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Assessing the knowledge and practices of anesthesiologists in anesthesia machine maintenance, calibration, and cleaning.

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Abstract

Background: Anesthesia equipment plays a vital role in ensuring patient safety and effective management during surgeries and other medical procedures. However, the maintenance, calibration, and cleaning of these devices are often overlooked. As anesthesia machines become more complex, incorporating computerized systems and microprocessors, the challenges related to their upkeep have increased. Proper knowledge and training among anesthesiologists are essential to ensure the effective functioning and safety of these devices. This study aimed to assess the knowledge of anesthesiologists working in Karachi's tertiary care institutions regarding the maintenance, calibration, and cleaning of anesthesia devices

Methodology: This cross-sectional study was conducted in four major tertiary care hospitals in Karachi: The Indus Hospital, Aga Khan University Hospital, Civil Hospital, and Liaquat National Hospital, from July to December 2022. A total of 119 anesthesiologists participated in the survey. A structured questionnaire was used, consisting of 24 questions divided into six sections: demographic information, general knowledge, maintenance, calibration, cleaning, and sterilization of anesthesia equipment, and general opinions on anesthesia equipment maintenance. Data was collected using a self-administered questionnaire designed to evaluate anesthesiologists' understanding of these critical procedures.

Results: The study sample had a mean age of 33.31±5.51 years. A significant portion of participants, specifically 74.8%, 67.2%, and 56.3%, demonstrated inadequate knowledge regarding the maintenance, calibration, and cleaning of anesthesia equipment, respectively. These findings highlight a critical gap in knowledge across all aspects of equipment upkeep. Demographic factors such as age, gender, education level, and work experience did not show any statistically significant correlation with knowledge levels.

Conclusion: The study reveals a concerning lack of knowledge among anesthesiologists in Karachi regarding the essential procedures for the maintenance, calibration, and cleaning of anesthesia devices. This knowledge gap could lead to adverse patient outcomes due to malfunctioning or improperly maintained equipment. These findings underscore the need for targeted educational interventions and training programs to improve anesthesiologists' proficiency in maintaining the safety and functionality of anesthesia equipment.

Keywords

Anesthesia Equipment, Maintenance, Medical Calibration, Cleaning, Anesthesiology

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Introduction

The effectiveness of surgical procedures is heavily reliant on the seamless collaboration of an interdisciplinary team, including anesthesia technicians, surgical technicians, and nurses. Each team member plays a critical role in ensuring patient safety, surgical efficiency, and optimal outcomes[1]. Within this team, anesthetists hold significant responsibility for delivering care throughout the pre-, intra-, and post-anesthesia stages[2].

Anesthesia devices are fundamental in administering anesthesia and establishing direct contact with a patient's body, such as through breathing circuits or invasive procedures. These devices must be meticulously maintained, calibrated, and cleaned to ensure their functionality and patient safety. Modern anesthesia systems are increasingly complex, incorporating advanced computerized technology and microprocessors, which present unique challenges for their upkeep. Each piece of anesthesia equipment is composed of various components such as oxygen sensors, flow sensors, canisters, and waste gas systems that require specific maintenance procedures. The proper functioning of these systems is essential to ensure the safety of both patients and healthcare professionals.

Maintenance procedures for anesthesia machines include routine checks performed by trained anesthesia technicians, as well as authorized service center interventions for more complex issues. These maintenance tasks, including calibrations, are often tracked through checklists or automated processes integrated into the devices themselves[3-7]. Despite these safeguards, anesthesia machines can still require additional maintenance due to malfunctions or infection risks. Anesthesia professionals, including both anesthesiologists and anesthesia technicians, are responsible for performing routine checks and ensuring maintenance at designated intervals (e.g., every 6 months or annually). Inadequate cleaning and sterilization of anesthesia equipment may lead to infections, either transmitted from patient to patient or from patients to healthcare workers. Microorganisms from the respiratory system can be aerosolized and transmitted to the lower respiratory tract, leading to severe infections[7].

Proper cleaning and sterilization protocols for anesthesia equipment vary based on machine brands and models, with certain designs offering superior infection control features. To prevent the transmission of viruses, high-performance hydrophobic filters with virus-rejecting properties are recommended[6]. Specific models of anesthesia machines are equipped with advanced infection control mechanisms, further emphasizing the importance of proper maintenance and calibration. Moreover, the inclusion of battery backups in anesthesia machines is critical, particularly during emergencies. Users must be well-versed in identifying potential obstructions in the breathing circuit and conducting tests to ensure that equipment can perform adequately during automated checkouts[9,10]. A failure to calibrate anesthesia machines properly sometimes caused by misleadingly similar oxygen sensors has been documented. However, many of these issues can be mitigated by thorough pre-anesthetic inspections. Identifying and addressing the underlying causes of equipment failures is essential for delivering safe healthcare[11,12].

This survey aims to assess the knowledge and attitudes of anesthesiologists in Karachi's tertiary care institutions regarding the maintenance, calibration, and cleaning of anesthesia devices. Despite the essential nature of these practices, anesthesia machine checkups are conducted infrequently in healthcare systems today[10]. There is a lack of comprehensive data, especially from developing countries, regarding the routine maintenance and inspection of anesthesia devices. Notably, a substantial 85% of surveyed respondents expressed a need for further training on the upkeep of anesthesia equipment[13]. A study published in the Canadian Journal of Anesthesia found that providing training on machine inspections to junior residents resulted in improved performance, underscoring the importance of structured training programs[14].

Given the current circumstances in Pakistan, it is likely that junior anesthesiologists and specialists may lack sufficient expertise in the maintenance, calibration, and cleaning of anesthesia devices. Additionally, anesthesia machines are often not inspected according to internationally recognized standards due to factors such as heavy patient volumes, limited time between procedures, and inadequate awareness among operating room staff. This study seeks to address these concerns and raise awareness among anesthesia professionals and teaching institutes. It is critical to evaluate whether anesthesiologists are equipped with the necessary knowledge to perform regular inspections of their equipment. By improving training and implementing routine checks, we can enhance the safety and effectiveness of anesthesia practices, ultimately promoting better perioperative patient outcomes.

Methodology

Study Design

This research was designed as a cross-sectional study, aimed at evaluating the knowledge and practices of anesthesiologists regarding the maintenance, calibration, and cleaning of anesthesia devices. The cross-sectional design was chosen as it provides a snapshot of anesthesiologists' knowledge and practices at a specific point in time, offering insights into the current state of understanding and practices within the field. The study was conducted over a six-month period, from July to December 2022, at four major tertiary care hospitals in Karachi.

Ethics

Ethical approval for the study was obtained from the Institutional Review Board (IRB) of all participating hospitals. The study adhered to the ethical standards set forth in the Declaration of Helsinki, ensuring the protection of participants' rights and confidentiality. Informed consent was obtained from all participants before their inclusion in the study, and they were informed about the purpose of the research, the voluntary nature of participation, and their right to withdraw at any time without any consequence. To maintain participant privacy, all collected data were anonymized during the data analysis process.

Setting

The study was conducted at four major tertiary care hospitals in Karachi: The Indus Hospital, Aga Khan University Hospital, Civil Hospital, and Liaquat National Hospital. These hospitals were selected because of their high patient volume, the presence of well-established anesthesiology departments, and the representativeness of their practices as tertiary care institutions in the region. The setting was crucial as it provided a comprehensive view of the knowledge and practices of anesthesiologists working in diverse healthcare environments, which are typically reflective of different institutional frameworks.

Participants

a. Inclusion criteria

The study targeted anesthesiologists working at the four participating hospitals. Inclusion criteria for participation were:

- Anesthesiologists who are consultants, specialists, or FCPS residents with a minimum of two years of experience in anesthesiology at a tertiary care institution.
- Participants aged between 23 and 75 years.
- Participants who voluntarily consented to take part in the study.

b. Exclusion criteria

- Anesthesiology residents with an MCPS qualification, as they were expected to have different levels of training and experience compared to the consultants and FCPS residents.
- Individuals working in hospitals that provide only primary or secondary care, as their exposure to advanced anesthesia devices and procedures may be limited.

The final sample consisted of anesthesiologists from a mix of public and private institutions, ensuring a diverse participant pool that reflected various institutional practices.

Variables

The primary variables assessed in this study were:

- **Knowledge:** The level of understanding of anesthesiologists regarding the maintenance, calibration, and cleaning of anesthesia equipment.
- **Demographic factors:** Age, gender, years of experience, and educational qualifications.
- **Institutional factors:** Type of institution (public vs. private) and the participant's level of expertise (consultant vs. resident).

These variables were examined in relation to anesthesiologists' knowledge of critical equipment procedures.

Data Sources/Measurement

Data for this study were collected using a structured, self-administered questionnaire that was specifically designed for the purpose of this research. The questionnaire contained 24 questions, divided into six sections:

- **Section A:** Demographic information, including age, gender, educational qualifications, and years of experience.
- **Section B:** General knowledge of anesthesia equipment maintenance.
- **Section C:** Knowledge of maintenance protocols for anesthesia devices.
- **Section D:** Knowledge of calibration procedures for anesthesia equipment.
- **Section E:** Knowledge of cleaning and sterilization procedures.
- **Section F:** Participants' general opinions on the importance of maintenance, calibration, and cleaning.

The questionnaire was administered to eligible participants after obtaining their informed consent. The responses were then recorded and digitized for analysis. This approach allowed for the consistent collection of data from all participants, ensuring the reliability of the findings.

Bias

Efforts to minimize biases in the study included using non-probability consecutive sampling to ensure broad representation of anesthesiologists. A standardized questionnaire was employed to reduce information bias and ensure consistency in data collection. To minimize recall bias, the study focused on participants' current knowledge and practices, rather than relying on retrospective recollections. This approach helped maintain accuracy and comparability throughout the study.

Study Size

The sample size for the study was calculated using OpenEPI software, with assumptions of a 95% confidence interval, a precision of 9%, and a 15% reported percentage for sterilization of flow and oxygen sensors[15]. The required sample size was determined to be 119 participants, which was proportionally allocated across the four participating hospitals based on the number of anesthesiologists at each institution. The distribution was as follows: 26 participants from The Indus Hospital, 35 from Aga Khan University Hospital, 29 from Liaquat National Hospital, and 29 from Civil Hospital, ensuring a representative sample from each institution.

Statistical Methods

Data analysis was performed using SPSS version 26.0. Descriptive statistics, including means and standard deviations, were calculated for continuous variables such as age and years of experience. Frequency and percentage were computed for categorical variables such as gender, qualifications, type of institution, and knowledge of equipment maintenance, calibration, and cleaning procedures.

To assess relationships between categorical variables (e.g., gender, type of institution, and knowledge levels), Chi-square tests were conducted. Additionally, a post-stratification chi-square test was applied to control for potential confounding variables, ensuring that the analysis was not skewed by demographic or institutional factors. A p-value of less than 0.05 was considered statistically significant, indicating that the observed

associations were unlikely to have occurred by chance.

Results

Participants

The study comprised a total of 119 anesthesiologists who were selected from various tertiary care centers in Karachi, including The Indus Hospital, Aga Khan University Hospital, Civil Hospital, and Liaquat National Hospital. Among the participants, the age range was between 25 and 55 years, with a mean age of 33.31±5.51 years. The majority (78.15%) of the anesthesiologists were aged between 25 and 35 years. The sample included a higher proportion of male participants (58.82%) compared to females (41.18%). Regarding professional qualifications, the majority were postgraduate trainees, while a smaller proportion held FCPS and MCPS qualifications.

In terms of the sector of employment, 62.18% of participants were employed in the private sector, while the remaining 38.72% worked in the public sector.

Descriptive Data

The study assessed the anesthesiologists' knowledge in three main areas: maintenance, calibration, and cleaning of anesthesia machines. The findings revealed significant gaps in knowledge in all three areas. Specifically, 74.8% of participants lacked adequate knowledge on equipment maintenance, 67.2% on calibration, and 56.3% on cleaning procedures. The overall knowledge score, calculated across all areas, was 34.26±12.435.

The analysis of demographic and professional factors such as age, gender, education, experience, and type of institution (public vs. private) showed varying levels of knowledge but no statistically significant differences between these factors in relation to the overall adequacy of knowledge.

Outcome Data

The outcome data revealed significant knowledge gaps among anesthesiologists regarding the maintenance, calibration, and cleaning of anesthesia machines. A substantial proportion, 74.8%, demonstrated inadequate knowledge of maintenance, while 67.2% showed insufficient understanding of calibration, and 56.3% lacked knowledge about cleaning procedures. The findings suggest that knowledge deficits were most pronounced in maintenance and calibration, with the area of cleaning showing slightly better knowledge among the participants.

Age group differences were observed in cleaning knowledge, with a statistically significant difference across the age groups ($p=0.014$). Younger anesthesiologists (aged 25-35) had more inadequate knowledge about cleaning anesthesia machines compared to their older counterparts in the 36-45 and 46-55 age groups. However, no significant differences were found between male and female anesthesiologists across the three knowledge areas maintenance, calibration, and cleaning.

Educational qualifications (Postgraduate Trainee, MCPS, FCPS) did not influence the level of knowledge, as there were no statistically significant differences between these groups. Similarly, years of experience did not show any marked impact on knowledge levels. Both anesthesiologists with 2-3 years of experience and those with more than 3 years of experience exhibited similar deficiencies in all areas.

Finally, the type of institution (public vs. private) did not reveal significant differences in the knowledge levels of the participants in any of the areas assessed. These findings suggest that further educational interventions may be necessary to address the knowledge gaps, particularly for younger anesthesiologists, and emphasize the importance of ongoing training regardless of gender, experience, or institutional setting.

Main Results

The study revealed that a large proportion of anesthesiologists in Karachi's tertiary care hospitals had inadequate knowledge regarding the maintenance, calibration, and cleaning of anesthesia machines. Specifically, 74.8%, 67.2%,

and 56.3% of participants demonstrated insufficient knowledge in maintenance, calibration, and cleaning, respectively.

Despite stratification by various demographic and professional characteristics, such as age, gender, education, experience, and type of institution, no statistically significant associations were observed, with the exception of the age factor influencing cleaning knowledge.

The overall knowledge score of the group was relatively low (34.26±12.43), suggesting a need for further educational interventions to address these knowledge gaps, particularly in the maintenance and calibration of anesthesia equipment.

Table 1: Level of knowledge of anesthesiologists about the maintenance, calibration, and cleaning of anesthesia machines (Overall Knowledge).

Variables		Inadequate Knowledge n(%)	Adequate Knowledge n(%)	p-value
Age Groups	25-35	88(94.6)	5(5.4)	<0.01*
	36-45	24(100)	-	
	46-55	-	2(100)	
Gender	Male	66(94.3)	4(5.7)	0.926
	Female	46(93.9)	3(6.1)	
Education	Postgraduate Trainee	69(95.8)	3(4.2)	0.551
	MCPS	15(93.8)	1(6.3)	
	FCPS	28(90.3)	3(9.7)	
Experience	2-3 years	58(96.7)	2(3.3)	0.233
	>3 years	54(91.5)	5(8.5)	
Type of Institute	Public	44(97.8)	1(2.2)	0.186
	Private	68(91.9)	6(8.1)	

*p<0.05 is considered statistically significant.

Table 2: Knowledge of anesthesiologists about the maintenance of anesthesia machines.

Variables		Inadequate Knowledge n(%)	Adequate Knowledge n(%)	p-value
Age Groups	25-35	69(74.2)	24(25.8)	0.633
	36-45	19(79.2)	5(20.8)	
	46-55	1(50)	1(50.0)	
Gender	Male	51(72.9)	19(27.1)	0.562
	Female	38(77.6)	11(22.4)	
Education	Postgraduate Trainee	52(72.2)	20(27.8)	0.698
	MCPS	13(81.3)	3(18.8)	
	FCPS	24(77.4)	7(22.6)	
Experience	2-3 years	48(80.0)	12(20.0)	0.187
	>3 years	41(69.5)	18(30.5)	
Type of Institute	Public	35(77.8)	10(22.2)	0.558
	Private	54(73.0)	20(27.0)	

*p<0.05 is considered statistically significant.

Table 3: Knowledge of anesthesiologists about the calibration of anesthesia machines.

Variables		Inadequate Knowledge n(%)	Adequate Knowledge n(%)	p-value
Age Groups	25-35	64(68.8)	29(31.2)	0.734
	36-45	15(62.5)	9(37.5)	
	46-55	1(50.0)	1(50.0)	
Gender	Male	47(67.1)	23(32.9)	0.981
	Female	33(67.3)	16(32.7)	
Education	Postgraduate Trainee	50(69.4)	22(30.6)	0.808
	MCPS	10(62.5)	6(37.5)	
	FCPS	20(64.5)	11(35.5)	
Experience	2-3 years	36(60.0)	24(40.0)	0.09
	>3 years	44(74.6)	15(25.4)	
Type of Institute	Public	28(62.2)	17(37.8)	0.364
	Private	52(70.3)	22(29.7)	

*p<0.05 is considered statistically significant.

Table 4: Knowledge of anesthesiologists about the cleaning of anesthesia machines.

Variables		Inadequate Knowledge n(%)	Adequate Knowledge n(%)	p-value
Age Groups	25-35	48(51.6)	45(48.4)	0.014*
	36-45	19(79.2)	5(20.8)	
	46-55	-	2(100)	
Gender	Male	41(58.6)	29(41.4)	0.551
	Female	26(53.1)	23(46.9)	
Education	Postgraduate Trainee	37(51.4)	35(48.6)	0.308
	MCPS	9(56.3)	7(43.8)	
	FCPS	21(67.7)	10(32.3)	
Experience	2-3 years	29(48.3)	31(51.7)	0.077
	>3 years	38(64.4)	21(35.6)	
Type of Institute	Public	26(57.8)	19(42.2)	0.502
	Private	41(55.4)	33(44.6)	

*p<0.05 is considered statistically significant.

Discussion

The anesthesia machine is an indispensable tool for anesthesiologists, playing a pivotal role in ensuring the safe administration of anesthesia during surgical procedures. The safe operation of these machines depends not only on the design and safety features of the equipment but also on the expertise and competence of the anesthesiologist. Gündoğmuş highlighted the critical responsibilities of anesthesia and resuscitation specialists, who oversee all aspects of patient care during anesthesia and surgery[16]. These responsibilities

extend to managing technicians, procuring, maintaining, and utilizing medical devices, medications, and sanitation materials. In legal cases involving fatalities attributed to equipment failures, both anesthesiologists and technicians are held equally accountable[17]. This underscores the importance of understanding and adhering to safety protocols, such as those outlined in the safety checklist provided by the Association of Anesthetists of Great Britain and Ireland (AAGBI 2012)[18]. Proper calibration of anesthesia machines, including components like the oxygen analyzer, vaporizer, and EtCO2 sensors, is also critical to maintaining operational safety[19].

Our study provides valuable insight into a crucial aspect of perioperative care: the knowledge and proficiency anesthesiologists have concerned the maintenance, calibration, and sanitation of anesthesia machines. Alarmingly, 74.8% of the anesthesiologists surveyed demonstrated inadequate understanding of machine maintenance. This gap in knowledge raises significant concerns about the potential risks to patient safety and the reliability of these life-sustaining devices. One possible explanation for this deficiency could be the lack of comprehensive training programs or insufficient emphasis on the importance of routine maintenance within the anesthesia community.

For example, in Turkey, only 44.7% of anesthesiologists consistently replaced the soda lime canister. Half of the respondents reported never disassembling their anesthesia machines, and 21.2% were unaware of the location of the flow sensor, 32.7% did not know where the oxygen sensor was located, and 58.4% failed to check the battery. Furthermore, a striking 85% of the respondents expressed a need for additional training on the maintenance of anesthesia devices and equipment[14]. These findings emphasize the importance of targeted educational initiatives to address these deficiencies.

The literature suggests that a significant portion of adverse events during medical procedures could be prevented with better equipment management. For instance, research indicates that 75% of cardiac arrests during medical procedures are avoidable[19], with 12% of these incidents linked directly to issues with anesthetic equipment[20]. Our study also revealed a troubling gap in anesthesiologists' understanding of calibration techniques, with 67.2% failing to demonstrate the required level of knowledge. Calibration is essential for accurately administering anesthetic agents and monitoring vital parameters. The observed gap in knowledge underscores the urgent need for continuous education and competency assessments to enhance skills in anesthesia machine maintenance. Cleaning practices were also found to be problematic, with 56.3% of anesthesiologists demonstrating insufficient knowledge in this area. Proper cleaning is crucial not only for preventing infections but also for ensuring the longevity and optimal performance of anesthesia equipment. The lack of awareness highlights the pressing need for better education on cleaning protocols and their critical role in maintaining sterile conditions.

In conclusion, our findings reveal that 94.12% of anesthesiologists lack sufficient knowledge regarding the maintenance, calibration, and cleaning of anesthesia machines. This significant gap in knowledge calls for immediate, organized interventions to address these deficiencies. Insufficient expertise in these critical areas can compromise patient safety, disrupt the smooth progression of surgeries, and lead to equipment malfunctions with potentially serious consequences. Several factors may contribute to this lack of knowledge, including the absence of standardized training programs, variations in curricula, and a lack of emphasis on equipment maintenance in existing training environments. To address these challenges, it is essential to promote a culture of continuous learning, ensure regular competency assessments, and implement standardized training programs on best practices in anesthesia machine management.

It should be noted that the sample size of this study was limited, which may restrict the generalizability of the results. To validate and strengthen these findings, future research should aim to increase the

sample size and include a broader representation of anesthesiologists across tertiary care hospitals in Pakistan.

Conclusion

This study highlights a significant knowledge gap among anesthetists regarding the maintenance, calibration, and cleaning of anesthesia equipment. The findings underscore the urgent need for targeted efforts to enhance patient safety and elevate the overall quality of perioperative care. Addressing these gaps requires a multi-faceted approach, including the improvement of educational programs, the implementation of standardized training protocols, and a strong commitment to rigorous machine maintenance practices. Collaboration between educational institutions, professional associations, and healthcare organizations is essential to bridge these knowledge gaps and foster a culture of excellence in anesthesia practice. By prioritizing these efforts, we can ensure that anesthesiologists are better equipped to provide safe, high-quality care to patients and reduce the risks associated with anesthesia-related complications.

Conflicts of Interest

The author(s) have no conflicts of interest.

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