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Research Article

Comparison Of Gas Man® Simulated Low Flow Anaesthesia With Real-Time, Using Sevoflurane - Air Oxygen Mixture

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ABSTRACT

Background & Aims: Gas Man simulation software has not been validated on humans using sevoflurane – air-oxygen mixture. This study was undertaken to see the predictability and correlation of the Gas Man software with the real time measured sevoflurane concentration in air oxygen mixture.

Methods: After obtaining ethical committee approval and informed consent, thirty ASA I and 2 patients of either sex, between 20 - 50 years were selected. Gas Man simulation was done prior to anaesthetizing the patients. The inspired (Fi_{Sevo}) and end-tidal concentration (Et_{Sevo}) of sevoflurane values were generated every minute. The anaesthesia induction was done by a standard protocol, maintained with low flows (air + O_2 mixture and sevoflurane) and semi closed circle system with same fresh gas flows and dial setting of vaporizer as Gas Man simulation. The Fi_{Sevo} and Et_{Sevo} values were collected every minute. The model performance was assessed Varvel's criteria.

Results: The median absolute performance error (Fi_{Sevo}=10.22%,Et_{Sevo}=12.12%), median performance error(Fi_{Sevo}= -3.67% ,Et_{Sevo}= -4.96), wobble (Fi_{Sevo}= 12.01%, Et_{Sevo}=14.40%) and divergence(Fi_{Sevo} = 0.09%, , Et_{Sevo} = 0.19%) were comparable.

Conclusion: The FiSevo and EtSevo predicted by Gas Man were close to real patients.

Keywords: Gas Man, Real Time, Inspired Sevoflurane, End Tidal Sevoflurane

INTRODUCTION

Gas Man® software, a computer-based simulation tool, explains the uptake and distribution of the anaesthetic gases in the body. Many studies had proved that Gas Man® was a good educational tool,[Paskins et al 1985, Garfield JM et al 1989) in contrast to presentations and lectures. Gas Man® can be used to plan one's technique of administering different inhalational agents. A study comparing Gas Man® simulator with real-time using oxygen-nitrous oxide and isoflurane was done in this Institute, (Athiraman U. et al. 2015) which showed a good predictability of Gas Man®. Since, the blood gas solubility and tissue gas coefficient are different for different agents and the flow dynamics of the circle system plays a major role in determining the inspired concentration of the agent in low-flow anaesthesia, this study has been designed to check the accuracy of Gas Man® simulator with real-time sevoflurane concentrations during low-flow anaesthesia using air-oxygen mixture.

MATERIALS AND METHODS

Patients admitted to a medical teaching institute in South India for elective surgeries under general anaesthesia needing endotracheal intubation formed the study group. Approval of the hospital ethics and research committee was obtained for the conduct of the study. The study was conducted according to the declaration of Helsinki Patients in the age group between 20–50 years of either sex belonging to ASA I & II undergoing elective surgeries with anticipated blood loss less than 500 ml were selected for the study. The selection process was continuous sampling and a sample size was decided as 30, since it was a comparison and evaluation of a computer-simulated model.

Patients undergoing emergency surgery were excluded. The night before surgery after a thorough pre operative check up, the patients were informed about the study and informed consent was taken from the patient. The patient's age and weight were recorded for use in the simulation. Simulation was carried out in Gas Man® simulation software for a period of five hours by entering the patient's weight, type of the circuit and the anaesthetic agent a day before surgery. Datex Omeda 9100C anaesthesia machine with advanced breathing system was used for all cases. The breathing circuit volume was measured by filling the whole system with water and determined it to be 3.6 litres. The same circuit volume of 3.6 litres was set in the default setting of Gas Man® for all these simulations. The study parameters were recorded every 1 minute. In Gas Man® simulator since air cannot be used, percentage of nitrogen was used. The simulation was started with a FGF of 6 L/min, sevoflurane concentration of 4% and nitrogen concentration of 52.6% to represent a gas mixture of 4 L/min of air and 2 L/min of oxygen. The simulation was run for 10 min with this setting and was changed to FGF of 800 ml/min, sevoflurane concentration of 3% and nitrogen concentration of 49.4% to represent a gas mixture of 500 ml of air and 300 ml of oxygen. The simulation was continued with this setting for a period of 5 hours. The bookmark is set to stop the simulation for every minute and the values generated in the Gas Man® software, were copied into our database.

The patients were pre-medicated with tab. diazepam 10 mg orally on the night before and on the morning of surgery. In the operation theatre, patients were pre-medicated with Inj. Midazolam 0.05mg/kg iv and inj. Morphine 0.1 mg/kg iv 10 min before start of induction. After connecting the anaesthesia monitor to record the study parameters i.e., ECG, NIBP, EtCO2, SpO2 and the inspired and end-tidal agent concentrations, pre-oxygenation was started with 6 L/min of oxygen. After 3 minutes, patients were induced with Inj. Propofol 1.5mg/kg iv bolus followed by 150 μg/kg/min as infusion. Tracheal intubation was accomplished after administering Inj. Vecuronium 0.1mg/kg iv, with cuffed oral or nasal endotracheal tube. Patients were ventilated with Datex-Ohmeda9100c ventilator using 100% oxygen to have the end-tidal CO2 within normal limits (32 – 36 mmHg). Once the patient was stable, the FGF was changed to 4 L/min of air and 2 L/min of oxygen and sevoflurane was set to 4%to match the start of simulation and propofol infusion was stopped.

For the first 10 minutes, the gas flows were 6 liters (4 liters air, 2 liters oxygen) and 4% sevoflurane. After 10 minutes the gas flows were reduced to 800ml (500ml air and 300ml oxygen) and 3% sevoflurane. These dial concentrations and gas flows were formulated after doing a pilot study to ensure adequacy of anaesthesia. Inj. vecuronium 0.02 mg/kg iv was used to maintain intraoperative neuromuscular blockade. Inj. Morphine 1.5mg iv every 45 minutes was supplemented intra-operatively. Mechanical ventilation was done with tidal volume 6-8ml/kg with a respiratory rate 12-15/min to adjust the end-tidal carbon dioxide within normal limits. Ringer's lactate was used as the maintenance intravenous fluid.

Ten minutes before the expected end of surgery, sevoflurane was cut off without changing the gas flows. After the wound dressing, patients were ventilated with 100% oxygen. The patients were reversed from neuromuscular blockade and they were extubated when the extubation criteria were satisfied. The time at which agent was cut off in real-time was bookmarked in Gas Man® simulator and the simulation would end there.

The study parameters i.e., end-tidal and inspired concentrations of sevoflurane, haemodynamic parameters, SpO_2, $EtCO_2$, MAC were captured using vital signs capture software every 1 minute and intraoperative awareness was studied based on a questionnaire. The patients requiring changes in agent conc. due to haemodynamic alterations were excluded from the study. The strength of the correlation between two variables was analyzed using the coefficient of determination (R^2) and regression analysis. Predictive performance of the model was analyzed based on Varvel's criteria by calculating the Median Performance Error (MDPE), Median Absolute Performance Error (MDAPE), Wobble and Divergence

RESULTS

Our study included the patient population of 20-50 years (mean 36 years) of age. There was no significant difference between the male and female distribution in our study. Patients undergoing elective ENT and urology procedures were recruited for the study. (Table1)

The mean inspired and end-tidal values for sevoflurane generated by Gas Man® and real-time were studied for the entire population. The simulated values were much close to the measured values. (Figure 1&2)

Figure 3 and 4 shows the scatter plot diagram with the coefficient of determination and linear regression analysis with 95% confidence intervals for inspired and end-tidal values of measured and simulated (Gas Man®) values. The coefficient of determination (R^2) between inspired sevoflurane real- time and simulated values is 0.60. The coefficient of determination (R^2) between end-tidal sevoflurane real-time and simulated values is 0.36. The Gas Man® values for inspired sevoflurane was obtained by the regression equation, Inspired sevoflurane Gas Man® = 0.06 + 0.97 × Inspired sevoflurane Real-Time. Similarly the Gas Man® values for end-tidal sevoflurane can be obtained by the regression equation, End-tidal sevoflurane Gas Man® = 0.36 + 0.79 × End-tidal sevoflurane Real-Time. Predictive Performance of the model was analysed based on Varvel's criteria by the following parameters: Median performance error (MDPE), Median absolute performance error (MDAPE), Divergence, Wobble were within acceptable limits (Table 2). The calculated performance error for all 30 patients was plotted against time. The performance error for inspired & end-tidal sevoflurane was -13.56 to 6.22% and -14.53 to 4.61% respectively. (Figure 5, 6)

Intraoperative haemodynamics in the form of mean heart rate, mean systolic blood pressure, mean diastolic pressure, mean of mean arterial pressure, mean oxygen saturation was recorded every 5 min and plotted against time for all 30 patients. The intraoperative haemodynamic parameters were stable throughout the surgery. None of the patients had intraoperative awareness.

DISCUSSION

This study was conducted in a medical teaching institute in South India, in the operation theatre among patients undergoing elective ENT and urology surgeries under general anaesthesia. Our study included the patient population of 20-50 years (mean 36 years) of age. The extremes of age group population were not included in the study due to differences in requirements, pattern of uptake and distribution of inhalational agent. There was no significant difference between the male and female distribution in our study. Kennedy et al have included patients with 8 – 88 years age group, 30 – 90 kg and without specifications of the sex distribution(Kennedy et al 2002). Major blood loss, emergency surgeries causing changes in cardiac output can alter the requirements of the inhalational agents. We maintained the similar agent concentration during the conduct of anaesthesia to match the values obtained by simulation.

Several studies have demonstrated the effectiveness of the Gas Man® simulator as an educational tool.(Tanner G et al 1982. Short TG et al 1996). Athiraman et al 2015 have validated the Gas Man®. In their study, patient's physiological data in real-time was collected before simulation. The simulation was done after the real-time to see the correlation between Gas Man® and Real-Time. The changes in FGFs were done according to the simulated Gas Man® flows during maintenance of general anaesthesia. The data generated after this was used to correlate between the two methods and assess reliability performance of Gas Man® software. Different anaesthesia machines have different wash-in and re-breathing characteristics. Hence, all the cases were done on the same anaesthesia machine after performing the leak and the calibration checks. The study parameters recording was terminated once sevoflurane was stopped at ten minutes before the expected end of surgery. The wash-out phase was not included in our study because elimination of sevoflurane is variable on the type of breathing circuit used, changes in FGF, flushing the circuit etc. Therefore, it was not compared with Gas Man®.

The mean inspired and end-tidal values for sevoflurane generated by Gas Man® and real-time plotted against time were studied for the entire population. The simulated values were close to the measured values (Figure: 1, 2). The model predicts the inspired and end-tidal concentrations of sevoflurane with a good accuracy and minimal bias and deviation.

Predictive performance of our model i.e. Gas Man® was analysed based on Varvel's criteria.(Varvel JR. et al. 1992) The measurement of time related trends of the measured concentrations towards or away from targeted concentrations is defined as divergence. The model's divergence is expected to be close to 0 for a good performance of the model. The inspiratory divergence of our model is 0.09% per hour and 0.19% per hour (end-tidal divergence) which implies a very good predictive performance of the model (Table 2). Performance Error (PE) is plotted against time (minutes) for each of 30 patients. This plot allows the performance of the model in each patient to be visualized, providing a graphical representation of the bias and time-weighed variability. Each line represents one patient. (Figure 5, 6). The PE for inspired and end-tidal sevoflurane was between -13.56 to 6.22% and -14.53 to 4.31%, The median absolute performance error for inspiratory and end-tidal sevoflurane was 10.22% and12.12%, median performance error for inspiratory and end-tidal was -3.67% and -4.96, wobble for inspiratory and end-tidal was 12.01% and 14.40%, divergence for inspiratory and end-tidal was 0.09 and 0.19% per hour. All criteria were within limits of the acceptable performance of the model.

Swinhoe et al have defined the acceptable limits for TCI pumps as MDPE 10-20% and MDAPE 20-40%(Swinhoe et al 1998). Other authors also (Kennedy et al 2002, Short TG et al. 1996) have used Varvel's criteria to study the propofol infusion model used for TCI systems. The range of mean values for MDAPE from these results was 21% to 24.1%, for MDPE -12.1% to 16.2%, for divergence -17%/h to -2.9%/h and for wobbles 7%/h to 11.6% / h. MDPE,MDAPE, Divergence are calculated from the performance error (PE).Our results of this model were better than the above mentioned limits (Table: 2). Kennedy (Kennedy et al 2002)states that when wobble and divergence are less, the user can assume that the bias remains constant in an individual patient.

In our study for the initial 10 min following intubation, a fresh gas flow (FGF) of 6 L/min (4L air, 2 L oxygen) was kept followed by a FGF of 800 ml/min (500ml air, 300ml oxygen till 10 minutes before the end of surgery. Baxter described the pharmacokinetic behaviour and practical aspects of low (0.5–1 L/min) and minimal (0.25–0.5 L/min) flow anaesthesia(Baxter AD 1997). The advantages of low / minimal flows being reduced cost and environmental pollution with scavenged gases. There should not be any concern with low-flow techniques with modern gas monitoring technology. Cotter also conducted a survey (Cotter SM et al. 1991)on advantages of low-flows in the form of agent consumption and annual cost savings.

In our study, medical air (nitrogen) was used instead of nitrous oxide as nitrous oxide affects the uptake and elimination of sevoflurane. Thereby, the over estimation of inspired and end-tidal sevoflurane concentrations will be avoided. Baum described about the various types of carrier gases. He has stated that there is no evident contraindication to medical air unlike nitrous oxide and 100% oxygen. Baum concluded that many anaesthetists around the world are using air/oxygen than nitrous oxide/oxygen mixture because of the inertness of nitrogen in relation to metabolism and the environment.(Baum JA 2004)

The incidence of intraoperative(Schwender D et al 1998, Sebel PS et al 2004) awareness was assessed in the form of a questionnaire. None of the patients had intraoperative awareness. Ranta et al studied on the factors contributing to the intraoperative awareness. They interviewed 2612 patients of whom, ten (0.4% of those interviewed) patients were found to have undisputed awareness and there were nine (0.3%) patients with possible awareness. (Ranta et al 1998)The doses of isoflurane and propofol were smaller in patients with awareness. In our study the doses of propofol and sevoflurane were adequate. The haemodynamic parameters, MAC, ETCO2 and SPO2 were stable throughout the intraoperative period.

The Gas Man® software does not consider Body Mass Index (BMI), inter tissue diffusion and metabolism of that inhalational anaesthetics while calculating the uptake and distribution. The inter tissue diffusion of the inhaled anaesthetics in obese patients occur from highly perfused organs (vessel rich group – VRG- heart, kidney, liver) to the perirenal, omental, mesenteric, pericardial fat. Similar diffusion occurs from the poorly perfused organs (muscle, skin) to the fat and bones. These factors are also not considered in Gas Man® software. The future studies can be conducted with Gas Man® by using low-flows and other inhalational agents like Desflurane for analysing cost.

Gas Man® is licensed for use in two ways. One way is the single user license which can be installed only in one computer and the other is the site license which is used by the hospitals, University departments. The single user licence software is available for download free of cost (trial version). The user friendly manual (Philip JH 2015)can be downloaded from the website[15].

CONCLUSION

We concluded that, the variation in the inspired and end-tidal sevoflurane values between the real-time and Gas Man® is statistically insignificant. There is a good correlation between real-time and Gas Man® values. The PE was not more than 25%. Divergence was only 0.09%/h and 0.19%/h for inspired and end-tidal sevoflurane respectively which mean the predictability of Gas Man® software is quite accurate. With the combination of the clinician's judgment and the Gas Man® technology of anaesthetic administration can not only be taught in the real-time patients but also helps the anaesthetists for better tailoring of their technique and usage of inhalational anaesthetics.

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Conflict of interest – nil

Author Contributions

Dr MR has devised the concept
Dr Anusha has collected the data
Dr VRHK – statistics and data collection
Dr SPS has done the write up , communication and supervision
Ethical approval – YES
Patients consent in designated form : YES

REFERENCES

1. Athiraman U, Ravishankar M, Jahagirdhar S. Performance of computer simulated inhalational anesthetic uptake model in comparison with real time isoflurane concentration. J Clin Monit Comput. 2015;1–6.

2. Baum JA. The carrier gas in anaesthesia: nitrous oxide/oxygen, medical air/oxygen and pure oxygen. Curr Opin Anaesthesiol. 2004;17:513–6.
3. Baxter AD. Low and minimal flow inhalational anaesthesia. Can J Anaesth. 1997;44:643–53.
4. Cotter SM, Petros AJ, Doré CJ, Barber ND, White DC. Low-flow anaesthesia. Anaesthesia. 1991;46:1009–12.
5. Garfield JM, Paskin S, Philip JH. An evaluation of the effectiveness of a computer simulation of anaesthetic uptake and distribution as a teaching tool. Med Educ. 1989;23:457–62.
6. Kennedy RR, French RA, Spencer C. Predictive Accuracy of a Model of Volatile Anesthetic Uptake: Anesth Analg. 2002;95:1616–21.
7. Paskins, Raemer DB, Garfield JM,Philip JH: Is computer simulation of anesthetic uptake and distribution an effective teaching tool for anesthesia residents? J Clin Mon.1985; 1:87.
8. Philip JH. User Manual for Gas Man: a simulation and teaching tool [Internet]. [cited 2015 Sep 27] Available from: http://www.gasmanweb.com/software.html.
9. Ranta SO-V, Laurila R, Saario J, Ali-Melkkila T, Hynynen M. Awareness with Recall During General Anesthesia: Incidence and Risk Factors. Anesth Analg. 1998;86:1084–9.
10. Schwender D, Kunze-Kronawitter H, Dietrich P, Klasing S, Forst H, Madler C. Conscious awareness during general anaesthesia: patients' perceptions, emotions, cognition and reactions. Br J Anaesth. 1998;80:133–9.
11. Sebel PS, Bowdle TA, Ghoneim MM, Rampil IJ, Padilla RE, Gan TJ, et al. The Incidence of Awareness During Anesthesia: A Multicenter United States Study: Anesth Analg. 2004;99:833–9.
12. Short TG, Lim TA, Tam YH. Prospective evaluation of pharmacokinetic model-controlled infusion of propofol in adult patients. Br J Anaesth. 1996 1;76:313–5.
13. Swinhoe CF, Peacock JE, Glen JB, Reilly CS. Evaluation of the predictive performance of a "Diprifusor" TCI system. Anaesthesia. 1998;53:61–7.
14. Tanner G. Pharmacokinetics of inhalation anesthetics: a three-compartment linear model. Anesth Analg 1982;61:587–94.
15. Varvel JR, Donoho DL, Shafer SL. Measuring the predictive performance of computer-controlled infusion pumps. J Pharmacokinet Biopharm. 1992 1;20:63–94.

LEGENDS FOR TABLES AND FIGURES

Table 1: Type of Surgery

TYPE OF SURGERY	NO. OF PATIENTS
Cortical Mastoidectomy	15
Myringoplasty	2
Functional endoscopic sinus surgery	3
Ureteroscopic lithotripsy	10

Table 2: Performance Error Statistical Variables For Inspired Sevoflurane & End-Tidal Sevoflurane (The values of MDPE, MDAPE, wobble, divergence are expressed with 95% confidence interval)

VARIABLES	Inspired sevoflurane (mean)	End tidal sevoflurane (mean)	95% CONFIDENCE INTERVAL	
			Inspired sevoflurane	End tidal sevoflurane
MDAPEi(%)	10.22	12.12	3.74 to 16.70	6.28 to 17.96
MDPEFi(%)	-3.67	-4.96	-13.56 to 6.22	-14.53 to 4.61
WOBBLEFi(%)	12.01	14.40	9.82 to 14.20	8.89 to 19.91
DIVERGENCE Fi(%h)	0.09	0.19	-0.65 to 0.47	-0.91 to 0.53

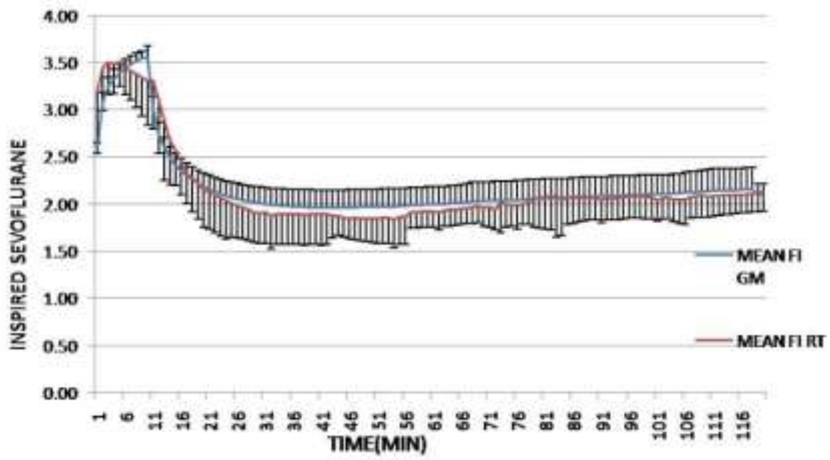

Fig.1: Inspired Sevoflurane/Time(Min) Of Gm-Gas Man®& Rt-Real-time.

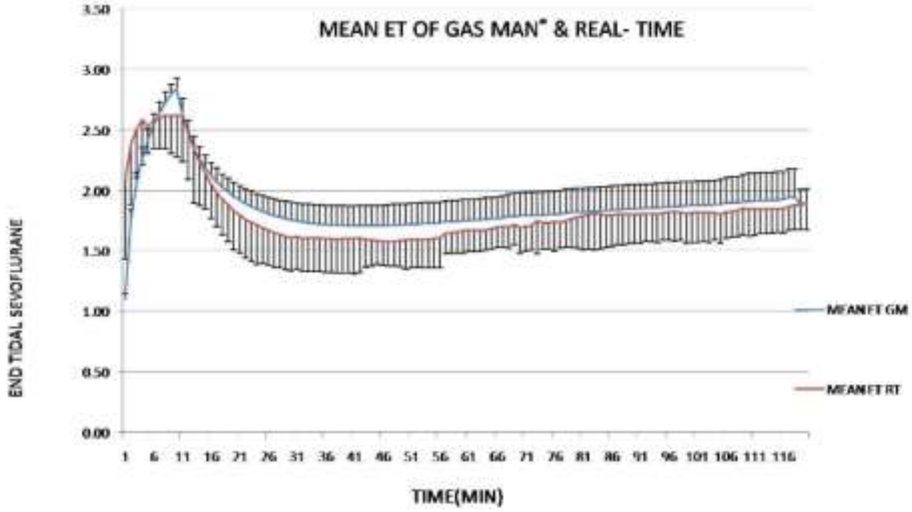

Fig.2: End-tidal Sevoflurane/Time(Min) Of Gm-Gas Man®&Rt-Real-time.

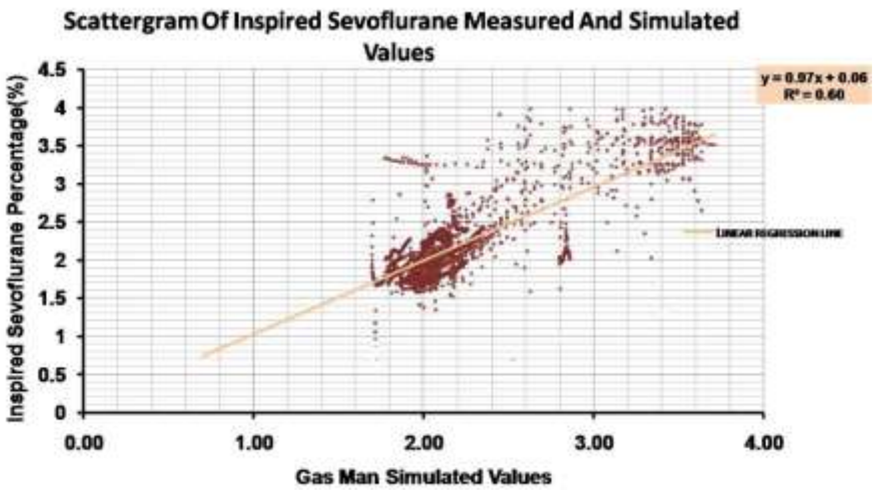

Fig.3: The scattergram with coefficient of determination (R2) and linear regression analysis for Inspired sevoflurane (%) for measured and simulated values.

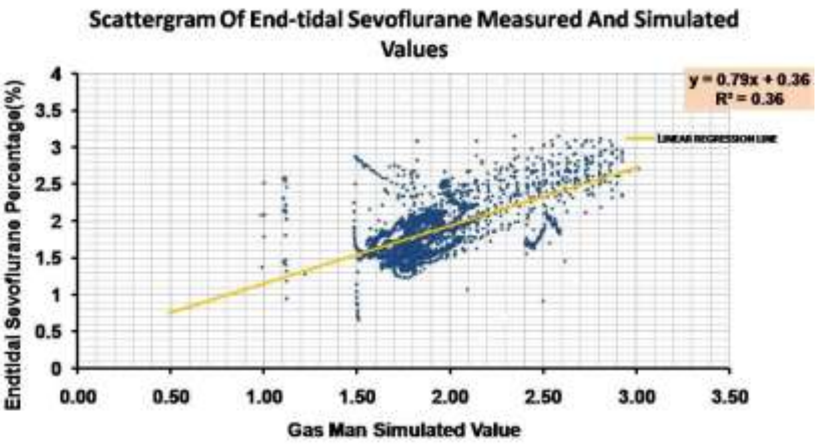

Fig.4: The scattergram with coefficient of determination (R2) and linear regression analysis for end-tidal sevoflurane (%) for measured and simulated values.

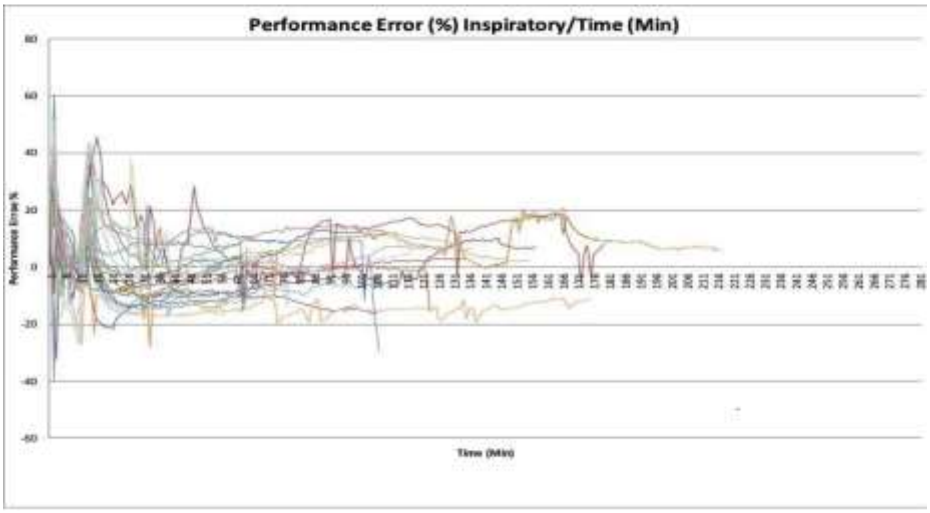

Fig.5: Performance Error%(Inspiratory)/Time(Min).

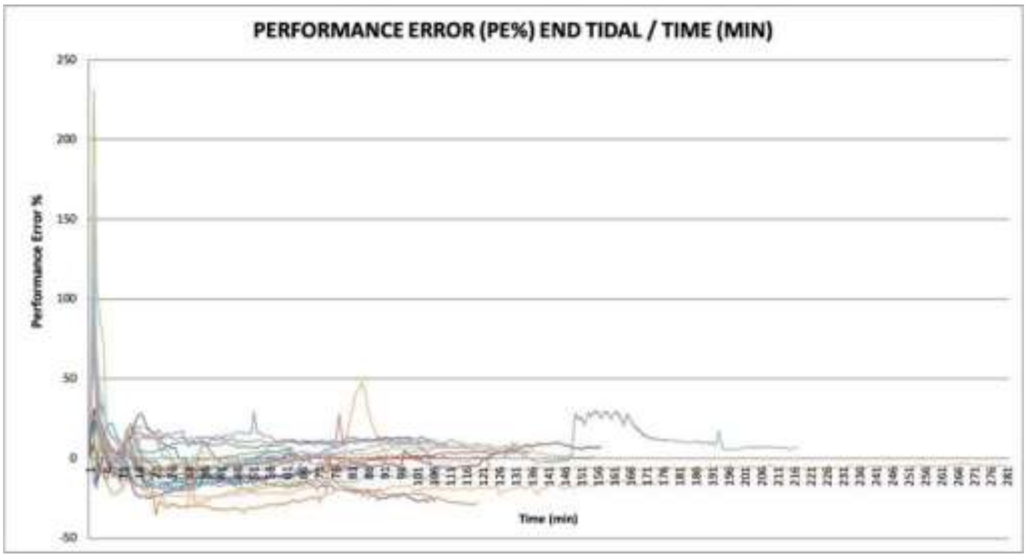

Fig.6: Performance Error%(End-Tidal)/Time(Min).