Predictive Accuracy of Gas Man® Simulation Model in Datex Avance CS2 Anesthesia Work Station Using Low Flow Anesthesia with Isoflurane, Sevoflurane, and Desflurane

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ABSTRACT

Introduction: Gas Man® is a computer simulation program used for understanding the pharmacokinetics of volatile agents. On entering the patient details, fresh gas flow (FGF), volatile anesthetic concentration, and ventilatory details, it can predict the end-tidal concentration of volatile agents. ICOLLECT software is available for collection of real-time data from the workstation as well as hemodynamic parameters as it functions as a multichannel monitor. It is an electronic anesthetic record. We have used both these computer-based programs to study low flow anesthesia (LFA) in clinical practice.

Aims: The primary purpose of this study was to compare the expired volatile anesthetic concentrations predicted by the Gas Man® simulation model with those actually occurring during general anesthesia (GA) using isoflurane, sevoflurane or desflurane in clinical practice using low FGF.

Material and methods: Study area—the study was conducted in the Department of Anesthesiology, CARE Hospital, Hyderabad, Telangana, India. Study population—all patients who are posted for surgery under GA between the age groups 18–65 years, of either sex, and those belonging to the American Society of Anesthesiologists physical status I–II will constitute the study population. Sample size—a total of 30 patients undergoing GA with isoflurane, sevoflurane, and desflurane have undergone the validation trial using LFA. Our sample size calculation is based on a similar validation study. Study design—observational. Study duration—the proposed study was conducted over a period of 1 month (September 2016). Data collection techniques and tools—we collected relevant data directly from the Datex CS2 workstation via the ICOLLECT software for 30 anesthetics (isoflurane, sevoflurane, and desflurane) during the maintenance phase employing LFA. The measured concentration of volatile agent as well as the calculated concentration obtained by the Gas Man® equation were tabulated for each patient at 5-minute intervals. The performance error (PE), divergence, median predictive error, and wobble were determined for all three agents using the actual measured concentration end tidal agent against the predicted concentration. The statistics used for predicting the accuracy of volatile anesthetics uptake have been described by Varvel et al. Their model is based on those described for intravenous drug delivery systems. Multiple studies have validated this as a reliable model for predicting the accuracy of volatile anesthetics too. We calculated the median absolute performance error (MDAPE) median predictive error (MDPE) divergence, and wobble from the PE for all our cases. We calculated the MDAPE, MDPE, divergence, and wobble from the PE for all our cases.

Results: Mann–Whitney U test done for each study group demonstrated that there was no statistically significant difference between the median measured end-tidal concentrations of volatile agents versus that predicted by the Gas Man® anesthesia simulator. The three groups were similar with respect to the measured and predicted end-tidal concentration of the anesthetic agent. Kruskal–Wallis test was undertaken to study the intergroup variability with respect to measured and predicted end-tidal concentration of volatile agents. We obtained a p-value of <0.01, confirms a statistically significant difference between the three groups. This is expected as the minimum alveolar concentration (MAC) requirements of the three agents studied are different.

Discussion: In spite of the oversimplification of volatile kinetics, the Gas Man® simulation is an accurate predictor of the actual volatile agent's end-tidal concentrations achieved during LFA. It can serve as a useful educational tool for the implementation of LFA.

Conclusion: There is good correlation between measured and predicted end-tidal concentrations of all three volatile anesthetics during LFA.

Keywords: Desflurane, Gas man, ICOLLECT, Isoflurane, Low flow anesthesia, Sevoflurane.

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INTRODUCTION

- Gas Man® is a computer simulation program designed for understanding the pharmacokinetics of volatile agents. On entering patient details, FGF, volatile anesthetic concentration on the vaporizer, and ventilatory details, it can predict the end-tidal concentrations of volatile agents in steady state.1,2
- ICOLLECT software collect real-time data from the workstation. It is an electronic anesthetic record linked to the workstation which also records all vital parameters via a multichannel monitor. We have used both these computer-based programs to study LFA in clinical practice.

AIMS
The primary aim of this study was to compare the concentrations of expired volatile anesthetics predicted by the Gas Man® anesthesia simulator with concentrations occurring in real-time GA (isoflurane, sevoflurane, or desflurane) in clinical practice using low FGF.

MATERIAL AND METHODS

Study Area
The study was done in the Department of Anesthesiology, CARE Hospital, Hyderabad, Telangana, India.

Study Population
Our study population consisted of all adult patients (18–65 years) scheduled for elective surgical procedures under GA who belonged to the American Society of Anesthesiologists physical status I–II.

Sample Size
After a review of previous validation studies using LFA, we decided to enroll 30 patients undergoing GA with isoflurane, sevoflurane, and desflurane.

Study Design
Observational

Study Duration
The proposed study was conducted over a period of 1 month (September 2016).

Data Collection Techniques and Tools
We collected relevant data directly from the Datex CS2 workstation via the ICOLLECT software for 30 anesthetics (isoflurane, sevoflurane, and desflurane) during the maintenance phase employing LFA (Total gas flow 0.8–1 liter/minute).

The measured concentration of volatile agent as well as the calculated concentration obtained by the Gas Man® equation were tabulated for each patient at 5-minute intervals.

The PE, divergence, median predictive error, and wobble were determined for all three agents using the actual measured concentration (ET AGENT) against the predicted concentration. The acceptable values for these parameters are tabulated below (Table 1).

Varvel and colleagues have described the statistical methods involved in predicting the accuracy of volatile anesthetics uptake.9 Their model is based on those described for intravenous drug delivery systems. Multiple studies have validated this as a reliable model for predicting the accuracy of volatile anesthetics too. We calculated the MDAPE, MDPE, divergence, and wobble from the PE for all our cases.

RESULTS

- Demographics
- The three groups consisted of 10 patients; each was similar with respect to age and weight (Table 2 and Fig. 1).

Relationship between measured and predicted end-tidal concentrations of three volatile agents (isoflurane, sevoflurane, and desflurane) (Table 3).
- Test of significance (Mann–Whitney U Test) was conducted for the three groups, and we did not find a statistically significant difference in the measured and predicted median values of the three agents (Fig. 2).

Table 1: Values for MDPE, MDAPE, divergence, and wobble for all 30 cases, separated by the volatile anesthetic used

<table>
<thead>
<tr>
<th>Variables</th>
<th>Normal values</th>
<th>All cases (n = 30)</th>
<th>Isoflurane (n = 10)</th>
<th>Sevoflurane (n = 10)</th>
<th>Desflurane (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDPE (%)</td>
<td>−12–16%</td>
<td>−0.24 (5.19–4.72)</td>
<td>3.46 (11.74–4.82)</td>
<td>3.36 (2.93–9.11)</td>
<td>3.3 (3–4)</td>
</tr>
<tr>
<td>MDAPE (%)</td>
<td>11–24%</td>
<td>13.7 (10.6–16.8)</td>
<td>17.2 (11.7–22.7)</td>
<td>10.9 (8.5–13.4)</td>
<td>11 (5–15)</td>
</tr>
<tr>
<td>Divergence (%/h)</td>
<td>−17–2.9%/h</td>
<td>2.29 (3.95–8.53)</td>
<td>3.94 (6.48–14.4)</td>
<td>0.85 (6.7–8.4)</td>
<td>0.9 (5–10)</td>
</tr>
<tr>
<td>Wobble (%/h)</td>
<td>7–11.6%</td>
<td>3.96 (2.67–5.25)</td>
<td>3.98 (1.78–6.18)</td>
<td>3.75 (2.225–28)</td>
<td>2.9 (1–3)</td>
</tr>
</tbody>
</table>

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Conflict of interest: None
The three groups were similar with respect to measured and predicted end-tidal concentration of anesthetic agent (Table 4).

- Kruskal–Wallis test was undertaken to study the inter-group variability with respect to measured and predicted end-tidal concentration of volatile agents.
- We obtained a $p$-value of $<0.01$, which illustrates that there was a statistically significant difference between the three groups. This is expected as the MAC requirements of the three agents studied are different.

### Isoflurane

This is a graphical display of the measured and predicted end-tidal concentration of isoflurane on a linear time scale (Fig. 3).

### Sevoflurane

This is a graphical display of the measured and predicted end-tidal concentration of sevoflurane on a linear time scale (Fig. 4).

### Desflurane

This is a graphical display of the measured and predicted end-tidal concentration of desflurane on a linear time scale (Fig. 5).

We obtained an overall MDPE of $-0.24$, MDAPE of $13.7$, a divergence of $2.29$, and wobble of $3.96$. (from Table 1) All these values collectively, as well as individual agents, fall within acceptable limits.

### Discussion

- Our observational study consisted of 30 consecutive anesthetics with three commonly employed volatile anesthetics. No randomization was undertaken for sample selection. We analyzed these three groups and found them similar with respect to age and weight, as displayed in Table 2 and Figure 1.

![Fig. 1: Patient demographics (age, weight)](image)

**Table 2: Patient demographics (age, weight)**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Isoflurane</th>
<th>Sevoflurane</th>
<th>Desflurane</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>$138 \pm 10.03$</td>
<td>$41 \pm 8.41$</td>
<td>$45 \pm 7.61$</td>
</tr>
<tr>
<td>[mean ± standard deviation (SD)]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>$64 \pm 12.45$</td>
<td>$65 \pm 13.34$</td>
<td>$63 \pm 8.46$</td>
</tr>
<tr>
<td>(mean ± SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3: Relationship between measured and predicted end tidal concentrations of volatile agents**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Measured expired anesthetic agent concentration (%vol)</th>
<th>Gas Man predicted end tidal concentration (%vol)</th>
<th>$p$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>median (min-max)</td>
<td>median (min-max)</td>
<td></td>
</tr>
<tr>
<td>Isoflurane</td>
<td>$0.92 (0.88–0.97)$</td>
<td>$0.97 (0.86–0.98)$</td>
<td>$0.17$</td>
</tr>
<tr>
<td>Sevoflurane</td>
<td>$1.9 (1.8–1.97)$</td>
<td>$1.89 (1.85–1.96)$</td>
<td>$0.67$</td>
</tr>
<tr>
<td>Desflurane</td>
<td>$5.5 (5.4–5.9)$</td>
<td>$5.4 (5.4–5.8)$</td>
<td>$0.27$</td>
</tr>
</tbody>
</table>
• The Gas Man® simulation model has been used by investigators to prove that changing volatile agents at the end of surgery may not hasten recovery in patients (Neuman et al.).

• Screen-based simulation has been employed to study the differences and similarities between intravenous induction as compared to volatile agent-based induction of GA (Philip et al.). The importance of expired end-tidal concentration of volatile agents has been stressed by various investigators. The expired concentration of volatile anesthetic agent is a direct reflection of the level achieved within the target organ, that is, the human brain (Van Zundert et al.).

• To attain 1 MAC, isoflurane, sevoflurane, and desflurane end-tidal anesthetics concentration are 1.2, 2, and 6 vol%, respectively. This concept is demonstrated in Table 4 and Figures 3 to 5.

• Kruskal–Wallis test was undertaken to study the intergroup variability with respect to measured and predicted end-tidal concentration of volatile agents. We obtained a p-value of <0.01 for both measured

Fig. 2: Relationship between measured and predicted end tidal concentrations of volatile agents

![Graph 2](image)

Fig. 3: Graphically display of the measured and predicted end tidal concentration of isoflurane. Dotted line; measured end tidal anesthetic concentration. Continuous line: predicted end tidal anesthetic concentration

![Graph 3](image)

Fig. 4: Graphically display of the measured and predicted end tidal concentration of sevoflurane. Dotted line; measured end tidal anesthetic concentration. Continuous line; predicted end tidal anesthetic concentration

![Graph 4](image)

Fig. 5: Graphically display of the measured and predicted end tidal concentration of desflurane. Dotted line; measured end tidal anesthetic concentration. Continuous line; predicted end tidal anesthetic concentration

![Graph 5](image)

Table 4: Intergroup variability with respective to measured and predicted endtidal concentration of anesthetic agents

<table>
<thead>
<tr>
<th>Variable</th>
<th>Isoflurane</th>
<th>Sevoflurane</th>
<th>Desflurane</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expired</td>
<td>0.92 (0.88–0.97)</td>
<td>1.9 (1.8–1.97)</td>
<td>5.5 (5.4–5.9)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Predicted</td>
<td>0.97 (0.86–0.98)</td>
<td>1.89 (1.85–1.96)</td>
<td>5.4 (5.4–5.8)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>
and predicted tidal volatile agent concentrations. This implies that there is a statistically significant difference between the three groups. This is expected as the MAC requirements of the three agents studied are significantly different.

- Figures 3 to 5 illustrate the effect of high flow during induction for the first 15 minutes. There is a significant variation between the measured and predicted end-tidal concentration of volatile agents during this period. As time progress, the gap between the measured and predicted end-tidal concentration of volatile agents in the graph decreases. The equilibration of volatile agents is dependent on multiple factors. The 15–20 minutes of GA is needed to ensure that the expired concentration of the volatile agent is closer to the inspired concentration of the volatile agent; FGF can then be reduced to LFA recommendation for maintenance.

- Varvel et al. have described the statistics used for predicting the accuracy of volatile anesthetics uptake. Their model is based on those described for intravenous drug delivery systems. Multiple studies have validated this as a reliable model for predicting the accuracy of volatile anesthetics too. We calculated the MDAPE, MDPE, divergence, and wobble from the PE for all our cases.

**Conclusion**

Using the Gas Man® simulation model for calculating the predicted end-tidal concentration of the volatile agents is a reliable method for delivery of GA as it has a good correlation with the measured end-tidal concentration of isoflurane, sevoflurane, and desflurane during LFA.

**References**