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Original article

Assessment of Compliance with Pre-Anaesthesia Machine Check and Airway Equipment Preparedness in a Tertiary Care Hospital in Pakistan

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ABSTRACT

Background: Pre-anesthesia machine checks and adequate airway-equipment preparedness are essential components of perioperative safety, yet adherence to individual safety measures may remain inconsistent. Objective: To assess compliance with pre-anesthesia machine checks and preparedness of airway equipment among anesthesia personnel in a tertiary care hospital in Pakistan. Methods: A descriptive cross-sectional observational study was conducted at University of Lahore Teaching Hospital, Lahore, from December 2024 to March 2025. Forty-eight anesthesia personnel contributed 90 observations. A structured checklist assessed 22 machine-check and 10 airway-equipment components. Data were analyzed descriptively using frequencies and percentages. Results: Overall machine-check compliance was 87.6% (1,735/1,980 assessments). Compliance was 100% for self-inflating bag availability and functionality of pulse oximetry, capnography, and non-invasive blood-pressure monitoring, but was lowest for circuit configuration and connections (65.6%), backup-battery checking (75.6%), and cylinder-pressure checking (77.8%). Overall airway-equipment preparedness was 83.4% (751/900 assessments). Endotracheal tubes were universally available (100%), followed by bougie and stylet (97.8%) and I-gel (92.2%). Preparedness was lowest for nasal airways (63.3%), difficult-airway carts (72.2%), and functional laryngoscope illumination (72.2%). Conclusion: Machine-check compliance and airway-equipment preparedness were moderate overall, with specific deficiencies in technical machine checks and difficult-airway resources representing priority areas for improvement. Keywords: Anesthesia machine check; Airway equipment; Compliance; Patient safety; Perioperative safety; Pakistan.

EDITORIAL INFORMATION

Author Contributions: Concept: A, IU; Design: A, FR, IU; Data Collection: A, MAA, AA, TRU; Analysis: A, IU, AA; Drafting: A, FR, MAA, IU, AA, TRU.
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INTRODUCTION

Safe delivery of anesthesia depends on the reliable integration of trained personnel, functional equipment, appropriate monitoring, and standardized safety procedures. Although advances in anesthesia technology and perioperative monitoring have substantially improved the safety of surgical care, equipment-related failures and omissions during preparation remain preventable threats to patients. Systematic checking of the anesthesia workstation before use is therefore an essential component of perioperative risk reduction, particularly because failures involving gas delivery, breathing circuits, vaporizers, ventilation systems, alarms, and monitoring devices may compromise oxygenation and ventilation if they are not recognized before induction of anesthesia (1,2).

International standards for safe anesthesia practice emphasize that essential anesthesia equipment, oxygen delivery systems, ventilation devices, monitoring facilities, and airway-rescue equipment should be available and functional wherever anesthesia is administered (3). The WHO–WFSA International Standards for a Safe Practice of Anesthesia similarly identify reliable equipment, appropriate monitoring, and systematic preparation as fundamental components of safe anesthetic care across different healthcare settings (3). These principles are

particularly important in environments where differences in staffing, maintenance systems, equipment availability, workload, and institutional resources may influence adherence to recommended safety procedures.

Pre-anesthesia machine checking involves a sequence of safety-critical assessments designed to confirm the integrity and functionality of the anesthesia workstation before patient exposure. These include verification of the electrical supply and backup power, oxygen and cylinder pressures, gas-delivery systems, flowmeters, oxygen-failure alarms, breathing circuits, vaporizers, ventilators, scavenging systems, and essential physiological monitors. Contemporary perioperative technologies have improved the ability to detect physiological deterioration, but technological availability alone cannot substitute for appropriate equipment preparation and consistent application of safety procedures (1,4). Evidence from anesthesia practice indicates that deficiencies in equipment maintenance, calibration, and routine checking may persist even in institutions where modern anesthesia systems are available (5).

Airway preparedness represents a closely related component of anesthesia safety. Failure to establish or maintain an adequate airway can rapidly result in hypoxemia and serious perioperative harm. Consequently, routine airway devices and appropriate rescue equipment should be immediately accessible before induction. Endotracheal tubes, supraglottic airway devices, functioning laryngoscopes, suction systems, oral and nasal airways, bougies, stylets, and resources for difficult-airway management collectively provide progressively escalating options when routine airway management is unsuccessful (3,6). The presence of individual devices alone, however, does not constitute complete preparedness; appropriate sizes, functional components, and organized access to rescue equipment are also important for effective emergency airway management.

Evidence from resource-constrained healthcare environments suggests that availability of anesthesia equipment and adherence to pre-anesthesia safety checks may not progress uniformly. A cross-sectional assessment by Aytolign et al. demonstrated important variation in pre-anesthesia machine checking and airway-equipment preparedness, indicating that individual components of routine preparation may remain inadequately performed even when overall readiness appears acceptable (7,8). Such findings are particularly relevant to low- and middle-income settings, where differences in equipment supply, maintenance capacity, staffing patterns, training, and institutional safety systems may influence perioperative practice. In Pakistan, Ahmed et al. also identified gaps in knowledge and practices related to anesthesia-machine maintenance, calibration, and cleaning, supporting the need for closer evaluation of equipment-related safety practices within local anesthesia services (5,9).

Despite the clinical importance of these processes, institution-level evidence examining both actual pre-anesthesia machine-check compliance and airway-equipment preparedness remains limited in Pakistan. Assessing these domains together can identify whether safety vulnerabilities arise predominantly from inconsistent checking practices, limitations in equipment availability, or both. Such information can guide focused quality-improvement measures without assuming that the presence of equipment necessarily reflects its systematic verification before anesthesia. Therefore, this study aimed to assess compliance with pre-anesthesia machine checks and preparedness of airway equipment among anesthesia personnel in a tertiary care hospital in Pakistan.

MATERIALS AND METHODS

A descriptive cross-sectional observational study was conducted at University of Lahore Teaching Hospital, Lahore, Pakistan, from July 2024 to October 2024. The study included anesthesia personnel actively involved in perioperative care. A total of 48 personnel contributed 90 observations, comprising 21 residents, seven anesthesia technologists, and 20 anesthesia technicians. Personnel aged ≥18 years who were actively involved in anesthesia-related duties and provided written informed consent were eligible; those unwilling to participate or not directly involved in anesthesia care were excluded. Because some personnel were assessed more than once, participant characteristics were analyzed using 48 individuals, whereas machine-check compliance and airway-equipment preparedness were evaluated across 90 observations.

Data were collected using a structured observational checklist based on established anesthesia-safety recommendations, including the WHO–WFSA standards for safe anesthesia practice (3). The checklist assessed 22 components of pre-anesthesia machine checking, including power and gas supplies, alarms, flowmeters,

vaporizers, breathing circuits, ventilator function, scavenging systems, emergency ventilation equipment, and physiological monitors. Ten airway-preparedness components assessed the availability or functionality of endotracheal tubes, supraglottic airway devices, laryngoscope blades, suction apparatus, bougie and stylet, oral and nasal airways, difficult-airway carts, and laryngoscope illumination. Each item was recorded dichotomously (Yes=1; No=0). The predefined descriptive categories were good (≥90%), moderate (75–89%), and poor (<75%).

Data were analyzed using IBM SPSS Statistics version 27.0. Categorical variables were summarized as frequencies and percentages. Participant characteristics were reported using the participant denominator (n=48), while checklist outcomes were calculated from the 90 observations. Recalculation of the reported item-level data yielded 1,735 fulfilled machine-check assessments among 1,980 assessments (87.6%) and 751 fulfilled airway-preparedness assessments among 900 assessments (83.4%); these internally consistent values were used for the analysis. Given the descriptive design and repeated observations of some personnel, no unsupported inferential comparisons were performed.

Ethical approval was obtained from the Ethical Review Committee of the University of Lahore, and permission to conduct the study was obtained from University of Lahore Teaching Hospital and Research Centre (Ref. No.: DRC/DHPT028/06/24). Written informed consent was obtained from all participants. Participation was voluntary, confidentiality was maintained, and no personal identifiers were included in the study records.

RESULTS

A total of 48 anesthesia personnel contributed 90 observations during the study period. Residents constituted 21 (43.8%) of the participants, anesthesia technicians 20 (41.7%), and anesthesia technologists seven (14.6%). Because some personnel underwent more than one assessment, the distribution of the 90 observations differed from the participant distribution: technicians accounted for 48 (53.3%) observations, while residents and technologists each accounted for 21 (23.3%). Most participants had at least four years of professional experience, with 17 (35.4%) having 4–6 years and 14 (29.2%) having >6 years of experience (Table 1).

Table 1. Characteristics of Anesthesia Personnel and Distribution of Observations

Characteristic	Participants, n (%)	Observations,n (%)
Professional category		
Residents	21 (43.8)	21 (23.3)
Anesthesia technologists	7 (14.6)	21 (23.3)
Anesthesia technicians	20 (41.7)	48 (53.3)
Years of experience		
<1 year	10 (20.8)	20 (22.2)
1–3 years	7 (14.6)	15 (16.7)
4–6 years	17 (35.4)	20 (22.2)
>6 years	14 (29.2)	35 (38.9)
Total	**48 (100)**	**90 (100)**

Participant percentages are based on n=48 and observation percentages on n=90.

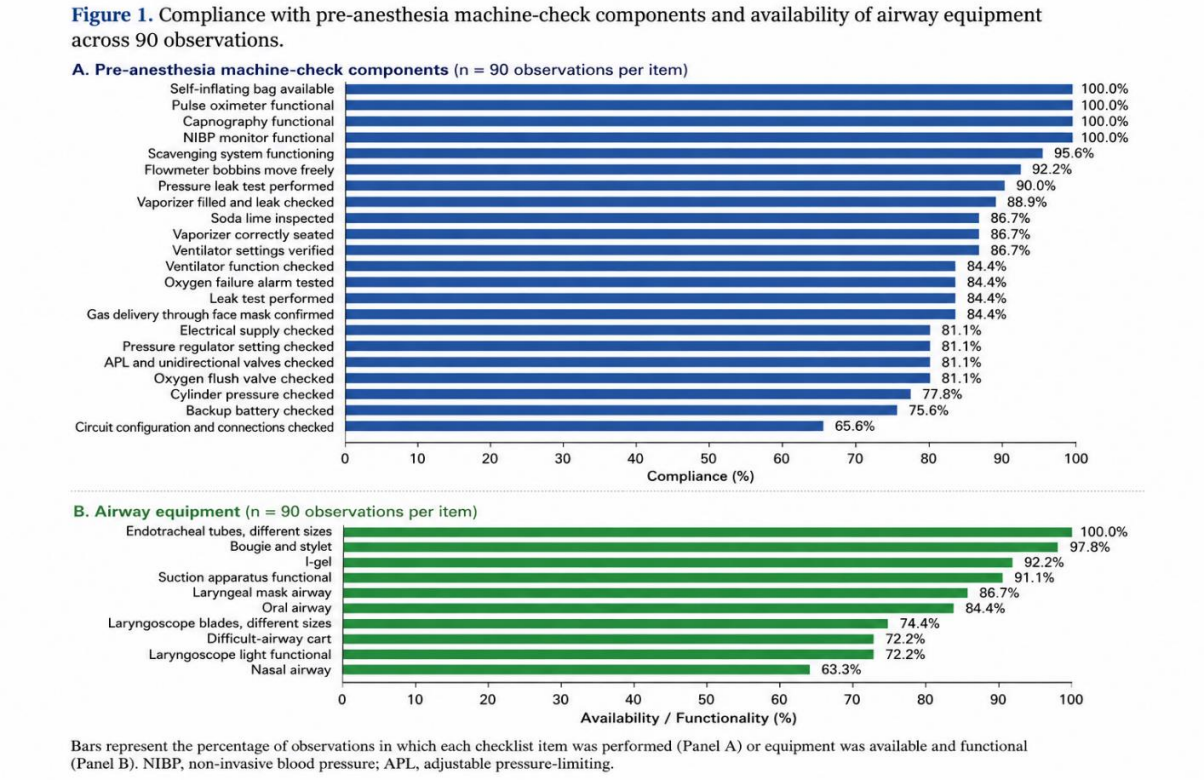
Across the 22 machine-check components, 1,735 of 1,980 item assessments were compliant, giving an overall compliance of 87.6%. According to the predefined study thresholds, this represented moderate overall compliance. However, substantial variation was evident across individual safety checks. Self-inflating bag availability and functionality of pulse oximetry, capnography, and non-invasive blood-pressure monitoring were documented in all 90 observations (100%). Scavenging-system functionality was also consistently assessed (95.6%), followed by free movement of flowmeter bobbins (92.2%) and pressure leak testing (90.0%). In contrast, the largest deficiency involved checking circuit configuration and connections, which was completed in only 59 of 90 observations (65.6%). Backup-battery checking (75.6%) and cylinder-pressure checking (77.8%) were also comparatively inconsistent (Table 2).

Table 2. Compliance with Pre-Anesthesia Machine Checks Across 90 Observations

Machine-check component	Compliant, n (%)	Non-compliant, n (%)
Electrical supply checked	72 (80.0)	18 (20.0)
Backup battery checked	68 (75.6)	22 (24.4)
Cylinder pressure checked	70 (77.8)	20 (22.2)
Pressure regulator setting checked	73 (81.1)	17 (18.9)
Oxygen failure alarm tested	76 (84.4)	14 (15.6)
Flowmeter bobbins move freely	83 (92.2)	7 (7.8)
Oxygen flush valve checked	73 (81.1)	17 (18.9)
Leak test performed	76 (84.4)	14 (15.6)
Vaporizer correctly seated	78 (86.7)	12 (13.3)
Vaporizer filled and leak checked	80 (88.9)	10 (11.1)
Circuit configuration and connections checked	59 (65.6)	31 (34.4)
Soda lime inspected	78 (86.7)	12 (13.3)
Pressure leak test performed	81 (90.0)	9 (10.0)
APL and unidirectional valves checked	73 (81.1)	17 (18.9)
Gas delivery through face mask confirmed	76 (84.4)	14 (15.6)
Ventilator settings verified	78 (86.7)	12 (13.3)
Ventilator function checked	76 (84.4)	14 (15.6)
Scavenging system functioning	86 (95.6)	4 (4.4)
Self-inflating bag available	90 (100.0)	0 (0.0)
Pulse oximeter functional	90 (100.0)	0 (0.0)
Capnography functional	90 (100.0)	0 (0.0)
NIBP monitor functional	90 (100.0)	0 (0.0)
Overall item-level compliance	1735/1980 (87.6)	245/1980 (12.4)

APL, adjustable pressure-limiting; NIBP, non-invasive blood pressure. Overall compliance was calculated from 22 components across 90 observations.

Figure 1. Compliance Rates for Pre-anesthesia Machine Checks and Availability of Essential Airway Equipment



The distribution indicates that monitoring and immediately visible safety equipment achieved the highest compliance, whereas several technical workstation checks were performed less consistently. The 34.4% non-

compliance for circuit configuration and connections represented the largest machine-check deficit, followed by omission of backup-battery checks in 24.4% and cylinder-pressure checks in 22.2% of observations. Thus, the overall compliance percentage concealed clinically relevant variation among individual machine-check components.

Airway-equipment preparedness showed a similar pattern of high availability for several essential devices but important deficiencies in selected rescue resources. Across the 10 components, 751 of 900 assessments demonstrated availability or functionality, corresponding to overall preparedness of 83.4%, categorized as moderate under the predefined thresholds. Endotracheal tubes in different sizes were available in all 90 observations (100%), while bougie and stylet availability reached 97.8%. I-gel devices were available in 92.2%, and functional suction apparatus was documented in 91.1% of observations. By contrast, nasal airways were available in only 63.3%, while difficult-airway carts and functional laryngoscope illumination were each documented in 72.2% of observations (Table 3).

Table 3. Airway Equipment Preparedness Across 90 Observations

Airway equipment	Available/functional, n (%)	Unavailable/non-functional, n (%)
Endotracheal tubes, different sizes	90 (100.0)	0 (0.0)
Laryngeal mask airway	78 (86.7)	12 (13.3)
I-gel	83 (92.2)	7 (7.8)
Laryngoscope blades, different sizes	67 (74.4)	23 (25.6)
Suction apparatus functional	82 (91.1)	8 (8.9)
Bougie and stylet	88 (97.8)	2 (2.2)
Oral airway	76 (84.4)	14 (15.6)
Nasal airway	57 (63.3)	33 (36.7)
Difficult-airway cart	65 (72.2)	25 (27.8)
Laryngoscope light functional	65 (72.2)	25 (27.8)
Overall item-level preparedness	751/900 (83.4)	149/900 (16.6)

Overall preparedness was calculated from 10 equipment components across 90 observations.

The largest airway-preparedness deficit concerned nasal airways, which were unavailable in **33 of 90** observations (36.7%). Difficult-airway carts and functional laryngoscope lights were unavailable or non-functional in 25 observations each (27.8%), while different-sized laryngoscope blades were unavailable in 23 (25.6%). In contrast, endotracheal tubes were universally available and bougie/stylet availability approached complete coverage. Overall, the findings demonstrate moderate machine-check compliance (87.6%) and moderate airway-equipment preparedness (83.4%), with the principal gaps concentrated in selected technical workstation checks and components relevant to airway rescue rather than basic monitoring and routine airway equipment.

DISCUSSION

This study identified moderate overall compliance with pre-anesthesia machine checks and moderate airway-equipment preparedness among anesthesia personnel in a tertiary care hospital in Pakistan. Although several fundamental monitoring and airway components demonstrated near-universal readiness, compliance was not uniform across the safety checklist. The most prominent deficiencies involved circuit configuration and connections, backup-battery assessment, and cylinder-pressure checking, while airway preparedness was principally limited by inconsistent availability of nasal airways, difficult-airway carts, functional laryngoscope illumination, and different-sized laryngoscope blades (10). These findings suggest that high availability of basic monitoring and airway equipment does not necessarily translate into consistently comprehensive pre-anesthesia preparation.

Overall machine-check compliance was 87.6%, indicating that most checklist components were completed but that potentially important omissions remained. Complete compliance was observed for the availability of a self-inflating bag and functionality of pulse oximetry, capnography, and non-invasive blood-pressure monitoring.

These findings are reassuring because continuous physiological monitoring and immediate access to alternative ventilation are fundamental components of safe anesthesia practice. International standards similarly emphasize reliable oxygenation, ventilation, circulation monitoring, and availability of essential equipment wherever anesthesia is administered (3,11). Contemporary developments in perioperative monitoring have further strengthened the ability to identify physiological deterioration, although their safety benefit remains dependent on appropriate equipment preparation and clinical use (11,4).

In contrast, circuit configuration and connections were checked in only 65.6% of observations, representing the lowest adherence among all machine-check components. Backup-battery and cylinder-pressure checks were completed in 75.6% and 77.8% of observations, respectively. These omissions are clinically relevant because breathing-system integrity, alternative power sources, and reserve gas supplies provide important safeguards against equipment or utility failure. The pattern is broadly consistent with previous evidence demonstrating that individual elements of anesthesia-machine preparation may be omitted despite relatively high overall checklist adherence. Aytolign et al. similarly reported variability in pre-anesthesia machine checking and equipment preparedness, supporting the importance of examining individual safety components rather than relying exclusively on an aggregate compliance score (7,12). Deficiencies in anesthesia-machine maintenance and safety-related practices have also been reported among anesthesia professionals in Pakistan, suggesting that equipment-related safety remains an appropriate target for continuing quality improvement (5,13).

Airway-equipment preparedness was 83.4% overall, with marked differences among individual devices. Endotracheal tubes in different sizes were available in every observation, while bougie and stylet availability reached 97.8%. I-gel availability and functional suction were also high at 92.2% and 91.1%, respectively. This pattern indicates strong readiness for routine tracheal intubation and several commonly required airway interventions. Such preparedness is consistent with international recommendations that essential airway and ventilation equipment should be immediately accessible during anesthesia care (3,6,14).

Nevertheless, preparedness was substantially lower for equipment that may become particularly important when routine airway management is unsuccessful. Nasal airways were available in only 63.3% of observations, while difficult-airway carts and functional laryngoscope illumination were each documented in 72.2%. Different-sized laryngoscope blades were available in 74.4%. The contrast between universal availability of endotracheal tubes and less consistent access to selected adjuncts and rescue resources suggests that routine airway preparation was stronger than comprehensive difficult-airway readiness. Because airway difficulty can be unexpected, reliable access to functioning rescue equipment is an important component of perioperative safety rather than a requirement limited to patients with an anticipated difficult airway (3,6,15).

Taken together, the findings reveal an important distinction between basic equipment readiness and completion of the entire safety process. Monitoring devices achieved 100% functionality in the observed assessments, yet several less immediately visible technical checks showed appreciably lower adherence. This pattern may indicate that routinely visible or frequently used equipment receives greater attention than components requiring deliberate verification before anesthesia. Standardized checklist implementation, periodic equipment audits, and focused reinforcement of frequently omitted technical checks may therefore offer more value than broad interventions directed equally at all checklist components. Previous work has similarly emphasized structured safety processes and systematic equipment assessment as components of safer anesthesia practice (5,7,16).

The findings should be interpreted within the study design. An important strength is the assessment of individual machine-check and airway-preparedness components rather than reliance on a single global measure, enabling specific safety gaps to be identified. The study also distinguishes 48 individual anesthesia personnel from the 90 observations they contributed, providing a clearer representation of the underlying sampling structure. However, the single-center design limits generalizability to other hospitals in Pakistan. Some personnel contributed repeated observations, and these observations cannot be assumed to represent 90 independent individuals. Direct observation may also have influenced staff behavior, potentially increasing apparent adherence. In addition, the study assessed compliance and equipment availability rather than perioperative complications; consequently, associations between identified deficiencies and patient outcomes cannot be inferred. Larger

multicenter studies incorporating standardized observational methods and patient-safety outcomes would help determine whether similar patterns occur across different anesthesia settings.

Overall, the study demonstrates that the principal opportunity for improvement lies not in universal deficiencies but in a relatively concentrated group of safety-critical processes and airway resources. Strengthening verification of breathing-circuit connections, backup power and cylinder pressure, alongside reliable availability of difficult-airway equipment and functional laryngoscopy components, could support more consistent pre-anesthesia preparedness. These findings provide institution-specific evidence that can inform targeted audit, checklist reinforcement, equipment management, and continuing professional training without implying causal effects on clinical outcomes.

CONCLUSION

Pre-anesthesia machine-check compliance and airway-equipment preparedness were moderate overall, at 87.6% and 83.4%, respectively, among anesthesia personnel at the tertiary care hospital. Compliance was consistently high for essential monitoring devices and emergency ventilation equipment but was lower for circuit configuration and connections, backup-battery verification, and cylinder-pressure checks. Similarly, routine airway equipment was generally well prepared, whereas nasal airways, difficult-airway carts, functional laryngoscope illumination, and different-sized laryngoscope blades showed comparatively lower availability. These findings indicate that strengthening adherence to specific technical machine checks and ensuring consistent readiness of difficult-airway resources are key areas for improving pre-anesthesia safety preparedness.

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