Respiratory Variation in Pulse Pressure and Plethysmographic Waveforms: Intraoperative Applicability in a North American Academic Center

Sinead Maguire, MD, Joseph Rinehart, MD, Shermeen Vakharia, MD, and Maxime Cannesson, MD, PhD

Dynamic variables are the best predictors of fluid responsiveness in patients under general anesthesia and mechanical ventilation; namely, respiratory variations in pulse pressure and in the plethysmographic waveform. However, these variables have potential limitations. Our aim was to evaluate their intraoperative applicability. We extracted clinical data from all anesthesia procedures performed at our institution in 2009 and identified the number of cases that presented predetermined conditions of application. Among the 12,308 procedures, 39% met the criteria for the noninvasive monitoring of variations in the plethysmographic waveform of which 23% had arterial lines and met the criteria for the invasive monitoring of variations in pulse pressure. (Anesth Analg 2011;112:94–6)

From the Department of Anesthesiology & Perioperative Care, School of Medicine, University of California, Irvine, Irvine, CA. Address correspondence and reprint requests to Maxime Cannesson, MD, PhD, Department of Anesthesiology & Perioperative Care, University of California, Irvine, 333 City Boulevard West Side, Orange, CA 92868-3301. Address e-mail to maxime_cannesson@hotmail.com.

Copyright © 2010 International Anesthesia Research Society.

Table 1. Type of Surgery and ASA Classification in the Whole Population

<table>
<thead>
<tr>
<th>Type of surgery</th>
<th>No. of patients</th>
<th>Percentage related to the whole population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdominal</td>
<td>4067</td>
<td>33.04%</td>
</tr>
<tr>
<td>Neck, throat, and eye</td>
<td>2452</td>
<td>19.92%</td>
</tr>
<tr>
<td>Orthopedic</td>
<td>2021</td>
<td>16.42%</td>
</tr>
<tr>
<td>Vascular</td>
<td>1125</td>
<td>9.14%</td>
</tr>
<tr>
<td>Urologic</td>
<td>977</td>
<td>7.94%</td>
</tr>
<tr>
<td>Gynecologic</td>
<td>842</td>
<td>6.84%</td>
</tr>
<tr>
<td>Neurosurgery</td>
<td>824</td>
<td>6.70%</td>
</tr>
<tr>
<td>ASA classification</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>1922</td>
<td>16%</td>
</tr>
<tr>
<td>II</td>
<td>6360</td>
<td>51%</td>
</tr>
<tr>
<td>III</td>
<td>3509</td>
<td>29%</td>
</tr>
<tr>
<td>IV</td>
<td>480</td>
<td>4%</td>
</tr>
</tbody>
</table>
can affect vasomotor tone and potentially the plethysmographic waveform\(^{16}\), and laparoscopic procedures (because insufflation increases intraabdominal pressure and can affect \(\Delta PP\) and/or \(\Delta POP\) values\(^{17}\)).

**Statistical Analysis**

Data are expressed as absolute number and percentages related to the whole population and/or to patients who met the criteria for \(\Delta PP\) and \(\Delta POP\) monitoring.

**RESULTS**

**Overall Population Description**

Over the 1-year study period, 12,308 anesthesia procedures were performed at our institution. Type of surgery and ASA classification are shown in Table 1. Incidence of conditions of application in the whole population are shown in Figure 1. In all, 4792 cases (38.9%) were found to have normal sinus rhythm as well as all of the above-mentioned conditions of application.

**Incidence of Invasive Arterial Pressure Monitoring**

The use of arterial lines was also recorded at multiple stages in this process. It was found that 1936 (15.7%) of the total 12,308 surgical procedures involved patients with an arterial line. General anesthesia was performed in 1898 cases (98.0%). Mechanical ventilation was used in 1847 cases (95.4%) with a \(V_t\) \(\geq 8\) mL/kg in 1182 cases (61.1%) and a PEEP \(\leq 5\) cm H\(_2\)O in 1091 cases (56.4%). Of this value, 72 cases (3.7%) involved patients with cardiac arrhythmias causing them to be excluded. In all, 1019 patients (52.6%) were found to have normal sinus rhythm as well as all of the above-mentioned conditions of application.

**DISCUSSION**

The results from our study show that 39% of the patients undergoing an anesthesiology procedure from January 1, 2009 to December 31, 2009 in our institution presented all conditions of application for the use of dynamic variables of fluid responsiveness based on cardiopulmonary interactions (77% noninvasively [\(\Delta POP\)] and 23% invasively [\(\Delta PP\)]). In all patients with an arterial line, 53% presented all conditions of application of \(\Delta PP\).

Recently, these variables have been proposed for goal-directed fluid management\(^{9,14}\) and studies conducted in the clinical setting have obtained promising results for improving patients' postoperative outcome\(^{7,8,18}\). However,
these indices require specific conditions to be of use. In the 39% of the whole population who met all of the prespecified conditions, a noninvasive index such as ΔPOP could be used for hemodynamic assessment and optimization. For the purpose of ΔPOP monitoring, an arterial line is required. In our population, 23% of the patients who presented no limitations to the use of dynamic variables of fluid responsiveness were equipped with an arterial line. These patients could be optimized using ΔPP during surgery. Interestingly, 63% of these patients were classified as ASA physical status III or IV and would potentially benefit from goal-directed hemodynamic optimization.

Another limitation has recently been described by De Backer et al.\(^\text{19}\) and is related to the respiratory rate. These authors have shown that a heart rate/respiratory rate ratio <3.6 decreased the ability of ΔPP to predict fluid responsiveness. We were unable to screen for this limitation in our population of patients. However, the study by De Backer et al. was conducted in the intensive care unit and the ratio between heart rate and respiratory rate was attributable to high respiratory rate values (up to 40/min). It is likely that such high respiratory rates would not be encountered in the operating room anesthesia setting. Also, we did not screen for right ventricular failure.

In conclusion, our study found that 39% of the patients undergoing surgical procedures in the operating room in our institution from January 1, 2009 to December 31, 2009 met the criteria for the monitoring of fluid responsiveness using noninvasively measured ΔPOP. Of the patients with arterial catheters, 53% met the criteria for the monitoring of ΔPP.

**AUTHOR CONTRIBUTIONS**

SM participated in the design of the study, collected the data, and drafted the manuscript. JR and SV collected the data. SM participated in the design of the study, collected the data, and drafted the manuscript. MC conceived and designed the study, analyzed the data, performed the statistical analysis, and helped to draft the manuscript. All authors read and approved the final manuscript.

**REFERENCES**