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

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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)

Dynamic variables (such as pulse pressure variation [ΔPP] or respiratory variations in the plethysmographic waveform amplitude [ΔPOP]) are the best predictors of fluid responsiveness in patients under general anesthesia and mechanical ventilation[1,2] and they can now be continuously and noninvasively monitored.[3–6] Moreover, recently published studies have suggested that they could be used for intraoperative goal-directed fluid management.[7–9] However, these variables present with conditions of application and potential limitations that may decrease their applicability in daily clinical practice. These conditions of applications are (1) general anesthesia,[2] (2) sinus rhythm,[2] and (3) mechanical ventilation[10] with (a) a tidal volume (VT) ≥8 mL/kg of body weight[11–13] and (b) a positive end-expiratory pressure (PEEP) <5 cm H_2O. Moreover, ΔPP calculation requires an arterial line whereas ΔPOP only requires a pulse oximeter.[2,14]

Consequently, the goal of this retrospective study was to define the clinical applicability of intraoperative use of these variables in an academic North American center.

METHODS

Surgical Procedures

After obtaining IRB approval (University of California Irvine, Irvine, CA), we extracted clinical data from anesthesia procedures performed at our institution (University of California Irvine, Medical Center, Orange, CA) from January 1, 2009 to December 31, 2009. Cardiac and thoracic surgery cases were excluded because these are not situations in which hemodynamic variables such as ΔPP and ΔPOP can be used (356 cases in 2009 at our institution). From this database (SIS Anesthesia™; Surgical Information Systems, Alpharetta, GA), we identified the number of cases that presented predefined conditions of application. Because this involved a retrospective electronic chart review, we relied on clinician input of data in patient files for the collection of data.

Essential Conditions of Applications

The following conditions of applications were screened in the general population and in the subpopulation of patients with an arterial line: (1) general anesthesia,[2] (2) mechanical ventilation[10] with (3) VT ≥8 mL/kg of body weight,[11–13] (4) PEEP <5 cm H_2O, and (5) sinus rhythm.[2] Mechanical ventilation was defined as volume or pressure-controlled ventilation with no spontaneous breathing activity. Data were collected in absolute values and were expressed as a percentage of the total number of procedures. Patients with an arterial line were also screened at each step.

Potential Limitations

From the resulting values, potential limitations to the use of dynamic variables of fluid responsiveness were screened. These potential limitations have not yet been definitively proven and are still under discussion. They include open chest procedures,[15] use of a vasopressor drip (because it

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

	No. of patients	Percentage related to the whole population
Type of surgery		
Abdominal	4067	33.04%
Neck, throat, and eye	2452	19.92%
Orthopedic	2021	16.42%
Vascular	1125	9.14%
Urologic	977	7.94%
Gynecologic	842	6.84%
Neurosurgery	824	6.70%
ASA classification		
I	1922	16%
II	6360	51%
III	3509	29%
IV	480	4%

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Conflicts of Interest: Maxime Cannesson, MD, PhD, is a consultant for Edwards Lifesciences and Masimo Corporation.

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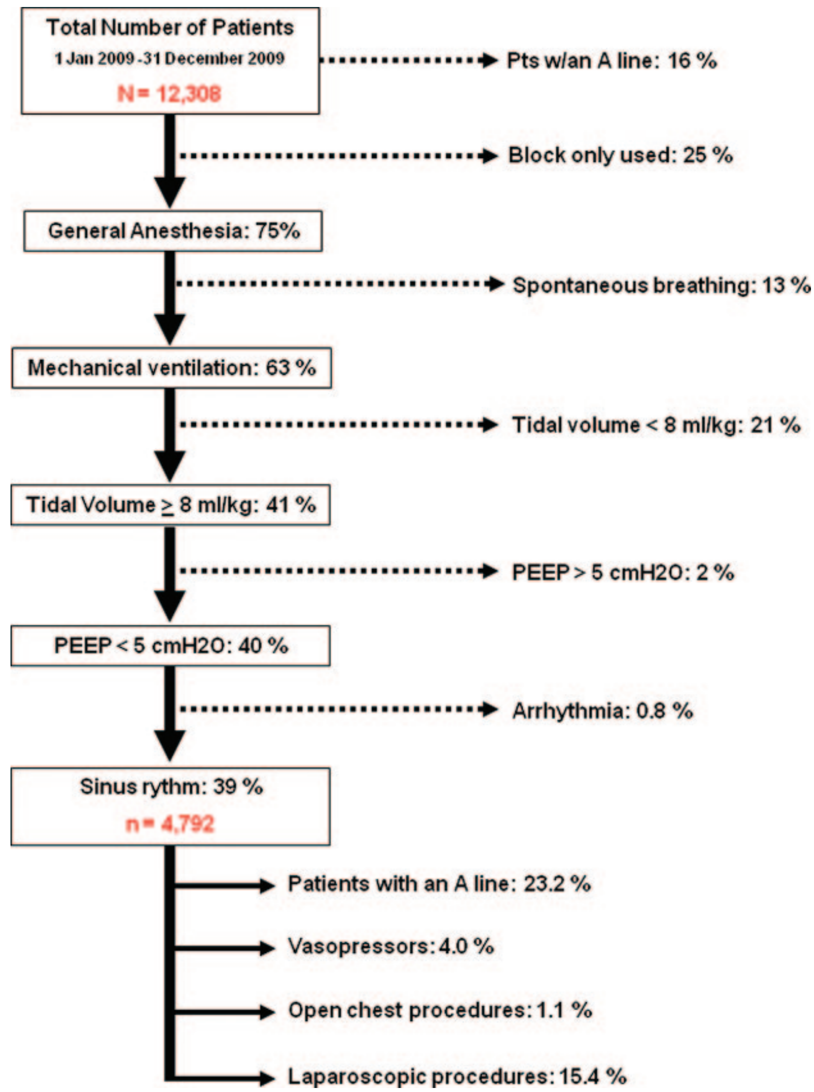

Figure 1. Flow chart showing methods involved to reach final value of patients to whom invasive and/or noninvasive dynamic variables of fluid responsiveness may be clinically applied. All percentages above and including sinus rhythm are related to the whole population (n = 12,308). Percentages below sinus rhythm are related to patients who met the criteria for variations in pulse pressure (ΔPP) and variations in the plethysmographic waveform (ΔPOP) monitoring (n = 4792). A line = arterial line; PEEP = positive end-expiratory pressure.

can affect vasomotor tone and potentially the plethysmographic waveform[16]), and laparoscopic procedures (because insufflation increases intraabdominal pressure and can affect ΔPP and/or ΔPOP 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 ΔPP and ΔPOP 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 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 ≥8 mL/kg in 1182 cases (61.1%) and a PEEP ≤5 cm H_2O 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 [ΔPOP] and 23% invasively [ΔPP]). In all patients with an arterial line, 53% presented all conditions of application of ΔPP.

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 ΔPP 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.[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 anesthesiology 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 and helped to draft the manuscript. MC conceived and designed the study, analyzed the data, performed the statistical analysis and final approval of the manuscript. All authors read and approved the final manuscript.

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