Coasting : Worth the Effort ?

J. F. A. Hendrickx (*), S. De Cooman (**), A. A. J. Van Zundert (***) , R. E. J. Grouls (****), E. Mortier (******) and A. M. De Wolf (*******)

Abstract : A new anesthesia machine incorporates a “coasting mode”, but the extent to which a coasting technique can maintain anesthesia at the end of a procedure under optimal conditions (closed circuit anesthesia) remains unknown.

Sixty-nine patients undergoing peripheral or abdominal surgery were assigned to 1 of 9 groups, depending on when desflurane coasting (in O2/air) was started (after 4, 9, 16, 25, 36, 49, 64, 81, or 100 min). The end-expired desflurane concentration was maintained at 4.5% in O2/air prior to coasting with a conventional anesthesia machine. After initiating coasting (using a closed-circuit technique), we examined when the end-expired desflurane concentration reached 70, 60, 50, and 40% of its value during maintenance (= 30, 40, 50 and 60% decrement times, respectively).

Decrement times increased with increasing duration of anesthesia, and varied widely. After 64 min of maintenance anesthesia, the end-expired desflurane concentration remained at or above 70, 60, 50, and 40% of its maintenance value during 10.3 ± 2.3, 16.0 ± 3.5, 25.0 ± 5.9, and 45.4 ± 19.3 min, respectively (average ± standard deviation).

Coasting can briefly maintain anesthesia towards the end of a procedure. While savings with an automated coasting mode are likely to be modest per patient, they may become substantial when multiplied by the number of procedures per day per operating room with no increase in the clinical workload of the anesthesia provider.

Key words : Inhaled anesthetics ; pharmacokinetics ; closed-circuit anesthesia ; coasting.

BACKGROUND

Increasing concern about possible environmental effects of inhaled anesthetics has heightened interest in techniques that reduce anesthetic waste and thus pollution. Waste can be reduced by using lower fresh gas flows (FGFs). The use of lower FGFs, especially 500 ml or less per minute, is facilitated by the use of anesthesia machines that employ automated closed-loop end-tidal feedback control. The algorithms of these machines continuously and separately adjust the FGF and administration rate of potent inhaled agents to minimize the consumption of potent inhaled anesthetic with a speed and accuracy that is hard to match with a conventional anesthesia machine. The Zeus® (Dräger, Lübeck, Germany) strives to truly close the circuit most of the time, while the Aisys® (GE Healthcare, Madison, WI) strives to use minimal flow conditions (500 mL/min FGF) in its target control mode.

In the current manuscript, we explore the potential usefulness of a complimentary technique that has been recently added as an optional mode in the Aisys®: automated coasting. Coast ing is a technique that can be used towards the end of a procedure in the clinical workload of the anesthesia provider.

Jan F. A. Hendrickx, Staff Anesthesiologist, M.D., Ph.D.; Sofie De Cooman, Staff Anesthesiologist, M.D.; André A. J. Van Zundert, Professor, M.D., Ph.D.; René EJ Grouls, Hospital Pharmacist, Pharm.D., Ph.D.; Eric Mortier, Professor, M.D., Ph.D.; André M. De Wolf, Professor, M.D.

(*) Department of Anesthesiology, Intensive Care and Pain Therapy, Onze Lieve Vrouwziekenhuis, Aalst, Belgium.
(**) Department of Anesthesiology, Sint-Jan Hospital, Brussels, Belgium.
(***) Department of Anesthesiology, Intensive Care and Pain Therapy, Catharina Hospital, Eindhoven, The Netherlands.
(****) Department of Clinical Pharmacy, Catharina Hospital, Eindhoven, The Netherlands.
(******) Staff Anesthesiologist, University of Gent, Gent, Belgium.
(*******Department of Anesthesiology, Northwestern University Medical School, Chicago, Illinois.

Correspondence address : Jan F. A. Hendrickx, Department of Anesthesiology, Onze Lieve Vrouwziekenhuis, Aalst, Belgium; Department of Anesthesiology, Sint-Jan Hospital, Brussels, Belgium; the Department of Anesthesiology, Intensive Care and Pain Therapy, Catharina Hospital, Eindhoven, The Netherlands; and the Department of Anesthesiology, Northwestern University Medical School, Chicago, Illinois.

This work was performed at the Department of Anesthesiology, Intensive Care and Pain Therapy, Onze Lieve Vrouwziekenhuis, Aalst, Belgium; Department of Anesthesiology, Sint-Jan Hospital, Brussels, Belgium; the Department of Anesthesiology, Intensive Care and Pain Therapy, Catharina Hospital, Eindhoven, The Netherlands; the Department of Clinical Pharmacy, Catharina Hospital, Eindhoven, The Netherlands; and the Department of Anesthesiology, Northwestern University Medical School, Chicago, Illinois.

Patients were enrolled at the Onze Lieve Vrouwziekenhuis, Aalst, Belgium and the Catharina Hospital, Eindhoven, The Netherlands.

This work has been supported by Departmental funds only.

© Acta Anaesthesiologica Belgica, 2011, 62, n° 3
procedure to further reduce anesthetic agent waste. According to Lowe and Ernst’s original definition of coasting (1), the administration of an inhaled anesthetic is stopped a while before the anticipated end of surgery, and the circuit is closed. Because no gas will be able to escape via the pop-off valve, the only means for the partial pressure to decrease is by continued agent uptake in tissues that have not been saturated at the time coasting is started. Anesthetic vapor will redistribute from the saturated tissues (vessel rich group, and possibly muscle group depending on the duration of anesthesia prior to coasting) to tissues where the partial pressure of the vapor is still below that in the blood a the start of coasting (most likely the fat and again muscle group, depending on the duration of anesthesia prior to coasting). The end-expired partial pressure will then decrease so slowly that a level of anesthesia can be maintained that is sufficient to ensure optimal conditions for wound closure yet already allows the level of anesthesia to be slightly decreased in anticipation of wakening up the patient.

Coasting has been described theoretically by Lowe and Ernst more than 20 years ago, and the authors actually came up with a model that predicts coasting times (1). However, clinical interest has remained limited to a few closed-circuit enthusiasts, and the literature on the topic remains scant to nonexistent. While this may indicate that the technique was considered too complex or cumbersome or just not worth the effort, the combination of environmental concerns and advanced technology have now led to a point where coasting has become clinically available as an automated mode in the Aysis®. We therefore wanted to examine the clinical potential of the coasting technique by studying coasting times with a modern inhaled agent (desflurane) in an O₂/mixture under the best of conditions, closed-circuit anesthesia with redirected of sampled gases to the circuit. The results will allow us to get an idea of what can be expected in terms of clinical usefulness (duration of coasting) and savings (is it worth the effort?).

**METHODS**

After obtaining IRB approval and informed consent, 69 adult ASA physical status I-II patients undergoing a variety of peripheral or abdominal procedures were enrolled. The patient’s age, height, and weight were obtained. Patients were randomly assigned to 1 of 9 groups (see Table 1), depending on when coasting was started: after 4, 9, 16, 25, 36, 49, 64, 81, or 100 min. After pre-oxygenation, anesthesia was induced with propofol (2.5-3 mg/kg) or etomidate (0.3 mg/kg). Tracheal intubation was facilitated by succinylcholine (1 mg/kg) or vecuronium (0.08 mg/kg). In all patients an initial period of a high FGF (4-8 L/min O₂) was used to denitrogenate the patient (end-expired nitrogen < 5%) and to hasten wash-in of the circle system and the patient’s functional residual capacity (FRC). An end-expired desflurane concentration (Fₐ, des) of 4.5% was achieved within 1 min in all patients and maintained until the start of coasting. The FGF before the coasting period was left to the discretion of the attending anesthesiologists (it was part of another study) and ranged from 0.5 to 8 L/min.

Ventilation was controlled and normocapnia was maintained throughout the procedure. All patients were mechanically ventilated with tidal volumes of 6-8 mL/kg and a respiratory rate of 10 breaths per minute. ADU anesthesia machines (Datex-Engstrom AS/3 Anesthesia Delivery Unit; Datex-Engstrom, Helsinki, Finland) were used, with soda lime as the carbon dioxide absorber. The leak of the anesthesia machine and circuit during controlled mechanical ventilation with a peak-inspiratory pressure of 30 cm H₂O was measured each morning by the system check leak test. The actual leak for each patient during the study period was calculated based on the system check leak test and the measured peak-inspiratory pressure and inspired-to-expired ratio, and ranged from 9 to 27 mL/min, assuming a first order (linear) leak. The sampled gases (150-200 mL/min) were redirected into the circuit, and 100% O₂ was used as the reference gas to avoid nitrogen accumulation during

### Table 1

<table>
<thead>
<tr>
<th>Duration of anesthesia (min)</th>
<th>n</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>8</td>
<td>45 ± 14</td>
<td>169 ± 5</td>
<td>69 ± 17</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>39 ± 19</td>
<td>175 ± 8</td>
<td>74 ± 11</td>
</tr>
<tr>
<td>16</td>
<td>7</td>
<td>59 ± 17</td>
<td>166 ± 6</td>
<td>72 ± 13</td>
</tr>
<tr>
<td>25</td>
<td>6</td>
<td>50 ± 16</td>
<td>172 ± 11</td>
<td>71 ± 14</td>
</tr>
<tr>
<td>36</td>
<td>7</td>
<td>54 ± 13</td>
<td>170 ± 15</td>
<td>73 ± 31</td>
</tr>
<tr>
<td>49</td>
<td>7</td>
<td>48 ± 22</td>
<td>162 ± 7</td>
<td>67 ± 14</td>
</tr>
<tr>
<td>64</td>
<td>12</td>
<td>53 ± 15</td>
<td>169 ± 8</td>
<td>74 ± 8</td>
</tr>
<tr>
<td>81</td>
<td>7</td>
<td>48 ± 14</td>
<td>169 ± 7</td>
<td>70 ± 17</td>
</tr>
<tr>
<td>100</td>
<td>8</td>
<td>67 ± 5</td>
<td>171 ± 7</td>
<td>77 ± 12</td>
</tr>
</tbody>
</table>
Decrement times (min; average ± standard deviation). The decrement % indicates how much the end-expired desflurane concentration has decreased relative to the end-expired concentration that existed just prior to the start of coasting.

<table>
<thead>
<tr>
<th>Duration of anesthesia prior to coasting (min)</th>
<th>4</th>
<th>9</th>
<th>16</th>
<th>25</th>
<th>36</th>
<th>49</th>
<th>64</th>
<th>81</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrement %</td>
<td>30</td>
<td>7.5 ± 1.3</td>
<td>7.2 ± 2.1</td>
<td>7.5 ± 1.5</td>
<td>9.3 ± 5.2</td>
<td>11.5 ± 3.9</td>
<td>10.3 ± 2.3</td>
<td>10.7 ± 3.0</td>
<td>9.4 ± 2.4</td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>10.6 ± 2.7</td>
<td>11.1 ± 2.1</td>
<td>13.8 ± 7.6</td>
<td>17.2 ± 6.0</td>
<td>16.0 ± 3.5</td>
<td>16.2 ± 4.4</td>
<td>15.0 ± 3.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>15.1 ± 3.6</td>
<td>16.0 ± 3.2</td>
<td>20.0 ± 10.6</td>
<td>25.5 ± 9.2</td>
<td>25.0 ± 5.9</td>
<td>25.4 ± 7.2</td>
<td>22.9 ± 5.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>22.7 ± 6.5</td>
<td>23.9 ± 5.1</td>
<td>29.5 ± 15.3</td>
<td>38.0 ± 17.0</td>
<td>45.4 ± 19.3</td>
<td>41.9 ± 19.8</td>
<td>35.6 ± 10.6</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. — Decrement times – raw data and linear fit to the different decrement times. The decrement % indicates how much the end-expired desflurane concentration has decreased relative to the end-expired concentration that existed just prior to the start of coasting.

Patient demographics are presented in Table 1. Decrement times increased with increasing duration of anesthesia, and varied widely (Table 2). For example, after 64 min of maintenance anesthesia, the end-expired desflurane concentration remained at or above 70, 60, 50, and 40% of its maintenance value during 10.3 ± 2.3, 16.0 ± 3.5, 25.0 ± 5.9, and 45.4 ± 19.3 min, respectively (average ± standard deviation). The linear fit made to each set of decrement times is presented in Figure 1.

© Acta Anaesthesiologica Belgica, 2011, 62, n° 3
**DISCUSSION**

During coasting, decrement times increase with increasing duration of anesthesia, but vary widely, exemplified by the large standard deviation and the lower average decrements times in the 100 min group compared to the 64 min group.

Is coasting likely to contribute anything in terms of saving agent? After 64 min of anesthesia, the end-expired desflurane concentration remained at or above 70, 60, 50, and 40% of its maintenance value during 10.4 ± 2.3, 16.0 ± 3.6, 25.0 ± 6.0, and 45.4 ± 19.4 min, respectively. We believe this does indeed imply coasting can briefly maintain anesthesia towards the end of a procedure. While savings with an automated coasting mode are likely to be modest per patient, they may become substantial when multiplied by the number of procedures per day per operating room with no increase in the clinical workload of the anesthesia provider. What still needs to be examined is whether the slightly higher FGF during automated coasting with the Aisys® will affect decrement times. We examined the coasting technique under the best of circumstances – a truly closed circuit. It is possible that the 200-300 mL/min FGF used by the Aisys® in excess of patient uptake shortens decrement times. If that would prove to be an issue, it could technically be resolved easily.

The credit for first describing the coasting technique (and for coining the term “coasting”) goes to Lowe and Ernst (1). The concept of decrement times for inhaled agents is analogous to the context-sensitive half-times of intravenous anesthetics (3, 4). However, the description of coasting times antedates that of intravenous agents. Lowe and Ernst were interested in “coasting times” because they hypothesized that during the slow Fₐ decay induced by the closed-circuit, the Fₐ would more closely reflect the partial pressure in the brain and thus could be more useful clinically to steer recovery towards the end of a procedure. This was in effect an attempt to circumvent the hysteresis issue – the delay between changes in end-expired and central nervous system partial pressure after the anesthesiologist has adjusted the inspired partial pressure. This issue is now resurfacing in the work of Ross Kennedy, who is developing a display that reflects central nervous system rather than end-expired partial pressures (5, 6).

Coasting can briefly maintain anesthesia towards the end of a procedure. While savings with an automated coasting mode are likely to be modest per patient, they may become substantial when multiplied by the number of procedures per day per operating room with no increase in the clinical workload of the anesthesia provider.

**References**