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ORIGINAL ARTICLE

Comparison of Manual Mode with Automatic Gas Control Mode for Sevoflurane Consumption in Maquet Flow-I Anesthesia Machine

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ABSTRACT

Background: Inhalational anesthetic agents used for general anesthesia can have adverse effects on operation theater staff and environment. The innovative automated gas controller reduces inhalational anesthesia agent consumption.
Aim: To compare sevoflurane consumption in manual mode versus automatic gas control (AGC™) mode on Maquet Flow-i anesthesia machine in adult laparoscopic surgeries.
Methods: This study was a randomized control trail conducted at Department of anesthesia, Security Forces Hospital Riyadh, Saudi Arabia and Pakistan Kidney and Liver Institute and Research Center, Lahore, Pakistan from December 2019 till December 2020. Sixty patients were randomly divided into two Groups A (Automatic Gas Control, AGC™) and Group B (Manual Mode). Sevoflurane consumption and sevoflurane consumption rate was calculated in both groups. Data was analyzed using SPSS V.20.
Results: Two groups were comparable in term of age, gender, and comorbidities. The mean sevoflurane consumption rate in group A was 23.92+4.6 as compared to 40.23+4.4 in group B (P=0.001). Similarly sevoflurane consumption rate is also statistically significant. (0.28 + 0.04 ml/min vs 0.47 + 0.02 ml/min, p=0.001)
Conclusion: Sevoflurane consumption and sevoflurane consumption rate is lower in AGC™ mode as compared to manual mode of Maquet Flow-I anesthesia machine.
Keywords: Sevoflurane, Maquet Flow-i, Automatic Gas Controller (AGC™), Laparoscopic Surgeries

INTRODUCTION

General anesthesia with inhalational anesthetic agents is the most common type of anesthetics used worldwide. Occupational exposure to residual inhaled anesthetics concentrations is not only associated with adverse health effects but also an environmental hazard being potent greenhouse gases[1,2]. Low flow anesthesia, circle systems, and modem vaporizers have been being used to reduce inhalational agent consumption and hence their release into the atmosphere[3].

Automated gas control for delivery of inhalational agents directly targets a desired end-expired partial pressure. This provides several benefits over conventional low flow delivery system such as decreased frequency of rotameter and vaporizer settings, decreased discrepancy between dialed settings and agent delivery to the patients. According to Avidan et al[4] anesthesiologists failed to maintain MAC above 0.7 MAC in more over 15% of the cases when they control the fresh gas flow and vaporizer settings themselves.Furthermore, there is risk of inspired hypoxic mixtures in non-automated low flow anesthesia even with the presence of hypoxic guard system[5]. Therefore, automated gas control prevents this risk by rapidly achieving desired FIO2, exponentially decreasing fresh gas flow simultaneously maintaining targeted inspired inhalational agent concentration[6].

The FLOW-i (Maquet, Solna, Sweden) offers a controlled automated low flow anaesthesia system, known as Automated gas control (AGC™). It is an innovative electronic injection vaporizer designed to reach the target end-tidal anesthetic agent in a precise manner and reduces the risk of under and overdosing.[7] Once the end-tidal target is reached, AGC™ automatically reduces the fresh gas flow (FGF) and agent delivery to minimal levels, enabling safe low-flow anesthesia. The reduced consumption of inhaled anesthetic agent through AGC™ reduce the well-known negative environmental impact of inhalational anesthesia[8].

This study was planned to determine the consumption of sevoflurane using the Maquet Flow-i AGC™ with a manual mode anesthesia machine for adult patients undergoing laparoscopic surgeries.

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METHODS

This study was randomized control trail conducted at Security Forces Hospital, Riyadh, Saudi Arabia and Pakistan Kidney and Liver Institute and Research Center, Lahore, Pakistan from December 2019 till December 2020. Ethical review board (KACST, KSA:H-01-R-069) obtained and inform consent was taken before including patient into the study. Sixty patients of age 21 to 60 years and American Society of Anesthesiologist status I & II undergoing laparoscopic surgeries were included in this study through non-probability consecutive sampling. Patients with known suspected history of malignant hyperthermia, cases where sevoflurane was not the primary anesthetic agent or cases sedated with total intravenous anesthesia (TIVA) were excluded from this study. A sample size of 60 patients (30 in each group) was calculated with estimated power of study 80%, confidence interval 95%, level of significance 5%, taking estimated sevoflurane consumption of 0.49+0.23 ml in AGC™ and 0.86+ 0.26 ml in manual mode derived from previous study[9].

All the cases were carried out in Maquet flow-i anesthesia machine which is equipped with built in Automatic Gas Control (AGC™) and Manual Mode. In AGC™ mode target end-tidal anesthetic agent was set while machine automatically adjusted the fresh gas flow and anesthetic agent supply. In manual mode, anesthetic agent supply and fresh gas flow is adjusted manually to reach a target end-tidal anesthetic agent. Anesthesia time (minutes) was as defined as the duration for which sevoflurane was delivered to the patient. Sevoflurane Consumption (ml) of sevoflurane during each case was determined from Log from Maquet Flow-i anesthesia machine log sheet. Sevoflurane consumption rate was calculated by dividing total sevoflurane consumption by total anesthesia time (ml/minute) during the case.

Patients were divided into two groups A & B by random number table. Anesthesia was maintained with oxygen and sevoflurane using AGC™ (Group A) or manual mode (Group B). In Group A, after securing the airway, following settings were used for maintenance; Mode: AGC™; Gas mixture 0_2/Air; Fi0_2 of 50%; and target end-tidal Sevoflurane of 2.0%, FGF and Sevoflurane supply was automatically adjusted by machine. (Figure 1) In Group B, once airway is secured following settings were used for maintenance; Mode: Manual; Gas mixture 0_2/Air; Fi0_2 of 50%, FGF 1 L/min. Sevoflurane supply was adjusted manually to achieve end-tidal Sevoflurane of 2.0%. (Fig. 2) These settings in both

groups were continued till conclusion of surgery and then changed to FiO_2 100%, Sevoflurane turned off and FGF was increased to 10 L/min till extubation. Data was analyzed using SPSS V 20.0. Chi Square test and Student t test were used to analyze the nominal and numerical data. P value < 0.05 was considered significant.

Figure 1AGC™ Mode

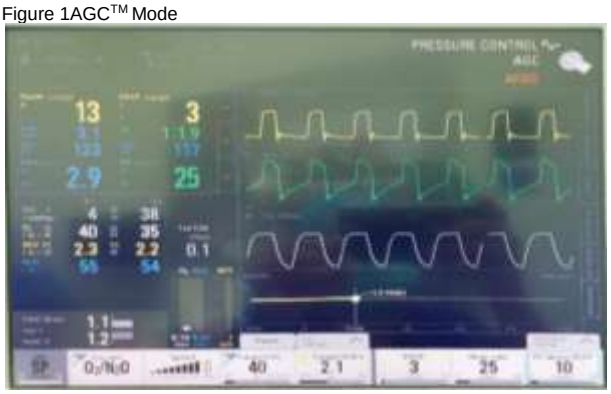
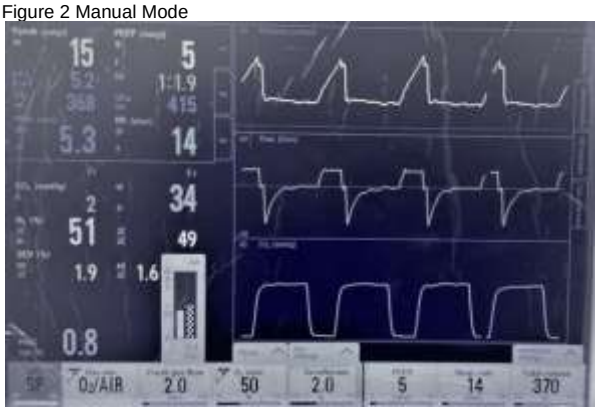


Figure 2 Manual Mode



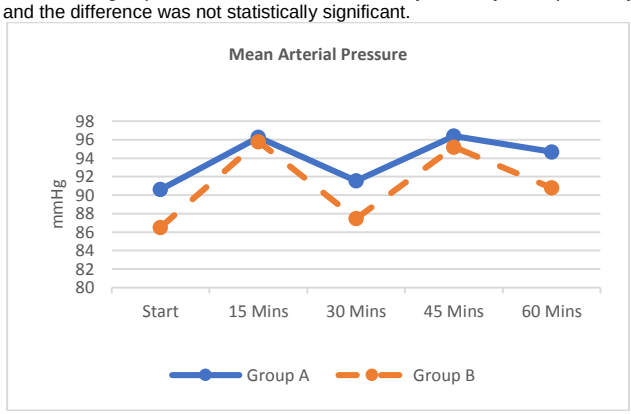
RESULTS

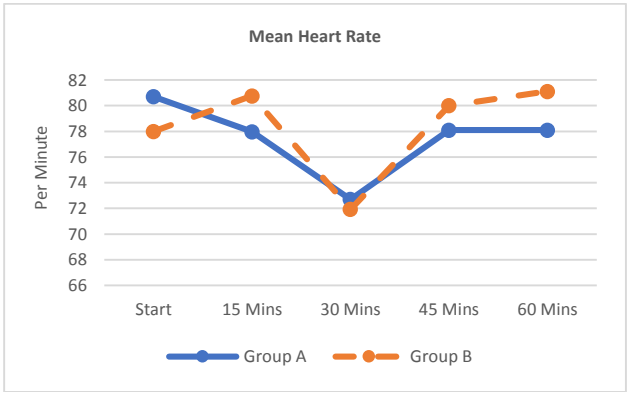
The mean age of patients in group A was 39.20+9.9 years while it was 36.73+9.7 years in group B. There was a predominance of females (63.3% vs 53.3%) than males (36.7% vs 46.7). Both groups were comparable in terms of BMI (24.7+2.8 Vs 25.9+3.5 Kg/m2). Hypertension and diabetes were common comorbidities present in patients of both groups. Both groups were comparable in terms of the mean duration of the case (97.3+10.5 min and 95.4+9.8 min). Similarly, the Inhalational agent delivery time was 85.1+10.1min in Group A as compared to 86.7+9.5 min in Group B. The demographics are shown in table 1.

Table 1: Demographics

	Group A (n=30)	Group B (n=30)	P Value
Age (mean + SD)	39.20 + 9.9	36.73 + 9.7	0.861
Male Female	11 (36.7) 19 (63.3)	14 (46.7) 16 (53.3)	0.297
BMI (Kg/m^2)	24.7 + 2.8	25.9 + 3.5	0.772
Comorbidities n (%) None Hypertension Diabetes CKD	18 (60.0) 7 (23.3) 5 (16.7) 0 (0.0)	24 (80.0) 3 (10.0) 2 (6.67) 1 (3.33)	0.243
ASA n (%) I II	 18 (36.7) 12 (63.3)	 14 (46.7) 16 (53.3)	0.297
Duration of surgery (Min)	97.3 + 10.5	95.4 + 9.8	0.481
Inhalational Agent Delivery Time (Min)	85.1 + 10.1	86.7 + 9.5	0.808

Graph 1 represents compares the mean arterial pressure (MAP) and heart rate of both groups. Patients were similar hemodynamically intraoperatively and the difference was not statistically significant.





Difference between mean sevoflurane consumption was significant (23.92+4.6ml vs 40.23+4.4ml, P=0.001). Sevoflurane consumption rate was also significant (Table 2).

Table 2 – Sevoflurane consumption

	Group A (n=30)	Group B (n=30)	P Value
Sevoflurane consumption (ml)	23.92+4.6	40.23+4.4	0.001
Sevoflurane consumption rate (ml/min)	0.28+0.04	0.47+0.02	0.001

DISCUSSION

The economical and eco-friendly technique of inhalational agent utilization has always strived. One of the techniques is to use low fresh gas flow to reduce inhalational agent consumption during general anesthesia[9]. Advancement in technology has modernized of inhaled anesthesia delivery system and revolutionized conventional flow over vaporizers to electronic vaporizers. These electronic vaporizers are equipped with advanced safety features that deliver inhalational agents in a precisely controlled way even with low fresh gas flow[10,11].

The results of our study reveal significantly low sevoflurane consumption in AGC™ group as compared to manual mode (23.92 + 4.6 ml Vs 40.23+4.4ml; P 0.001). These findings are comparable to Moran et al[12] reported similar results comparing manual and AGC™ in pediatric anesthesia. Sevoflurane consumption was significantly lower in AGC™ (median 0.46, IQR 0.32-0.72 mL/min) than manual mode (0.82, IQR 0.62-1.17 mL/min; P < 0.001). In addition, there was 33% reduction in sevoflurane utilization rate (0.81 ml/min vs 0.54 ml/min, P < 0.001). Lortat-Jacob et al[13] reported a 65% decrease of inhalational agent usage when comparing automated to manually controlled anesthesia using Zeus® anesthesia machine (0.07 ml/min vs 0.20 ml/min).

Lucangelo et al[14] compared manually controlled mode with end-tidal-controlled for anaesthetic consumption. The was no significance in sevoflurane delivery (17ml vs 15ml, p>0.05) or sevoflurane consumption rate (0.12 ml/min vs 0.11 ml/min, p >0.05) and target end tidal agent (sevoflurane 1%) was achieved quickly in manual mode. (71 sec vs 145 sec, P=0.00001). This difference could be due to the use of different anesthesia machine.

Kalmar at al[8] reported 17% lower consumption AGC® mode as compared to minimal flow group (5 ml versus 6.02 ml, P=0.001). This sevoflurane utilization is dependent on speed of induction with AGC® mode and increase up to 21% from speed 2 to speed 8. Rapid achievement of target concentration not always beneficial as can lead to hemodynamic instability, lower speed effectively achieves smooth and economical induction. Over the period of years, software versions of AGC have a steady trend of improvement, as sevoflurane utilization has decreased at speed than earlier studies.

There are environmental benefits to low consumption of inhalational agents. Inhalational anesthetic agents are minimally metabolized in the body and are released in the atmosphere. This property poses a risk of occupational hazard for healthcare workers. This unique chemical nature makes them stable in the atmosphere which causes a greenhouse effect[15]. About 27% reduction in cost and 44% reduction in greenhouse gas emission has been reported by Tay et al using automated control as compared to manual mode at the Northern Hospital, a university teaching hospital in Melbourne, Australia[16]. Because of its detrimental effect on the environment, anesthetist have an important responsibility to implement policies, techniques, and research to minimize the utilization and release of inhalational agents into the atmosphere[17]. AGC has a financial benefit as well with Maquet flow-I anesthesia machine. The decrease sevoflurane consumption reduces cost of purchasing it as well as additional benefits of low oxygen utilization. This mode allows majority of exhaled gas to be rebreathed after carbon dioxide removal[18].

There are certain limitations to our study. First, we did not determine the time to reach the target end-tidal concentration. It not only gives us insight into induction and maintenance time but also impacts inhalation agent consumption by using a high initial dial setting in manual mode. Second, we used only sevoflurane and further studies are required to assess the AGC™ mode using different inhalational agents.

Author contributions: M.J.: Study design and approval, data collection, manuscript editing, **S.S.:** Conception of the study, results, and analysis, writing literature review and methodology, **SH.:** Data collection, discussion writing, **HAB.:** Data collection, manuscript overview, **AUH.:** Supervision, critical review of manuscript

Conflict of interest: None

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