verification, and heightened team vigilance during this critical window. The high proportion of respiratory events — particularly oxygen desaturation and bronchospasm — highlights the importance of proficiency in airway management and the availability of advanced airway rescue equipment at all times.

The high proportion of emergency cases (47.2%) among incident patients underscores the need for structured emergency anaesthesia protocols and dedicated preoperative assessment pathways, even in time-constrained contexts. The establishment of a formalised and sustained critical incident reporting system — with protected, non-punitive reporting, systematic case review, and feedback to clinical teams — is essential for translating incident surveillance data into actionable safety improvements.

CONCLUSION

Critical incidents during anesthesia represent an important challenge to perioperative patient safety. In this prospective observational study, 360 of 4,000 patients experienced at least one critical incident, corresponding to an incidence of 9.0%, with a total of 400 incidents documented. Respiratory events constituted the largest proportion of incidents, followed by cardiovascular events. The induction phase was the most frequently affected period, while human and patient-related factors were the most commonly assigned probable contributors.

These findings highlight the importance of comprehensive preoperative assessment, careful airway management, continuous monitoring of respiratory and cardiovascular parameters, and prompt recognition and management of unexpected events. Improved communication among anesthesia, surgical, and nursing teams, appropriate preparation of anesthesia equipment, and adherence to established patient-safety protocols may further reduce preventable incidents.

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