Environmental And Economic Impact of Using A Higher Efficiency Ventilator And Vaporizer During Surgery Under General Anesthesia: A Randomized Controlled Prospective Cohort

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Abstract

Background: Compared to traditional breathing circuits, low-flow anesthesia machines utilize a low-volume breathing circuit system by injecting volatile agent into the circuit mainly during inspiration. We aimed to assess whether Maquet Flow-i C20 anesthesia workstation delivers volatile anesthetic more efficiently than a GE Aisys CS^2 during elective general surgery.

Methods: Eligible candidates enrolled in the study (2014-1248) met the following inclusion criteria: 18 – 65 years old, scheduled for surgery requiring general anesthesia at UC Irvine Health, and expected to receive sevoflurane for the duration of the procedure. Exclusion criteria: < 18 years old, history of COPD, cardiovascular disease, sevoflurane sensitivity, BMI > 30 kg/m^2, ASA > 2, pregnant, or surgery scheduled < 120 minutes. We calculated the total amount of sevoflurane delivered and consumption rates during induction/maintenance periods and compared the groups using parametric testing (Student's t-Test).

Results: In total, 103 subjects (Maquet: n=52, GE: n=51) were analyzed. Overall, the Flow-i C-20 group consumed significantly less sevoflurane (95.5 ± 49.3 g) compared to the $Aisys^2$ (118.2 ± 62.4 g) (p = 0.043 for group difference) corresponding to an approximately 20% efficiency improvement in overall agent delivery. When accounting for the fresh gas flow setting, agent concentration and length of induction, the Maquet machines delivered volatile agent at a significantly lower rate compared to the GE devices (7.4 ± 3.2 L/min vs. 9.2 ± 4.1 L/min; p = 0.017). Based on these results, we estimate that the Maquet Flow-i workstations can save an estimated average of $239,440 over the expected 10-year machine lifespan. This 20% decrease in CO_2 equivalent emissions corresponds to 201 metric tons less greenhouse gas emissions over a decade compared to the GE Aisys; equivalent to 491,760 miles driven by an average passenger vehicle or 219,881 pounds of coal burned.

Conclusions: Overall, our results from this pilot study suggest that the Maquet Flow-i delivers significantly less (~20%) volatile agent during routine elective surgery using a standardized anesthetic protocol compared to a traditional anesthesia system. The results demonstrate a strong opportunity for economic and environmental benefits if implemented across other medical institutions.

Introduction

Contributions to global warming in the form of greenhouse gas (GHG) emissions trace back to all specialties in the healthcare industry, and medical institutions have an opportunity to implement measurable improvements. In the context of perioperative care, general anesthesia administration during elective surgery is an ideal environment in which to exact meaningful change. Broadly speaking, the body metabolizes a small fraction of volatile anesthetic agent,(1–5) while the exhaled waste vents into the environmental atmosphere. One report calculated that the equivalent impact of anesthetic gases emitted by the researchers' institution corresponds to about one-third of the climate impact of that facility's use of electricity and district heating(6). The type of volatile anesthetic (desflurane, isoflurane, and sevoflurane) used during general anesthesia has an amplified effect on the atmosphere. For example, volatile agents

used in standard care: desflurane, isoflurane, and sevoflurane have a 20-year Global Warming Potential index (GWP_{20}) of 6810, 1800, and 440 respectively(7, 8). These values correspond to an atmospheric lifetime (years): Desflurane: 14, Isoflurane: 3.2, and Sevoflurane: 1.1 which provoked institutions such as the American Society of Anesthesiologists (ASA) to recommend utilizing low fresh gas flows during maintenance phase of procedures(5). Over time, the scientific community has reinforced the legitimacy of these recommendations resulting in a shift from desflurane to sevoflurane from 2012 to 2016(7). This shift in practice, combined with an efficient anesthesia delivery system, has environmental and economic benefits worth utilizing in the clinical workspace. While sustainable practice changes can be financially burdensome(9), the cost savings over time associated with an efficient volatile delivery system can be a worthy investment for medical institutions compared to traditional anesthesia systems.

Given the complexity of elements required to improve the efficiency of care in an operating room, we distilled our investigation down to whether utilizing a low-volume ventilator (Maquet Flow-i) in an anesthesia machine uses significantly less volatile agent compared to traditional high-volume system (GE Aisys). Since a choice in the anesthesia machine has a theoretical economic and environmental benefit, we sought to compare how the two devices perform during routine elective general surgery in patients receiving general anesthesia with sevoflurane. We hypothesized that the amount of anesthetic agent delivered by the Maquet device would be significantly lower than that of the GE device at equivalent volatile concentration and flows.

Methods

With institutional review board approval at the University of California Irvine Medical Center (HS#2014 – 1248), the research team screened for potential candidates using the surgical schedule from February 2018 – June 2019. The eligibility criteria included subjects 18–65 years old scheduled to receive general anesthesia with sevoflurane. An ineligible subject met the following exclusion criteria at the time of consent: a medical history of Chronic Obstructive Pulmonary Disease, a Body Mass Index (BMI) greater than 30, an American Society of Anesthesiologists (ASA) physical status classification greater than 2, a pregnant female, procedures scheduled less than 2 hours, a known sensitivity to sevoflurane, a known/suspected susceptibility to malignant hyperthermia, or severe cardiovascular disease with a left ventricular ejection fraction (LVEF) less than 30%. Subjects were randomized by recruitment day into either the Maquet Flow-i group (MQ) or the GE Aisys group (GE). It was not feasible to blind anesthesia providers and investigators collecting intraoperative data due to the physical differences in machines. This manuscript was drafted in compliance with the applicable CONSORT guidelines.

Anesthetic Management

All subjects received routine pre-operative care (intravenous access, midazolam administration, etc.), while the research team coordinated with the anesthesia technician team to provide two sevoflurane cassettes/vaporizers. Since the GE Aisys delivery system only allows one volatile agent cassette to be loaded at a time, the research team elected to exchange cassettes during steady state conditions (at first

incision) to distinguish agent delivered during the induction and maintenance period. Meanwhile, the Maquet device allows two vaporizers to be loaded simultaneously and enables switching through the device interface. The study team pre-filled and weighed the two cassettes/vaporizers to avoid disrupting the clinical workflow during the switching process. Additionally, the research team reviewed the standardized anesthetic management guidelines with the anesthesia provider prior to operating room transport.

Upon subject arrival in the operating room, the anesthesia provider followed the intraoperative setup procedures (patient transfer, monitor placement, etc.) while the research team logged the time and order of the induction period (propofol administration, intubation, etc.). The research protocol used 15 L/min fresh gas flow during induction phase — to standardize flow rates in both arms of the study — and tidal volumes of 6–8 mL/kg ideal body weight, with a PEEP of 6 centimeters of water (cm H_2O). After reaching steady state conditions (first incision) of volatile anesthetic delivery, the anesthesia provider lowered the fresh gas flow to 2 L/min in maintenance phase and switched to the secondary cassette/vaporizer. During emergence, the research team continued to log key time points during the weaning period (decreasing concentration of anesthetic agent, flow rates, and extubation).

Data Collection

Aside from the randomization to group, there were no changes to the surgical or anesthetic procedures. It was deemed infeasible to randomize machine upon room entry due to patient safety concerns and operating room inefficiency.

The research team collected data intraoperatively, as well as collected data exported from the anesthesia device (Maquet) using a Universal Serial Bus (USB) drive at the end of the case, and lastly extracted preoperative data via chart review of the hospital's electronic medical record. The collected endpoints included age, sex, height, weight, BMI, procedure name, ASA status, randomization (GE or Maquet), and significant anesthetic time points (e.g. induction, intubation, weaning, extubation, and Aldrete > 8). The research team recorded any changes in device settings by the provider and measured values which include: ventilator setting, tidal volume (TV), respiratory rate (RR), positive end-expiratory pressure (PEEP), CO_2 and O_2 settings (ET/Fi), O_2 %, fresh gas flow (FGF), volume % gas, end tidal %, time of intubation, incision, extubation, the calibration weight, and the anesthetic agent cassette/vaporizer. The research team measured the weight of each gas cassette using a 0.1 g precision scale at three different times: before induction, at first incision, and after volatile agent cessation. Additionally, a team member tracked the following time points intraoperatively: intubation (T_0), incision (T_1), and weaning (T_2).

Outcomes and Definitions

Our primary purpose centered on evaluating the Maquet anesthesia workstation in regard to savings of volatile agent compared to conventional machines. The primary endpoint was consumption of volatile anesthetic over the duration of the surgical case measured in grams of agent. Secondary endpoints included gas vaporized per minute during the individual induction and maintenance phases, the length of

time to reach Aldrete > 8, time to extubation from weaning, and Maquet firmware-based volatile anesthetic consumption data.

To calculate the consumption rates, we compared anesthetic consumption during the wash-in period (T_0-T_1), at steady state maintenance of anesthetic depth (T_1-T_2), and total comparative anesthetic consumption (T_0-T_2). Additionally, we calculated the rate of volatile agent delivered (g / (% Anesthetic Agent Setting • Fresh Gas Flow • Time) during the induction and maintenance period to account for any variations during said time intervals.

Statistical Analysis

With a power of 0.8 (20% type II risk), a significance level of 0.05 (type I risk of 5%),and using a one-sided t-test to compare groups, we calculated two groups of 55 patients (n = 110 total) in each group – Maquet Anesthesia Machine or GE Anesthesia Machine– to detect a 25% difference in sevoflurane delivered. An additional 11 subjects (10% attrition rate) were included to the target sample size to account for unforeseen circumstances leading to an exclusion i.e. mechanical failure, incomplete data, different anesthetic device etc. Group data are summarized as mean ± standard deviation, or as counts and percentages as appropriate. Parametric testing (Student's t-Test) was performed between groups using Rstudio (www.rproject.org) to compare the primary/secondary endpoints. Based on our calculations and local cost of sevoflurane, the Maquet machine must use 25% less sevoflurane in order to fully replace its acquisition expense during the expected service life. With a per-case cost of $9.60 ± 5.00 for the conventional group, we calculated 55 subjects in each group to have sufficient power to differentiate whether the Maquet group has a cost of $7.20 ± 5.00 per case (assuming equal case variance for this group).

Results

Case Information

110 consented patients participated in the study – seven subjects were excluded due to unforeseen circumstances in the clinical workflow (e.g. a change in anesthetic preference, canceled surgery, etc.) leaving 103 subjects (Maquet: n = 52, GE: n = 51) for analysis. Patient and case demographics are shown in **Table 1.**

Table 1

Back to top: A summary of the subject profile (Mean ± Standard Deviation) included for analysis.

Demographics of Enrolled Subjects		
n = 103	**MQ**	**GE**
Subject Sex		
Female	35	29
Male	17	22
ASA Status		
ASA 1	6	8
ASA 2	46	43
Age (yrs)	42 ± 14	44 ± 13
Height (cm)	167 ± 11	169 ± 10
Weight (kg)	71 ± 12	70 ± 13
BMI (kg/m^2)	25 ± 3.0	24 ± 3.1
Total Case Length (min)	210 ± 122	236 ± 125
Induction Length (min)	27.0 ± 13.3	35 ± 14.2
Case Type		
General	12	18
Gynecology	18	5
Ophthalmology	2	2
Orthopedics	6	12
Otolaryngology	0	1
Plastics	6	7
Urology	8	6

Primary Outcome - Agent Consumption

The Maquet anesthesia machines consumed significantly less total inhalational anesthetic compared to the GE machines across the entire case duration (95.45 ± 49.3 vs. 118.3 ± 62.3; p = 0.043) (g). During the induction phase (the start of inhalational anesthetic delivery to first incision), the Maquet anesthesia machines used significantly less inhalational anesthetic compared to GE machines (24.3 ± 12.1 vs. 40.0 ± 34.6; p-value = 0.0031). However, during the maintenance phase – the time interval from first incision to

when volatile agent is turned off — there was not a significant difference between the amount of inhalational anesthetic delivered (71.2 ± 46.9 vs. 78.2 ± 47.0; p = 0.45) in either group, using our study design and conditions.

Rate of Inhalational Anesthetic Delivery

Despite randomization, the length of induction period was shorter in the cases with the Maquet compared to the GE device.

In order to correct for this, consumption per minute was also calculated (**Table 2**). When correcting for induction period length, the Maquet machines again used significantly less gas compared to the GE machines (0.9 ± 0.4 vs. 1.2 ± 1.0; p = 0.017) (g/min) (**Fig. 1**). Again, there was not a significant difference in agent delivered during the maintenance time interval between the Maquet and GE machine (0.4 ± 0.1 vs. 0.4 ± 0.1; p = 0.79).

Table 2

Back to top: A summary of the average (Mean ± Standard Deviation) amount of volatile agent, rate delivered per case, estimated cost per case, and time to reach recovery milestones.

Endpoints	MQ	GE	P-Value
Primary Endpoints			
Agent Delivered (g)			
Induction	24.3 ± 12.1	40.0 ± 34.6	0.003
Maintenance	71.2 ± 46.9	78.2 ± 47.0	0.45
Total	95.5 ± 49.3	118.3 ± 62.4	0.043
Rate Delivered (g/%Agent*FGF*min)			
Induction	7.4 ± 3.2	9.1 ± 4.1	0.017
Maintenance	7.5 ± 3.075	7.5 ± 2.1	0.98
Total Agent Cost ($)	27.3 ± 14.1	33.7 ± 17.8	0.043
Secondary Endpoints			
Wean - Extubation (min)	10.4 ± 6.3	10.8 ± 6.4	0.74
Aldrete > 8 (min)	98.1 ± 51.8	89.2 ± 52.1	0.38

Further, we evaluated the consumption taking into account both induction period length, the actual fresh gas flow rate, and the agent vaporizer % setting: (g / (% Anesthetic Agent Setting • Fresh Gas Flow • Time). When accounting directly for these factors, the Maquet anesthesia machines delivered volatile

agent at a significantly lower rate compared to the GE machines (7.4 ± 3.2 vs. 9.2 ± 4.1; p = 0.017). There was no difference in the rate of delivery between the two anesthesia machines during the maintenance phase (7.5 ± 3.1 vs. 7.5 ± 2.1; p = 0.98).

Cost Savings

The cost (USD: $) of inhalational anesthetic per case with the Maquet machine based on the per-minute consumption was significantly less compared to the GE machines (27.25 ± 14.07 vs. 33.74 ± 17.80; p = 0.043). In other words, surgical procedures performed with Maquet devices are approximately 20% more cost efficient compared to GE anesthesia machines with respect to inhalational anesthetic expense **(Fig. 2)**.

Secondary Endpoints

There was no significant difference between the Maquet and GE anesthesia machine when evaluating the time (minutes) from weaning to extubation (10.4 ± 6.3 vs. 10.8 ± 6.4; p = 0.74) or recovery milestones – Aldrete Score > 8 – (98.1 ± 51.8 vs. 89.2 ± 52.1; p = 0.38).

Discussion

Overall, our results from this pilot study suggest that a low flow anesthesia machine (Maquet Flow-i) delivers significantly less (~ 20%) volatile agent compared to conventional device (GE Aisys) during routine elective surgery using a standardized anesthetic protocol. A closer look suggests that this distinction is more clearly defined in the induction period; however, the study may not be sufficiently powered to detect a difference during the maintenance phase within the statistical parameters of the study. These results warrant further investigation to evaluate whether a broader trend of more efficient agent delivery correlates with utilization of a low flow device on a large scale. Additionally, while we did not observe a significant difference in the secondary outcomes, e.g. time to wean, extubation etc., the benefits of low blood and tissue solubility during low and minimal flow invites further study.

A post-hoc analysis, accounting for the published specific gravity of sevoflurane (1.5203 g/mL)(10), suggests that based on the average cost savings per case, a Maquet anesthesia machine using only sevoflurane can reasonably replace its acquisition cost within its expected service life (**Fig. 3**). For example, at a median usage of 5.5 cases/day [3.3, 7.8] over 5.0 years [3.5, 8.5], it is reasonable to assume the savings may enable an institution to purchase another machine. Granted, this cost savings analysis does not account for other maintenance related costs. It also does not factor in the use of volatile agents other than sevoflurane. If desflurane were to be used as the sole volatile anesthetic, the Maquet anesthesia machine would pay for itself after a median caseload of 5.5 cases/day [3.3,7.8] in 3.0 years [2.1, 5.1]. A significant portion of the improvements were present in induction phase; therefore, it is reasonable to assume that high turnover procedural cases could benefit even more from this technology(**Fig. 4**).

To put the sevoflurane usage reduction found in this study in the larger context, over the course of one year in a surgical facility with 20 operating rooms performing 5.5 cases per day, the total difference in greenhouse gas production between the two anesthesia machines would be approximately 402.26 metric tons of CO_2(10, 11). This is equivalent to the greenhouse gas production from an average passenger vehicle driven 983,521 miles, the CO_2 emissions from 48.2 homes' energy use for one year, or the greenhouse gas emissions avoided by 140 tons of waste recycled instead of landfilled(12). By extension, the potential for reduced environmental impact is much greater on the national and global scales. Sulbaek Andersen and colleagues estimate that the annual anesthetic emissions in the United States and worldwide is equivalent to CO_2 emissions of 660,000 metric tons and 4.4 million metric tons, respectively(13). Theoretically, global adoption of anesthetic-sparing machines could represent a decrease of 127,050 metric tons of CO_2 within the US and 847,000 metric tons of CO_2 globally. This would be equivalent to eliminating the annual CO_2 emissions from 26,975 to 179,830 standard passenger vehicles.

Of course, it is important to view the environmental impact of anesthetic agents in the global context of total greenhouse gas emissions. By one estimate, the total contribution of waste anesthetics to climate change is approximately 0.01% of that produced by worldwide fossil fuel combustion(8). While the impact of inhaled anesthetics may appear small in the global context, it is important to not dismiss them simply because they are medically essential agents. Rather, these data can aid anesthesiologists and surgical institutions in making informed medical and business decisions that are in agreement with their ethical, professional, and environmental values. We also recognize that our protocol speaks to only one facet of environmental impacts as it relates to volatile agent delivery and not a full life cycle assessment of carbon footprint in the larger context. However, our results resonate with the growing support that anesthesia providers should avoid unnecessarily high fresh gas flow rates for all inhaled drugs(1, 14) and employ technologies that are more efficient.

A separate study indicated that the average amount of sevoflurane wasted by inserting or removing the cassette for the Aisys and FLOW-i corresponded to 0.21 and 0.04 mL of liquid agent respectively. This difference was not large enough to decrease the average amount of sevoflurane wasted during machine checkout with the Aisys and FLOW-I were 1.78 and 1.67 mL respectively(14) within the statistical parameters of the study. After evaluating the difference in weighted measurement and device calculation, we found there was not a significant difference between the physical measurement (mL) and the internal calculated amount of agent used (62.8 ± 32.4; 62.1 ± 34.2; 95% CI: -13.65, 12.29; p = 0.9175) for the Maquet Flow-i. These results suggest that the device's internal calculation of volatile agent delivered are valid.

Limitations

We acknowledge several limitations to the study. These include – but are not limited to – the following: a small overall sample size, fluctuations in the concentration of volatile agent setting or fresh gas flow (due to positioning during surgical preparation), and variations in time precision provider charting of the

secondary endpoints (weaning, gas off, time in recovery, recovery criteria completion). The protocol procedures were standardized across both devices, however there are factors such as lack of blinding that the authors could not feasibly account for and should be taken into consideration when drawing conclusions from these data.

Conclusions

With the growing coalition aimed at addressing climate change, our results support the idea that a low-volume anesthetic machine (Maquet Flow-i) significantly reduced volatile anesthetic agent consumption by 20% compared to a traditional system (GE Aisys) during surgery. Further studies should investigate the environmental impact when implemented on a larger scale. We argue that the modern healthcare team should be cognizant of the environmental implications of medically necessary care and open toward investing in anesthesia machine technology aimed at delivering cost efficient and quality care.

Abbreviations

chronic obstructive pulmonary disease (COPD), American Society of Anesthesiologists (ASA), greenhouse gas (GHG), global warming potential (GWP), left ventricular ejection fraction (LVEF), positive end expiratory pressure (PEEP), tidal volume (TV), respiratory rate (RR), fresh gas flow (FGF), University of California (UC), Institutional Review Board (IRB), General Electric (GE), Body Mass Index (BMI)

Declarations

Ethics approval and consent to participate:

This study was approved by the local institutional review board at the University of California Irvine Medical Center (HS# 2014-1248). Written consent was obtained from study participants before research procedures to place.

Consent for publication:

Not applicable

Availability of data and materials:

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request

Competing interests:

The authors declare that they have no competing interests

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Authors' contributions:

RF, Lead Researcher responsible for overseeing all aspects of the study which include: access to identifiable data, patient recruitment/consenting, research procedures, analysis and manuscript drafting/revisions.

MC, Clinical Researcher involved with patient recruitment, data acquisition, analysis and manuscript drafting/revisions.

SR, Medical Student involved with primary literature review, data analysis, manuscript drafting/revisions.

MM, Clinical Researcher involved with patient recruitment, data acquisition, analysis and manuscript drafting/revisions.

HM, Clinical Researcher involved with patient recruitment, data acquisition, analysis and manuscript drafting/revisions

PM, Clinical Researcher involved with patient recruitment, data acquisition, analysis and manuscript drafting/revisions

JR, Co-Researcher responsible for supporting all aspects of the study which include: access to identifiable data, patient recruitment/consenting, research procedures, analysis and manuscript drafting/revisions.

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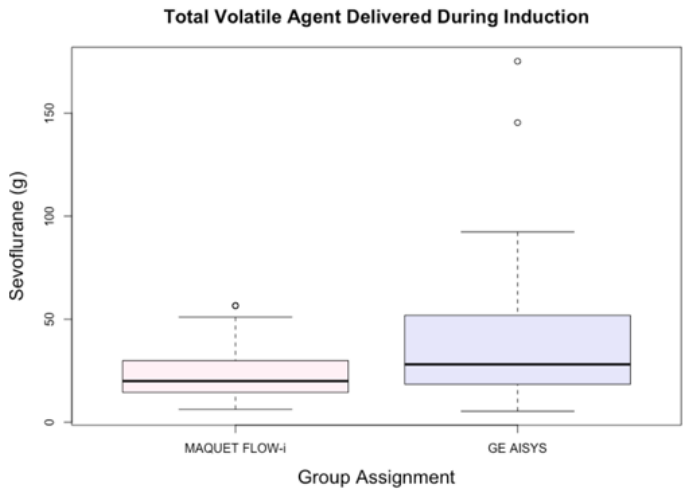
References

1. Sherman J, Le C, Lamers V, Eckelman M. Life Cycle Greenhouse Gas Emissions of Anesthetic Drugs. Anesth Analg [Internet]. 2012 May [cited 2019 Jul 30];114(5):1086–90. Available from: https://insights.ovid.com/crossref?an=00000539-201205000-00025
2. Yasny JS, White J. Environmental Implications of Anesthetic Gases. Anesth Prog. 2012;
3. Gadani H, Vyas A. Anesthetic gases and global warming: Potentials, prevention and future of anesthesia. Anesth Essays Res. 2011;5(1):5.
4. Ryan SM, Nielsen CJ. Global Warming Potential of Inhaled Anesthetics. Anesth Analg. 2010;111(1):92–8.
5. American Society of Anesthesiologists Committee on Equipment and Facilities- Task Force on Environmental Sustainability. Greening the Operating Room and Perioperative Arena: Environmental Sustainability for Anesthesia Practice. Am Soc Anesthesiol [Internet]. 2014; Available from:

https://www.asahq.org/resources/resources-from-asa-committees/environmental-sustainability/greening-the-operating-room%0Ahttp://www.asahq.org/~/media/sites/asahq/files/public/resources/asa committees/greening-the-or2015.pdf

6. Clinical Innovation Poster Abstracts. Can J pain. 2020;4(2):A1–21.
7. Alexander R, Poznikoff A, Malherbe S. Greenhouse gases: the choice of volatile anesthetic does matter. Canadian Journal of Anesthesia. 2018.
8. Andersen MPS, Nielsen OJ, Wallington TJ, Karpichev B, Sander SP. Assessing the impact on global climate from general anesthetic gases. Anesth Analg. 2012;114(5):1081–5.
9. Charlesworth M, Swinton F. Anaesthetic gases, climate change, and sustainable practice. Vol. 1, The Lancet Planetary Health. Elsevier B.V.; 2017. p. e216–7.
10. Laster MJ, Fang Z, Eger EI. Specific Gravities of Desflurane, Enflurane, Halothane, Isoflurane, and Sevoflurane. Anesth Analg. 1994;78(6):1152???1153.
11. Campbell M, Pierce JMT. Atmospheric science, anaesthesia, and the environment. BJA Educ. 2015;15(4):173–9.
12. US EPA O. Greenhouse Gas Equivalencies Calculator [Internet]. United States Environmental Protection Agency. 2018 [cited 2019 Sep 11]. Available from: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator
13. Sulbaek Andersen MP, Sander SP, Nielsen OJ, Wagner DS, Sanford TJ, Wallington TJ. Inhalation anaesthetics and climate change. Br J Anaesth [Internet]. 2010;105(6):760–6. Available from: http://dx.doi.org/10.1093/bja/aeq259
14. Dehouwer A, Carette R, De Ridder S, De Wolf AM, Hendrickx JFA. Accuracy of inhaled agent usage displays of automated target control anesthesia machines. J Clin Monit Comput. 2016;30(5):539–43.

Figures



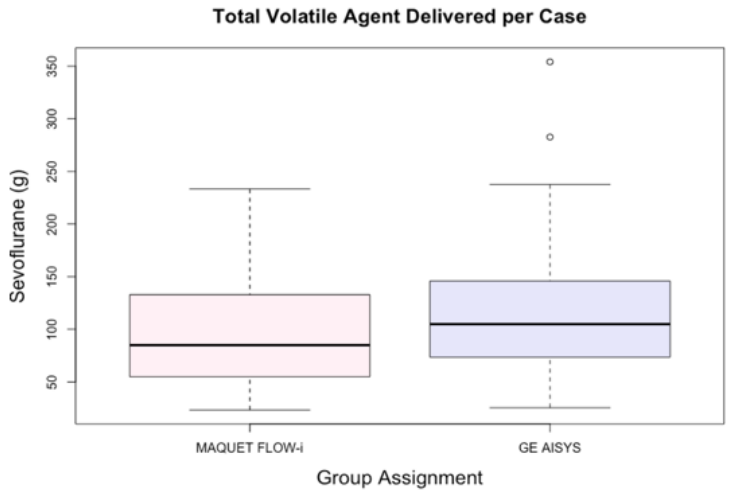


Figure 1

An illustration of the amount of sevoflurane delivered during the induction (24.26 ± 12.12 vs. 40.03 ± 34.61; p = 0.003) period and overall (95.48 ± 49.29 vs. 118.25 ± 62.38; p = 0.043) for both anesthesia machines (Maquet Flow-i & GE Aisys).

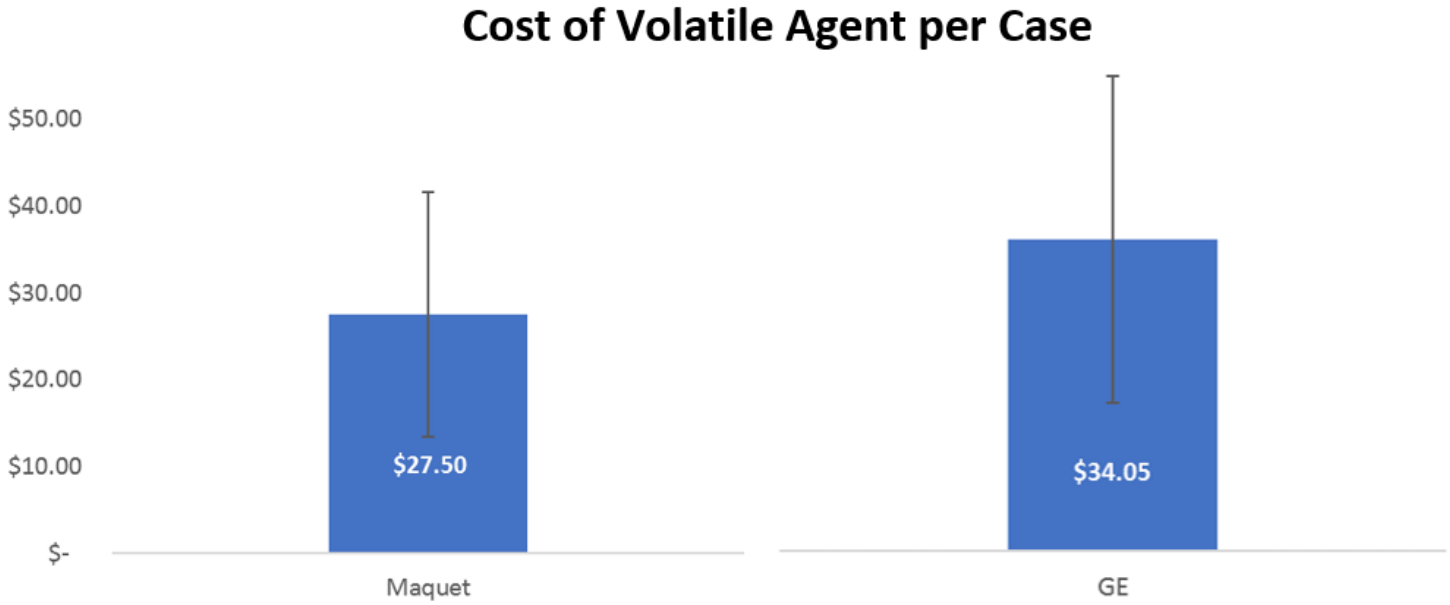


Figure 2

An illustration comparing the calculated cost of volatile agent (Sevoflurane) during cases with Maquet vs. GE ($27.25 ± $14.07 vs. $33.74 ± $17.80; p = 0.043).

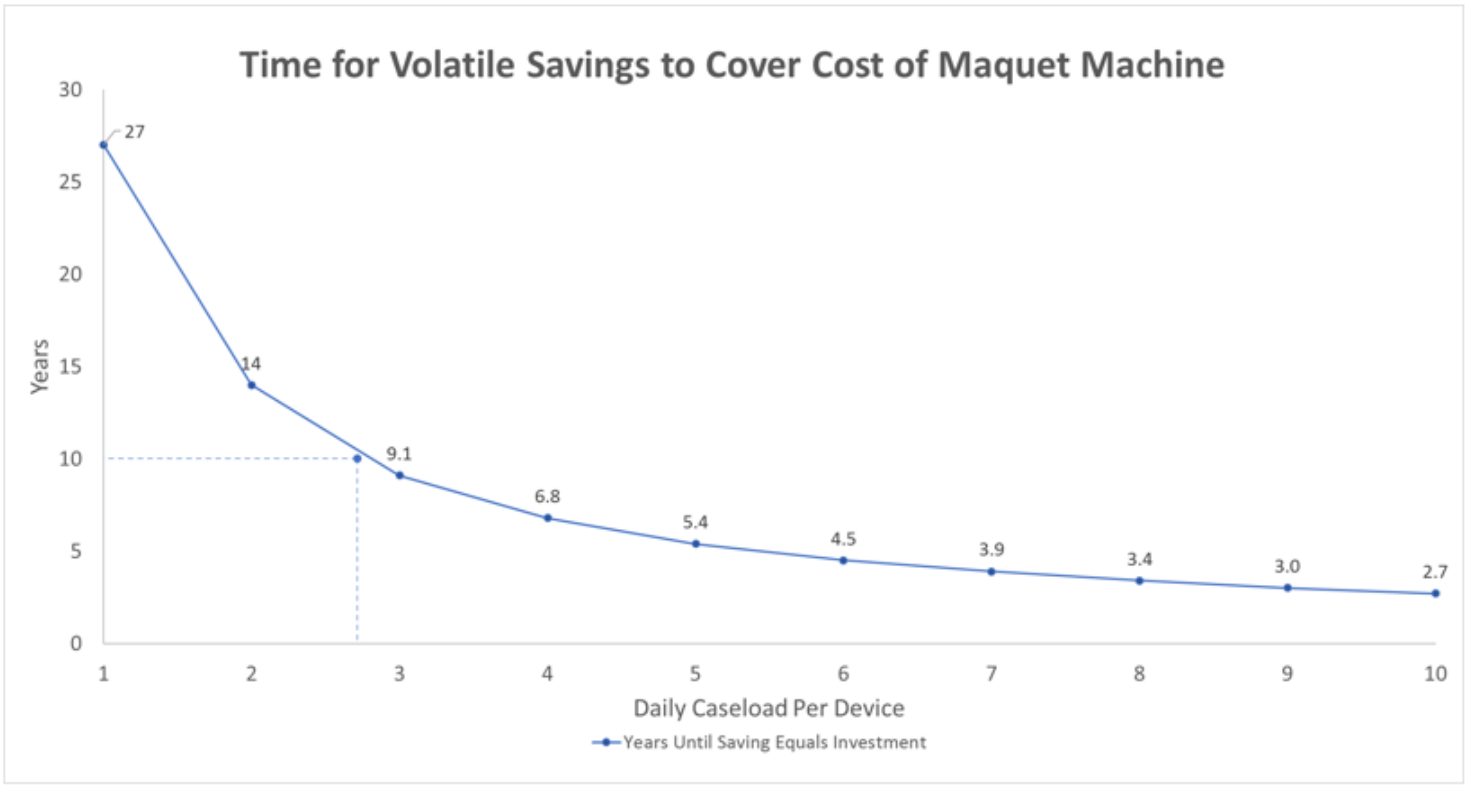


Figure 3

An illustration of the estimated daily caseload for the savings when using sevoflurane to equal the cost of the Maquet Flow-i. We estimate 2.7 cases per day would allow the device to pay for itself within the expected 10-year machine lifespan.

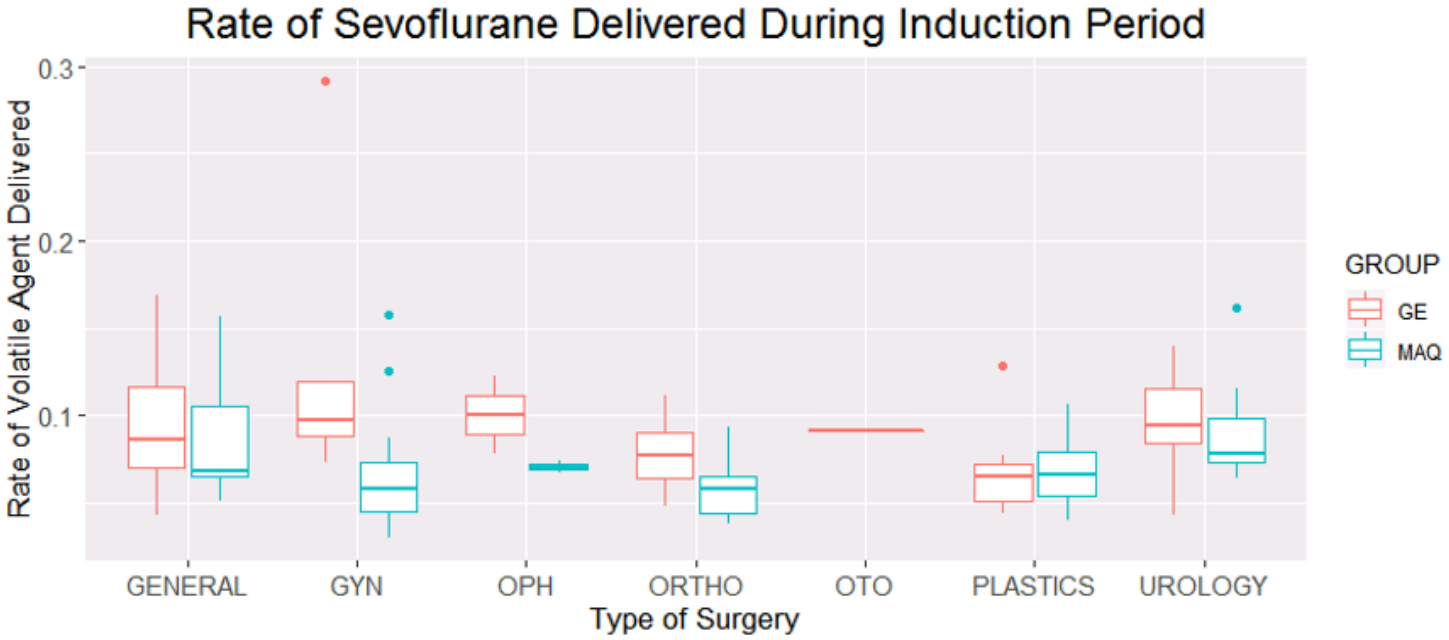


Figure 4

A visualization of the rate of volatile agent delivered during the induction period accounting for the fresh gas flow, agent concentration setting and length of induction (g / (% Anesthetic Agent Setting • Fresh Gas Flow • Time).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- CONSORT2010FlowDiagram.doc