Original Research Article

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Minimum Alveolar Concentration (MAC) of Desflurane for Effective Tracheal Intubation (MAC-EI)

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Abstract

Introduction: The minimum alveolar concentration (MAC) which prevents movement in response to surgical incision in 50% of patients for halothane and enflurane is less than that which prevents movement in response to laryngoscopy and tracheal intubation . Desflurane may differ from older anaesthetics in its capacity to prevent movement in response to laryngoscopy and tracheal intubation. *Aim:* To calculate the minimum alveolar concentration of desflurane for effective endo tracheal intubation.

Materials and Method: It was a prospective study conducted at Nizam's Institute of Medical Sciences, between July 2015 and September 2015. The study recruited seventy patients scheduled for general anaesthesia for an elective surgery with age ranging between 18 to 60 years of either gender with ASA physical status I and II. After giving the induction drugs, nitrous oxide in oxygen (50:50), each at 4 litres/minute with desflurane was commenced. Desflurane was started at 2% and increased by 2% every 30 sec, until patient lost consciousness, with entropy less than 60 and permitted manual ventilation. Then the dial setting was changed to achieve predetermined end-tidal desflurane concentration within the first 5 min, to start with 6% in the first patient (best guess for MAC-EI). After establishing and maintaining the target end-tidal concentration for 5 more minutes, tracheal intubation was attempted at 11th minute without neuromuscular relaxants and ±0.5% difference in the predetermined/target end-tidal desflurane concentration was allowed. Each concentration at which tracheal intubation was attempted was predetermined according to the up-and-down method (with 1% as step size). Outcome measure of success/failure (unresponsive/responsive) for intubation was based on a score formulated on parameters like, ease of intubation, vocal cords position & movement , reaction to intubation (in terms of movements)- score of 3-6 being regarded as success and ≥7 as failure. The Dixon's methodological principles were applied to determine MAC-EI in the present study. Values for MAC-EI were obtained by calculating the midpoint concentration of all independent pairs of patients involving a crossover, *i.e.,* responsive (failure) to unresponsive (success). We also calculated the eighteen crossover pairs, success to failure. Minimum alveolar concentration was defined as the average of the crossover midpoints in each crossover subgroup. Blood pressure (SBP & DBP), heart rate, saturation, response entropy, state entropy and train of four count (neuro muscular junction monitor) were noted at baseline. Along with these, desflurane dial setting, inspired concentration, endtidal concentration, FIO_2 and ET N_2O were also noted at 5minutes, 10minutes (pre-intubation) and 1 min, 3 min & 6 min post-intubation.

Results: The state entropy similar to the response entropy decreased across the time periods with least value noted just before intubation. The post hoc analysis showed significant decrease in all periods when compared to base line. There were no significant changes in oxygen saturation. Post hoc analysis of the heart rate data showed that there was a significant increase in heart rate when compared to base line at the time of intubation and one and 3 minute after intubation but this returned to normal at 6 min after intubation. There was significant decrease in Systolic and diastolic blood pressure across all periods when compared with the base line and was significant. The difference in desflurane dial concentration and inspired desflurane across the time periods was clinically not significant. The end tidal desflurane rose to the level of set concentration at the end of 5min, and was maintained at this level till intubation. The krushkal wallis test of the desflurane dial concentration, inspired concentration and end tidal concentration compared at different time periods revealed significant changes only in time period 1 (5 minutes after starting Desflurane). Although the desflurane decreases the entropy very fast,

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there is still a difference between failure and success groups and there is a difference also in the end tidal desflurane concentration between the success and failure groups, successful cases had a greater concentration of end tidal desflurane which corresponded to lower entropy values and successful intubation The MAC-EI for desflurane in 50% N_2O was calculated to be 6.37%.

Conclusion: The minimum alveolar concentration of desflurane for effective endo tracheal intubation is 6.37 using 50% N_2O. Desflurane is a safe and effective option to intubate patient, but it cannot be used as a sole agent because of risk of bronchospasm.

Keywords: Minimum Alveolar Concentration; End-tidal Desflurane Concentration; Effective Tracheal Intubation; Entropy.

Introduction

Tracheal intubation was usually performed under deep inhalational anaesthesia with ether. The continuing use of this technique to facilitate tracheal intubation with halothane and subsequently sevoflurane is still established, especially in paediatric practice. The technique has gained a small but popular niche in the armoury of the anaesthetist, when use of a neuromuscular blocking drug is undesirable. It may be used when there is a contraindication to a neuromuscular blocking drug, or in cases where tracheal intubation is necessary but prolonged muscle relaxation is not, such as in short ENT or gynaecological procedures. One avoids the potential serious and unwanted side-effects of succinylcholine, as well as the less common ones of non-depolarizing drugs, such as anaphylaxis.

The pharmacodynamic effects of inhaled anaesthetics must be based on a dose, and this dose is the minimum alveolar concentration or MAC , the alveolar concentration of anaesthetic at one atmosphere that prevents movement in response to a surgical stimulus in 50% of patients. It is analogous to the ED50 expressed for intravenous drugs. The MAC_{EI} is the minimum alveolar concentration for endotracheal intubation. MAC_{EI} of sevoflurane is 2.69% (endtidal concentration) in paediatric patients [1] and 4.52% (endtidal concentration) in adults [2]. The ED95 for tracheal intubation in adults is 8.07% (end tidal concentration) [2]. The minimum alveolar concentration (MAC) of desflurane in oxygen is 7.25% in the 18-30-yr age group, and 6.0% in the 31-65-yr age group [3].

Anaesthetics produce dose dependent effects on the Electro encephalogram (EEG) causing an increase in power combined with a decrease in the average EEG frequency. Various EEG derived parameters are used to describe the anaesthetic related effects. A novel EEG derived parameter for measuring the depth of anaesthesia is entropy. In adults, entropy values have been shown to correlate to the patient's anaesthetic state. High values of entropy indicate high irregularity of the signal, signifying that the patient is awake. A more regular signal produces low entropy values which can be associated with low probability of consciousness.

There are two Entropy parameters the fast reacting Response Entropy (RE) and the more steady and robust State Entropy (SE). State Entropy consists of the entropy of the EEG signal calculated up to 32 Hz. Response Entropy includes additional high frequencies up to 47Hz. Consequently the fast frontalis EMG (FEMG) signals enable a fast response time for RE [4].

The main purpose of the study was to calculate the minimum alveolar concentration of desflurane for effective endo tracheal intubation .

Materials and Method

This was a prospective study conducted, after institutional ethics committee approval , at Nizam's Institute of Medical Sciences, Hyderabad. This study was conducted between July 2015 and September 2015. The study recruited 70 patients scheduled for general anaesthesia for an elective surgery.

Inclusion Criteria

Age ranging between 18 to 60 years of either gender with ASA physical status I and II.

Exclusion Criteria

Patients with airway malformation, clinical evidence of a difficult airway, asthma or any signs of upper respiratory tract infection on preoperative examination. Patients who were taking sedatives, anti histaminics, CNS depressants or anti-seizure medication, or who had CNS disorders.

General Procedure

All the patients were premedicated with oral ranitidine 150mg the night before surgery and on the morning of surgery. In the operating room intravenous access was secured. The patients were monitored with pulse oximetry, electrocardiogram (lead II and V5), noninvasive blood pressure (with a cycle time of 5min), end tidal carbon dioxide ($ETCO_2$), expired concentration of nitrous oxide, concentration fraction of inspired oxygen (FIO2), inspired and expired concentration of desflurane and MAC using Datex Ohmeda Aestiva 5 anaesthesia work station monitor, neuromuscular junction monitor (train of four count), and entropy for depth of anaesthesia. Accuracy of end tidal measurements was maximized by confirming the return of the $ETCO_2$ trace to zero and a plateau of the exhaled concentration values.

Premedication with inj fentanyl 1 mcg/kg IV prior to induction was done. Anaesthesia induction with propofol 1mg/kg and midazolam 1mg was done following which nitrous oxide in oxygen (50:50), each at 4 litres/minute with desflurane was commenced. Desflurane was started with 2% and increased by 2% every 30 seconds until patient lost consciousness, with entropy less than 60 and permitted manual ventilation. Then the dial setting was changed to achieve predetermined end-tidal desflurane concentration , to start with 6% in the first patient (best guess for MAC-EI) . The $ETCO_2$ during mask ventilation was maintained at 35±5 mmHg by adjusting the the TV and Respiratory rate given by the performer. Oral airway was inserted, when necessary during mask ventilation. After establishing and maintaining the target end-tidal concentration for 5 more minutes, tracheal intubation was attempted at 11th minute without neuromuscular relaxant and ± 0.5% difference in the predetermined/target end-tidal desflurane concentration was allowed. Each concentration at which tracheal intubation was attempted was predetermined according to the up-and-down method (with 1% as step size).

Baseline readings (Time period - 1) of blood pressure (SBP & DBP), heart rate, saturation, response entropy, state entropy and TOF count (neuro muscular junction monitor) were noted.

After giving the induction drugs , desflurane was started at 2% and increased by 2% every 30 sec, and reached the target end tidal concentration within the first 5 min . At this time second readings (Time period - 2) were noted along with desflurane dial setting, inspired concentration, endtidal concentration, FIO_2 and ET N_2O (Time period - 1 for these parameters as they weren't noted priorly at baseline). All these readings were repeated at 10 min (just before intubation) (Time period - 3 for those parameters whose readings were noted from baseline and Time period - 2 for those parameters whose readings were noted first at 5 minutes), 1 min after intubation, 3 min after intubation and 6 min after intubation (Time periods - 4 to 6 for those parameters whose readings were noted from baseline and Time periods- 3 to 5 for those parameters whose readings were noted first at 5 minutes) .

Intubation was attempted after waiting for a period of 10 min (Intubation was done at the 11th minute) ie, after a period of 5 min since the desflurane achieved the target end tidal concentration. The ETN2O was roughly uniform (50%) across all the patients at intubation. The TOF count of the neuromuscular junction monitor exhibited all the 4 twitches till intubation. Post Intubation, patients were mechanically ventilated by volume control mode with tidal volume of 8-11ml/kg and inspiratory and expiratory ratio of 1:2 and respiratory rate was adjusted to maintain the end tidal carbondioxide within 35± 5 mmHg.

The dial conc of desflurane was left unchanged as was at intubation till 6 minutes post intubation and the flows of N_2O and O_2(1:1) were also left unchanged at 4l/min each till 6 minutes post intubation for uniformity of the procedure in recording/noting various variables. Post 6 minutes of intubation, anaesthesia was maintained with 50% nitrous oxide in oxygen at 1l/min each and isoflurane 0.4-0.6%. Also, appropiate dosage of neuromuscular blocking drug was administered at this juncture for apt muscle relaxation and conduct of surgery.

Response to intubation was graded as follows depending on scoring given to parameters like, Ease of intubation, Vocal cords position & movement, Reaction to Intubation (in terms of movements):

Score	Ease of Intubation	Vocal cords	Reaction to Intubation (Movements)
1	Good	Open full	None
2	Fair	Open midway	Diaphragmatic movements
3	Difficult	Movements	Moderate coughing
4	Poor	Close	Severe coughing & bucking

Intubating conditions based on summation of scoring points for the three parameters-

Total Score: 3-Excellent, 4 to 6-good; 7 to 9-Poor; 10 to 12 –inadequate. The outcome measure of success (unresponsive) was if the score was 3-6 and if a score of 7 and above was recorded it was regarded as failure (responsive) of successful intubation.

Dixon's (Up And Down) method: The 'Dixon's (Up And Down) method' is standard method to determine MAC of inhalational agents. The end-tidal concentration of the agent midway between highest concentration allowing and lowest concentration preventing a response would be taken as MAC value [5]. The Dixon's methodological principles [6] were applied to determine MAC-EI in the present study (with 1% as step size). The first patient received an initial target end-tidal desflurane concentration of 6%. If the outcome was "success", then the next patient received a target end-tidal desflurane concentration of 5%, otherwise the patient received a target end-tidal desflurane concentration of 7%. In other words, the target end-tidal desflurane concentration to be administered depended upon the response of the previous patient and outcome measure of intubation as success (score: 3-6) or failure (score: 7 -12).

Statistical Analysis

Data analysis: Average of pairs of concentration between success (unresponsive) and failure (responsive) outcomes over the total of 70 patients was the estimated MAC-EI . Descriptive statistics were estimated using non-parametric methods. The "up-and-down method of Dixon" uses a limited data set (pair of crossovers) and does not allow for display of continuous relationship between end-tidal concentration and outcome. There are currently no formal methods of sample size estimation for Dixon's Up-And-Down method as the technique involves continual reassessment based on the patient's response to a particular dose. The critical issue in the methodology is the starting dose which should neither be high to cause adverse effects nor below to cause failure of drug-effect . Since the starting dose is 2 times the MAC of desflurane in 50% nitrous oxide and the fact that proposed study used pre-treatment with propofol and fentanyl, it is believed that a sample of 70 patients would suffice considering the previous studies on MAC and MAC-EI [1-3,7,8].

Comparision of variables: Non-parametric statistical methods were used in the present study. Comparison of independent variables was done by Mann-Whitney U test (for continuous variables) for 2 groups and by Kruskal-Wallis test for multi-groups. Chi-squared test was used for comparison of categorical variables. Comparison of variables at different time periods was made by Friedman's Test (Repeated measures Analysis of Variance-ANOVA).

Post-hoc analysis was done by non-parametric methods as applicable. Data analysis was facilitated by Minitab statistical software (Version 14, 2010). Descriptive data for continuous variables were presented as median inter quartile range (IQR).

Results

The mean age was 42 years in failure group and 41 years in successful intubation group. There was no difference in the age, gender, body mass index between the failure and success groups, they were comparable and yielded no statistical significance.

Values for MAC-EI were obtained by calculating the midpoint concentration of all independent pairs of patients involving a crossover, *i.e.*, responsive (failure) to unresponsive (success). We also calculated the eighteen crossover pairs, success to failure . Minimum alveolar concentration was defined as the average of the crossover midpoints in each crossover subgroup. The MAC of desflurane for effective endo tracheal intubation in this study was 6.37%.

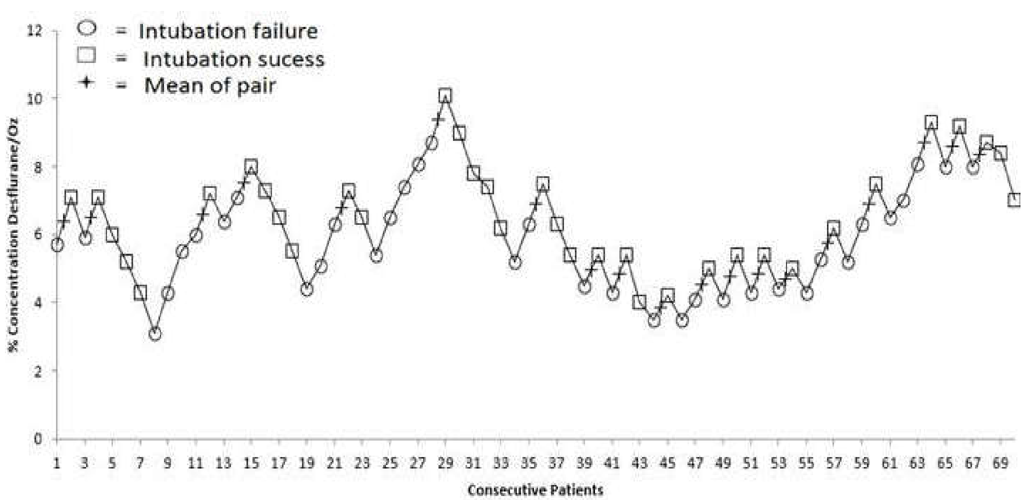

Fig. 1: The MACEI of desflurane for effective endotracheal intubation

Table 1: Response entropy and State entropy in different time periods

Variable	Time Periods	Median (IQR)	Significance in Comparision with base line
Response Entropy	Base line	97(94 - 98.25)	-
	5 min	35(29 - 49.25)	<0.01*
	Intubation	27.5(20 - 41.25)	<0.01*
	1 min after intubation	39(24 - 61.50)	<0.01*
	3 min after intubation	35(22.75 - 54.50)	<0.01*
	6 min after intubation	36(23 - 53.25)	<0.01*
State Entropy	Base line	87(87 - 89)	-
	5 min	33(27 - 45.75)	<0.01*
	Intubation	25(19 - 39)	<0.01*
	1 min after intubation	31.5(20 - 52.25)	<0.01*
	3 min after intubation	32(21.75 - 46.50)	<0.01*
	6 min after intubation	31(21.75 - 47.25)	<0.01*

*significance, P-value<0.05

Table 2: Vital parameters in different time periods

Vital parameter	Time Periods	Median (IQR)	Significance in Comparision with base line
Saturation (%)	Base line	100(99 - 100)	-
	5 min	100(99.75 - 100)	>0.05
	Intubation	100(99 - 100)	>0.05
	1 min after intubation	99(98 - 100)	>0.05
	3 min after intubation	99(97 - 100)	>0.05
	6 min after intubation	99(98 - 100)	>0.05
Heart rate (Beats/mt)	Base line	88.5(78 - 100)	-
	5 min	85(74.5 - 95)	>0.05
	Intubation	85(67.75 - 94)	<0.01*
	1 min after intubation	106(93 - 119)	<0.01*
	3 min after intubation	98(86 - 111)	<0.05*
	6 min after intubation	87(75.75 - 102)	>0.05
Systolic BP (mmHg)	Base line	122.5(117.5 to 140.25)	<0.01*
	5 min	111.5(100 to 131.25)	<0.01*
	Intubation	98(87 to 108.50)	<0.01*
	1 min after intubation	111.5(95.75 to 121)	<0.01*
	3 min after intubation	106(92.75 to 118.50)	<0.01*
	6 min after intubation	100(91 to 110.25)	<0.01*
Diastolic BP (mmHg)	Base line	77(71.75 - 83.50)	-
	5 min	72.5(66 - 85)	<0.01*
	Intubation	62(54 - 68.25)	<0.01*
	1 min after intubation	70.5(60 - 83.25)	<0.01*
	3 min after intubation	64.5(57.75 - 75)	<0.01*
	6 min after intubation	62(56.75 - 70)	<0.01*

*significance, P-value<0.05

The state entropy, similar to the response entropy decreased across the time periods with least value noted just before intubation. The post hoc analysis showed significant decrease in all periods when compared to base line.

There were no significant changes in saturation.

The heart rate decreased up to the time to intubation and then it increased. As opposed to what was expected, we did not find any increase in the heart rate when desflurane was started , this can probably be explained by the fact that the desflurane concentration was increased slowly. Post hoc analysis of the heart rate data showed that there was a significant increase in heart rate when compared to base line at the time of intubation and one and 3 minute after intubation but this returned to normal at 6 min after intubation.

There was significant decrease in Systolic and diastolic blood pressure across all periods when compared with the base line and was significant. The least systolic blood pressure was noted at 10 min or just before intubation.

Table 3: Concentration of Desflurane (%) in different time periods

Variable	Time Periods	Median (IQR)	Significance in comparision with base line (5 min)
Dial concentration of Desflurane	5 min	7(6 - 8)	-
	Intubation	7(6 - 8)	>0.05
	1 min after intubation	7(5.87 - 8)	>0.05
	3 min after intubation	6.75(5.87 - 8)	>0.05
	6 min after intubation	6.75(5.87 - 8)	>0.05
Inspired Desflurane concentration	5 min	6.4(5.5 - 7.5)	-
	Intubation	6.5(5.3 - 7.55)	>0.05
	1 min after intubation	6.5(5.3 - 7.7)	>0.05
	3 min after intubation	6.4(5.45 - 7.72)	>0.05
	6 min after intubation	6.4(5.3 - 7.7)	>0.05
End tidal Desflurane concentration.	5 min	6.0(4.97 - 7.10)	-
	Intubation	6.2(5.07 - 7.32)	<0.01*
	1 min after intubation	6.05(5.17 - 7.20)	<0.01*
	3 min after intubation	6.05(5.17 - 7.20)	<0.05*
	6 min after intubation	6.15(5.0 - 7.1)	<0.05*

*significance, P-value<0.05

Table 4: Comparison of Dial, Insp and ET Desflurane of different time periods by Kruskal- Wallis Test

Dial, Insp and ET des at time period	Median (IQR)	Significance
5 min	7.0(6.0 - 8.0) 6.4(5.5 - 7.5) 6.0(4.97 - 7.10)	<0.01*
Intubation	7(6 - 8) 6.5(5.3 - 7.55) 6.2(5.07 - 7.32)	0.065
1 min after intubation	7(6 - 8) 6.5(5.3 - 7.55) 6.05(5.07 - 7.32)	0.058
3 min after intubation	6.75(5.87 - 8.0) 6.40(5.45 - 7.72) 6.05(5.17 - 7.20)	0.061
6 min after intubation	6.75(5.87 - 8.0) 6.45(5.30 - 7.7) 6.15(5.0 - 7.10)	0.063

*significance, P-value<0.05

The desflurane variables were noted from 5 min onwards, so, that forms the base line value for this variable.

The difference in desflurane dial concentration and inspired desflurane concentration across the time periods was not significant.

The end tidal desflurane rose to the level of set concentration at the end of 5min, and was maintained at this level till intubation. The difference between the different time periods was not significant, though there was statistically significant difference when ETDes at different time periods was compared to that at base line (5 min) .

The Kruskal-wallis test of the desflurane dial concentration, inspired concentration and end tidal concentration compared at different time periods revealed significant changes only in time period 1 (at 5 mins), this shows that, desflurane because of its low blood gas solubility, equilibrates quickly in the body.

Although desflurane decreases entropy rapidly, there is still a difference in entropy between failure and success groups (with entropy being lower in success group) and there is a difference also in the end tidal desflurane concentration between the success and failure groups, cases in success group had a greater concentration of end tidal desflurane which corresponded to lower entropy values and successful intubation.

Table 5: Response, State Entropy and End tidal desflurane in Success and Failure groups

	Outcome	Median (IQR)	Significance
Response entropy			
at 5min	Failure	50(37 - 76)	0.2020
	Success	45(34 - 70)	
at intubation	Failure	59(34 to 90)	0.0165*
	Success	35(25 to 67)	
at 1 min after intubation	Failure	79(59 to 98)	0.00 *
	Success	39(30 to 66)	
State entropy			
at 5 min.	Failure	48(35 - 74)	0.2020
	Success	42(32 - 64)	
at intubation	Failure	49(31 - 78)	0.0447 *
	Success	34(23 - 59)	
at 1 min after intubation	Failure	67(50 - 91)	0.002*
	Success	34(27 – 56)	
End tidal desflurane			
at 5 min	Failure	6.5(5.4 - 8.7)	0.0209*
	Success	7.3(6.5 - 9.8)	
at intubation	Failure	6.5(5.5 - 8.7)	0.0147*
	Success	7.5(6.5 - 10.1)	
at 1 min after intubation	Failure	6.4(5.4 - 9.1)	0.0202*
	Success	7.4(6.3 - 10.2)	

*significance, P-value<0.05

Discussion

Desflurane because of its properties like low blood gas solubility is a rapidly acting inhalational agent and also, it is rapidly washed out of the body, without undergoing much metabolism which makes it the ideal agent for day care surgeries (where it is advantageous to avoid neuromuscular blocking drugs) and other small procedures. It may be used when there is a contraindication to a neuromuscular blocking drug or in cases where tracheal intubation is necessary but prolonged muscle relaxation is not, such as in short ENT or gynaecological procedures. One avoids the potential serious and unwanted side-effects of succinylcholine, as well as the less common ones of non-depolarizing drugs, such as anaphylaxis.

Minimum alveolar concentration (MAC) is a standard measure of potency of inhalational agents. It is defined as the minimum alveolar concentration of anaesthetic at one atmosphere which produces immobility in 50% of subjects exposed to a noxious stimulus, usually a skin incision. Variants of MAC have been described. For example, MAC that blocks the adrenergic responses is called as MAC-BAR, similarly MAC that is used for endo tracheal intubation is called as MAC-EI. There are no prior studies which calculate MAC-EI for desflurane, Kimura et al. [2], described MAC-EI for sevoflurane to produce "*effective intubation*". Unlike sevoflurane, desflurane is not suitable for sole inhalational induction because of it's pungent smell. Hence to enhance smooth induction, desflurane is usually pretreated with propofol.

In this study we calculated the minimum alveolar concentration of desflurane required for effective endo tracheal intubation. The '*Dixon's (Up And Down) method*' is standard method to determine MAC of inhalational agents. The end-tidal concentration of the agent midway between highest concentration allowing and lowest concentration preventing a response is taken as MAC value. Values for MAC were obtained by calculating the midpoint concentration of all independent pairs of patients involving a crossover, i.e., failure (responsive) to success (unresponsive). Minimum alveolar concentration was defined as the average of the crossover midpoints in each crossover subgroup. The MAC of desflurane for effective endo tracheal intubation in this study was 6.37%. As noted in the previous study, the minimum alveolar concentration (MAC) of desflurane/oxygen was 7.25±0.0% (mean±SD) in the 18-30-yr age group, and 6.0±0.29% in the 31-65-yr age group, the addition of 60% N_2O reduced the MAC to 4.0±0.29% & 2.83±0.58% respectively [3].

In a similar study , in patients older than 65 yrs MAC was 5.17±0.6% (mean±SD) in the desflurane/ oxygen group and 1.67±0.4% in the desflurane/ nitrous oxide/oxygen group [7]. Both these studies did not calculate the MACEI. There are no previous studies which calculated this value for desflurane but similar studies were conducted on sevoflurane which revealed the MACEI for sevoflurane which was as high as 2 to 3 times its normal value. At this high dose of sevoflurane there were significant hemodynamic alterations which are detrimental to the patients [2]. The calculation of MACEI of desflurane is complicated because it cannot be used as a sole induction agent, and cannot be used in children because of its upper airway irritating property.

Yakaitis and colleagues were the first to evaluate the optimum end-tidal concentration for intubation. The concept of MAC-EI (EI=endotracheal intubation) was described - the minimum alveolar concentration of halothane needed by 50% of the population to prevent all movement both during and immediately after tracheal intubation. They studied 37 children, aged 2–6 yr, and found the MACEI value of halothane to be 1.4%, and found by extrapolation that the MACEI value for 95% of this population was 1.9% [9].

The same group then applied these study techniques to enflurane in a similar age group of patients and found the corrected MACEI value to be 2.9% [10]. For both halothane and enflurane, the MACEI appears to be about 30% greater than the MAC value.

Halothane was largely superseded by sevoflurane in the mid to late 1990's. Inomata and colleagues determined MAC-EI and MAC of sevoflurane in paediatric patients [1]. They studied 36 children aged 1-9 yrs . After establishing and maintaining the end-tidal concentration for 15 min, tracheal intubation was attempted with an uncuffed tracheal tube without neuromuscular relaxants or other adjuvants. Each concentration at which tracheal intubation was attempted was predetermined according to the up-and-down method (with 0.5% as a step size). MAC-EI & MAC of sevoflurane were 2.69% & 2.03% respectively .

Kimura and colleagues determined MAC-EI and MAC of sevoflurane in adult patients [2]. They studied 86 adult patients aged 16-59 yr . After establishing and maintaining the predetermined end-tidal concentration for 20 min, tracheal intubation was attempted using a cuffed tracheal tube without muscle relaxant or other adjuvants. The MAC-EI & MAC of sevoflurane for 50% of the population were 4.52% & 1.58% respectively . The authors accounted for this difference of MAC-EI in adults when compared to children, by the irritation & subsequent coughing caused by the cuff of adult tracheal tube & the fact that children have a relatively greater brain perfusion & quicker uptake. They suggested that anaesthesia induction followed by tracheal intubation can be accomplished in adults when sevoflurane is administered as a sole anesthetic, but in excess of 8% end-tidal concentration .

Swan et. al., studied the interaction between nitrous oxide and sevoflurane during tracheal intubation in 72 children aged 1-7yrs. The addition of N_2O 33 & 66% has been shown to decrease the MAC-EI value by 18 & 40%, from 2.66% with sevoflurane alone, to 2.16% & 1.57% respectively [8].

Katoh et. al., studied sevoflurane requirements for tracheal intubation with or without fentanyl [11]. They pretreated a group of 80 adults with fentanyl - 1, 2 & 4 μg/kg, 4min before intubation. MACEI of sevoflurane was 2.07, 1.45 & 1.37% respectively in the pretreated groups, compared with 3.55% in the group without fentanyl pretreatment .

In healthy volunteers, in the absence of concomitant N_2O and/or opioid administration, sudden steep increases in the inspired concentration of desflurane may cause transient increases in sympathetic activity with associated increases in heart rate and blood pressure. The haemodynamic changes are more common at concentrations >6% and more severe with large (>1%), sudden increments. Without treatment, and without further increases in desflurane concentration, these increases in heart rate and blood pressure resolve in approximately 4 minutes [12]. Administration of sympatholytic drugs (fentanyl, alfentanil, esmolol, and clonidine) prior to a sudden steep increase of desflurane blunts or blocks the increase in heart rate and blood pressure.

In the present study we included 70 patients, & though the sample size estimation could not be done as there were no previous studies determining MAC-EI for desflurane, it was based upon previous studies determining MAC-EI & MAC of sevoflurane [1,2,8] or MAC of desflurane [3,7]. We started off with a desflurane concentration of 6% (best guess for MAC-EI). After premedicating the patient with fentanyl, propofol and midazolam we increased the dial setting of the desflurane by 2% every 30 sec until the target (predetermined) dial setting was achieved. Then this concentration was maintained for 5 more min and the patient was intubated in the 11th minute.This was done to equilibrate the desflurane dial , inspired and endtidal concentrations with each other, and also to wait for the effect of propofol to fade away. As the concentration of desflurane increased there was subjective difficulty in doing bag mask ventilation but there were no complications.

Previous studies which calculated the MAC value for inhalational agents used different time periods after achieving the target end tidal concentration.

Gold et. al. [7], while calculating the MAC value of desflurane (with and without 60% N_2O) in elderly patients, waited for 10 min & Fisher et. al. [13], when calculating the MAC value of desflurane in children with 60% N_2O, also waited for 10 min after the target end tidal concentration was achieved. In the studies by Inomata et. al. [1], in children and Kimura et. al. [2], in adults for calculating MAC-EI & MAC of sevoflurane and in the study by Swan et. al. [8], in children for calculating MAC-EI of sevoflurane in different concentrations of N_2O , they waited for 15, 20 and 10 minutes respectively after the target end tidal concentration was achieved. We considered pretreatment with drugs like fentanyl in our study based upon the findings in prior studies which indicated their role in decreasing the MAC-EI [11].

We intended to calculate MAC EI of desflurane in 50% N_2O , based upon the studies substantiating the reduction of MAC EI for sevoflurane [8] and MAC for Desflurane [3,7] with the addition of N_2O. Some studies also supported the addition of N_2O, which resulted in faster loss of consciousness and reduced excitement in rapid induction technique with sevoflurane [14].

Dixon's methodology which was used in our study to determine the MAC-EI of desflurane ,was priorly used in other studies also which determined MAC-EI and MAC for sevoflurane [1] and MAC for desflurane [3,7,13].

The scoring system used in our study for assessing success / failure of intubation was roughly based upon the same criteria (presence or absence of - purposeful muscular movements, vocal cord movements, coughing , bucking) used to regard an intubation attempt as successful (unresponsive) ,or as a failure (responsive), as in other studies which calculated MAC EI of sevoflurane [1,2,8].

The sympathetic stimulation which is associated with desflurane which causes increase in the heart rate and blood pressure was not seen probably because of the slow increase in the desflurane dial setting by 2% for every 30 sec, co-administration with N_2O and pretreatment with fentanyl. There was actually increase in the heart rate and blood pressure immediately after intubation showing that the concentration required for immobility is still insufficient to wipe out the autonomic responses (MAC-BAR). This raise in heart rate and blood pressure returned to pre-intubation levels within 6 min post-intubation.

The results of the study show that the MACEI for desflurane is 6.37, which is close to its MAC of 6 but this is calculated using 100% O_2 and in the present study we used 50% N_2O. We used N_2O in this study to make it cost effective, without the use of N_2O the MAC EI would be much higher. Entropy was also recorded in our study, which substantiated a greater depth of anaesthesia in those with a successful outcome of intubation, who also supposedly had a greater concentration of end tidal desflurane concentration.

Conclusion

The minimum alveolar concentration of desflurane for effective endo tracheal intubation is 6.37 using 50% N_2O. Desflurane is a safe and effective option to intubate patient, but it cannot be used as a sole agent because of risk of bronchospasm. Slow elevation of the desflurane concentration will decrease the hemodynamic alterations.

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