Journal of Cardiovascular Disease Research

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 12, 2024

Original research article

Minimum alveolar concentration (MAC) versus entropy in patients undergoing general anaesthesia: Hemodynamic changes

[1]Dr. Shweta, [2]Dr. L Ajaykumar

[1]Senior Resident, Department of Anaesthesia, Chandramma Dayananda Sagar Institute of Medical Education and Research (CDSIMER) Harohalli, Ramanagara, Karnataka, India

[2]Senior Resident, Department of Anaesthesia, BGS Medical College and Hospital, Nagarur, Bangalore North, Karnataka, India

Corresponding Author:
Dr. L Ajaykumar

Abstract

Minimum alveolar concentration provides a correlation between anesthetic dose and immobility. It can be applied to all inhalational anesthetics and is used to compare anesthetic potency. Research conducted in both animal and human subjects has revealed that volatile anesthetics depress the excitability of spinal motor neurons, underscoring the role of inhaled anesthetics in mediating immobilization primarily at the spinal cord level. Routine pre-anaesthetic check-up was done prior to the surgery as per the routine preoperative protocol, by collecting basic demographic details, history of comorbid illness and drug therapy. All the patients were subjected to general and systemic examinations. Also, airway assessment was carried out and documented. As per first 2 comparisons, the mean SBP of 118.47 ± 10.23 at 0.8 MAC was significantly higher than either 114.37 ± 8.19 at 1.0 MAC or 109.47 ± 7.36 at 1.3 MAC. In last comparison, the mean SBP of 114.37 ± 8.19 at 1.0 MAC was also found to be significantly higher than 109.47 ± 7.36 at 1.3 MAC. Thus in all 3 comparisons, the study found significant difference thereby confirming significant decrease in SBP with increase in MAC.

Keywords: Minimum alveolar concentration, general anesthesia, hemodynamic changes

Introduction

Most anaesthetics cause a dose-dependent depression of the cardiovascular and respiratory systems. The way in which this depression is manifested can vary considerably with different anaesthetics. Both the rate and depth of breathing may change, and so may the pattern of breaths. Cardiovascular system depression usually results in a fall in arterial blood pressure, but this may be associated with either a fall or a rise in heart rate.

Since its introduction in 1965, minimum alveolar concentration (MAC) has served as the standard measure of potency for volatile anaesthetic agents. It is defined as the minimum alveolar concentration of inhaled anaesthetic at which 50% of people do not move in response to a noxious stimulus. Within the last 20 years, it hsts been discovered that volatile anaesthetics inhibit mobility largely through action on the spinal cord, whereas the amnesic and hypnotic effects are mediated by the brain. In this study we are observing the relationship between MAC and haemodynamic changes

General anesthesia is a medically-induced loss of consciousness with concurrent loss of protective reflexes through the administration of anesthetic agents. A variety of drugs may be employed to initiate a state of unconsciousness, memory loss, pain relief, relaxation of skeletal muscles, and the inhibition of autonomic reflexes [1].

During this state, the patient is unarousable to verbal, tactile, and painful stimuli. In situations where the upper airway becomes obstructed while under general anesthesia, medical intervention such as the insertion of a laryngeal mask airway or an endotracheal tube is often required to preserve airway patency. Moreover, the patient's spontaneous ventilation may become insufficient, necessitating either partial or complete mechanical assistance through positive pressure ventilation [2].

In 1965, Eger *et al*. introduced the concept of minimum alveolar concentration, which subsequently became the standardized measure for assessing the potency of volatile anesthetic agents. Prior endeavors

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 12, 2024

to develop metrics for gauging the adequacy of anesthetic dosing, such as the Guedel stages of anesthesia or the Woodbridge concept of "nothria", were qualitative evaluations prone to variation based on the specific inhaled anesthetics employed. The innovation of MAC overcame this variability by introducing a single quantitative parameter: immobility [3].

It is defined as the concentration of inhaled anesthetic within the alveoli at which 50% of people do not move in response to a surgical stimulus. MAC uses the measurement of end-tidal anesthetic as a measure of the level of anesthetic within the alveoli and, in turn, at the level of the central nervous system. This metric stands as a consistent and replicable standard applicable to diverse volatile anesthetics, enabling the comparison of their potency [4].

Minimum alveolar concentration provides a correlation between anesthetic dose and immobility. It can be applied to all inhalational anesthetics and is used to compare anesthetic potency. Research conducted in both animal and human subjects has revealed that volatile anesthetics depress the excitability of spinal motor neurons, underscoring the role of inhaled anesthetics in mediating immobilization primarily at the spinal cord level. Other facets of anesthesia, such as amnesia and hypnosis, operate in the subcortical and cortical regions of the brain to further influence immobilization. This was underscored in rat studies wherein lesions were induced in the central nervous system to sever connections between the spinal cord and brain, revealing that such lesions did not alter MAC values [5].

Before the concept of MAC, the Meyer-Overton relationship was well established; it stated that all fat-soluble agents would function as anesthetics due to their ability to cross the lipid bilayer of neurons. While lipid solubility does not singularly dictate potency, as proteins are likely the primary target for volatile anesthetics, this principle remains valid for the realm of volatile anesthetics [6].

Methodology

Study Population

Patients aged between 21 and 50 years, of ASA Grading I to III undergoing elective surgeries under general anaesthesia using sevoflurane

Study Design

Prospective Clinical Observational Study.

Sample Size Calculation

The sample size (n) was estimated to be 18, which was rounded to the final sample size of 30 subjects, and will be considered for the study.

Inclusion Criteria

- Patients of either genders aged between 21 and 50 years.
- Patients with American Society of Anaesthesiology (ASA) Grade I to III.
- Patients posted for elective surgeries.

Exclusion Criteria

- Patients under 20 years and more than 50 years of age.
- Patients with American Society of Anaesthesiology (ASA) Grade IV.
- Patient undergoing emergency procedures.
- Pregnant patients.
- Patients with significant pre-existing systemic diseases.
- Patients' refusal.

Patients undergoing elective surgeries under general anaesthesia using sevoflurane, who were eligible for the study according to the above mentioned eligibility criteria were included in the study. The study design, purpose, interventions, possible risks, adverse effects and possible outcomes were explained to each patient in his/her mother tongue and written consent was obtained.

Routine pre-anaesthetic check-up was done prior to the surgery as per the routine preoperative protocol, by collecting basic demographic details, history of comorbid illness and drug therapy. All the patients were subjected to general and systemic examinations. Also airway assessment was carried out and documented.

All the patients were kept fasting for at least 6 hours before surgery. On arrival to the operating room, monitors were attached. Electrocardiogram (ECG), Non-invasive BP, $ETCO_2$, pulse-oximetry were connected. The entropy electrode (GE Health care) was applied on forehead of the patient in accordance with the manufacturer's instructions and was connected to the entropy monitor. Intravenous access was secured with 18/20 G intravenous cannula. Baseline vital parameters like heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and oxygen saturation (SpO_2) were noted.

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 12, 2024

Results

Table 1: Baseline vitals of the study subjects

Subjects (N=30)	Mean	SD	Median	Minimum	Maximum
HR (in bpm)	80.03	6.67	80.50	68.00	90.00
SBP (in mmHg)	123.53	8.24	122.50	110.00	140.00
DBP (in mmHg)	78.53	6.04	79.50	68.00	89.00

The vitals of all the subjects were recorded at the baseline in the study. The hemodynamic parameters considered were heart rate (HR) and blood pressure (BP). The mean HR was estimated to be 80.03 ± 6.67 bpm. The average systolic and diastolic blood pressures were found to be 123.53 ± 8.24 mmHg and 78.53 ± 6.04 mmHg respectively.

Table 2: Comparison of variation in heart rate with respect to different MAC

Heart Rate (in bpm)		Mean	SD	p-value[#]
Comparison_1	**At 0.8 MAC**	74.20	6.74	<0.001*
	At 1.0 MAC	70.47	5.24	
Comparison_2	**At 0.8 MAC**	74.20	6.74	<0.001*
	At 1.3 MAC	67.63	4.51	
Comparison_3	**At 1.0 MAC**	70.47	5.24	<0.001*
	At 1.3 MAC	67.63	4.51	

Paired t-test.
* Statistically significant.

The mean heart rate levels observed at different occasions where end-tidal concentration of anaesthetic being set to 3 different MAC i.e., 0.8, 1.0 and 1.3 MAC were compared to each other in the study. These 3 different mean levels were compared in 3 ways.
As per first 2 comparisons, the mean HR of 74.20 ± 6.74 at 0.8 MAC was significantly higher than either 70.47 ± 5.24 at 1.0 MAC or 67.63 ± 4.51 at 1.3 MAC. In last comparison, the mean HR of 70.47 ± 5.24 at 1.0 MAC was also found to be significantly higher than 67.63 ± 4.51 at 1.3 MAC. Thus in all 3 comparisons, the study found significant difference thereby confirming significant decrease in HR with increase in MAC.

Table 3: Comparison of variation in blood pressure with respect to different MAC

Blood Pressure (in mmHg)			Mean	SD	p-value[#]
SBP	**Comparison_1**	**At 0.8 MAC**	118.47	10.23	<0.001*
		At 1.0 MAC	114.37	8.19	
	Comparison_2	**At 0.8 MAC**	118.47	10.23	<0.001*
		At 1.3 MAC	109.47	7.36	
	Comparison_3	**At 1.0 MAC**	114.37	8.19	<0.001*
		At 1.3 MAC	109.47	7.36	
DBP	**Comparison_1**	**At 0.8 MAC**	74.73	5.94	<0.001*
		At 1.0 MAC	72.30	5.38	
	Comparison_2	**At 0.8 MAC**	74.73	5.94	<0.001*
		At 1.3 MAC	69.47	5.16	
	Comparison_3	**At 1.0 MAC**	72.30	5.38	<0.001*
		At 1.3 MAC	69.47	5.16	

Paired t-test.
* Statistically significant.

The mean blood pressure levels observed at different occasions where end-tidal concentration of anaesthetic being set to 3 different MAC i.e., 0.8, 1.0 and 1.3 MAC were compared to each other in the study. These 3 different mean levels were compared in 3 ways.
As per first 2 comparisons, the mean SBP of 118.47 ± 10.23 at 0.8 MAC was significantly higher than either 114.37 ± 8.19 at 1.0 MAC or 109.47 ± 7.36 at 1.3 MAC. In last comparison, the mean SBP of 114.37 ± 8.19 at 1.0 MAC was also found to be significantly higher than 109.47 ± 7.36 at 1.3 MAC. Thus, in all 3 comparisons, the study found significant difference thereby confirming significant decrease in SBP with increase in MAC.
Even in case of DBP, as per first 2 comparisons, the mean DBP of 74.73 ± 5.94 at 0.8 MAC was significantly higher than either 72.30 ± 5.38 at 1.0 MAC or 69.47 ± 5.16 at 1.3 MAC. In last comparison, the mean DBP of 72.30 ± 5.38 at 1.0 MAC was also found to be significantly higher than 69.47 ± 5.16 at 1.3 MAC. Thus, in all 3 comparisons, the study found significant difference thereby confirming significant decrease in DBP with increase in MAC.

ISSN: 0975-3583,0976-2833 VOL15, ISSUE 12, 2024

Discussion

Sevoflurane is a halogenated inhalational anesthetic that is FDA approved for the induction and maintenance of general anesthesia in adults and pediatric patients for inpatient and outpatient surgery. As a volatile anesthetic, sevoflurane functions to deliver hypnosis, amnesia, analgesia, akinesia, and autonomic blockade, thus ensuring the provision of these essential physiological states throughout the course of surgical and procedural interventions.

Sevoflurane is administered as an inhaled halogenated anesthetic, facilitated through a specially designed vaporizer calibrated for sevoflurane and connected to an anesthesia machine. The administration of sevoflurane occurs by delivering it via the lungs, where it is provided as a specific volume percentage of the gas that the patient inhales for anesthesia.

For sevoflurane to exert its effect, the agent must be passed from the inspired gas into the blood of the pulmonary capillaries, then circulated into the central nervous system. The onset of action of sevoflurane is determined by the inspired concentration of the agent, partition coefficients, the patient's minute ventilation, and the patient's pulmonary blood flow. These four factors are responsible for the speed of equilibration between the concentration gradient of sevoflurane between the alveoli, pulmonary blood flow, and the central nervous system. As a result, the interplay of these factors orchestrates the pace of induction into an anesthetic state.

Also, variation in the hemodynamic parameters such as heart rate and blood pressure levels were observed with respect to change in end-tidal concentrations of anaesthetic being set to 0.8, 1.0 and 1.3 MAC. On comparing the mean levels at each occasion, the study found significant difference thereby confirming significant decrease in both HR and BP with increase in MAC. Even these findings can be supported from the findings in studies such as Prabhakar H *et al*. [7], Whitlock EL *et al*. [8], Hor TE *et al*. [9] and Singh S *et al*. [10].

Conclusion

On comparing the mean levels at each occasion, the study found significant difference thereby confirming significant decrease in both HR and BP with increase in MAC.

References

1. Miller AL, Theodore D, Widrich J. StatPearls [Internet]. StatPearls Publishing; Treasure Island (FL): Inhalational Anesthetic; 2023 May.
2. Michel F, Constantin JM. Sevoflurane inside and outside the operating room. Expert Opin Pharmacother. 2009 Apr;10(5):861-73.
3. Mapelli J, Gandolfi D, Giuliani E, Casali S, Congi L, Barbieri A, *et al*. The effects of the general anesthetic sevoflurane on neurotransmission: an experimental and computational study. Sci Rep. 2021 Feb;11(1):4335.
4. Lockwood G. Theoretical context-sensitive elimination times for inhalation anaesthetics. Br J Anaesth. 2010 May;104(5):648-55.
5. Patel SS, Goa KL. Sevoflurane: a review of its pharmacodynamic and pharmacokinetic properties and its clinical use in general anaesthesia. Drugs. 1996 Apr;51:658-700.
6. Aranake A, Mashour GA, Avidan MS. Minimum alveolar concentration: ongoing relevance and clinical utility. Anaesthesia. 2013 May;68(5):512-22.
7. Prabhakar H, Ali Z, Bithal PK, Singh GP, Laithangbam PK, Dash HH. EEG entropy values during isoflurane, sevoflurane and halothane anesthesia with and without nitrous oxide. Journal of Neurosurgical Anesthesiology. 2009 Apr;21(2):108-11.
8. Whitlock EL, Villafranca AJ, Lin N, Palanca BJ, Jacobsohn E, Finkel KJ, *et al*. Relationship between bispectral index values and volatile anesthetic concentrations during the maintenance phase of anesthesia in the B-Unaware trial. The Journal of the American Society of Anesthesiologists. 2011 Dec;115(6):1209-18.
9. El Hor T, Van Der Linden P, De Hert S, Mélot C, Bidgoli J. Impact of entropy monitoring on volatile anesthetic uptake. Anesthesiology. 2013 Apr;118(4):868-73.
10. Singh S, Bansal S, Kumar G, Gupta I, Thakur JR. Entropy as an indicator to measure depth of anaesthesia for laryngeal mask airway (LMA) insertion during sevoflurane and propofol anaesthesia. Journal of Clinical and Diagnostic Research: JCDR. 2017 Jul;11(7):UC01.