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Case Report

Hypotension prediction index together with cerebral oxygenation in guiding intraoperative hemodynamic management: a case report

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Abstract

Intraoperative hypotension happens in everyday clinical practice. It was suggested to have a strong association with adverse postoperative outcomes. Hypotension prediction index (HPI) was developed to predict intraoperative hypotension (mean arterial pressure <65 mmHg) in real time. However, pressure autoregulation also plays an important role in maintaining adequate organ perfusion/oxygenation during hypotension. A cerebral oxygenation monitor provides clinicians with the values of organ oxygenation. We reported a case that the cerebral oxygenation monitor was used together with HPI to guide intraoperative blood pressure management. We found that cerebral oxygenation was maintained in the event of hypotension during surgery. The patient had no intraoperative or postoperative adverse outcomes despite the hypotension. We believe this can provide an individualized intraoperative blood pressure management to avoid over- or under-treating hypotension.

Keywords: hypotension prediction index, cerebral oxygenation, hemodynamic, intraoperative

Introduction

Annually over 300 million patients worldwide undergo surgical procedures, and perioperative complications and mortality rate within 30 days of major noncardiac surgeries remain surprisingly high. Blood pressure (BP) changes may signal morbid events during anesthesia. The incidence of intraoperative hypotension is striking and varies from 5% to 99% depending on different chosen thresholds[1]. Intraoperative hypotension can result in tissue hypoperfusion and subsequent organ damage, and it is strongly associated with adverse perioperative outcomes, such as myocardial infarction, acute kidney injury (AKI), and stroke[2]. Furthermore, these adverse events result in higher hospital costs, increased length of hospital stay, and post-surgery mortality rate. Hence, optimizing intraoperative BP management can reduce the incidence of intraoperative hypotension and decrease the harm to patients.

Recently, the hypotension prediction index (HPI) was developed to predict intraoperative hypotension in

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real time using machine-learning[3]. However, different surgeries in different patient populations have different impacts on BP and organ perfusion. Pressure autoregulation plays an important role in maintaining appropriate blood flow for organ perfusion across a range of BP. Furthermore, different organs have heterogeneity of pressure autoregulatory capacities, and the pressure autoregulation of specific organs is affected by multiple clinical factors[4]. It is unknown whether proactive treatment guided by the HPI will improve outcomes. We presented a case where integration of HPI and end-organ oxygenation were used to facilitate the management of optimal BP in a patient. Informed consent from the patient was obtained, and the ethical standards of the institutional committee on human experimentation and the Helsinki Declaration were followed.

Case report

A 35-year-old woman was admitted for a hepatectomy. She had a history of colorectal cancer (stage Ⅳ), for which she had undergone two rounds of chemotherapy. The patient's height and weight were 157 cm and 70 kg, respectively, with a body mass index of 28.44 kg/m^2. The patient had no known drug allergy and no personal or family history of anesthesia-related complications. Preoperative blood tests showed normal hemoglobin and electrolyte, normal renal function and liver function.

No preoperative medications were administered before arrival to the operating room, where monitors, including pulse oximetry, electrocardiography, invasive BP monitoring by left radial artery catheterization, HPI, processed electroencephalogram, regional cerebral oxygen saturation (rSO_2), end-tidal carbon dioxide, and temperature, were established. After preoxygenation, general anesthesia was induced with intravenous (IV) injection of propofol 150 mg, fentanyl 100 μg, lidocaine 100 mg, and rocuronium 100 mg. After tracheal intubation, ventilation was established with pressure-controlled ventilation-volume guaranteed (PCV-VG) model and adjusted to target an end-tidal carbon dioxide between 35 and 45 mmHg. Anesthesia was maintained using continuous sevoflurane and propofol, IV bolus of fentanyl and rocuronium. A root monitor (Masimo, USA) was used to measure the depth of anesthesia and cerebral oxygenation during surgery. The bilateral transversus abdominis plane block was performed at the end of the surgical procedure with 60 mL of 0.375% ropivacaine. The patient received a total of 200 mL of lactated Ringer's solution, 300 mL of saline, 200 mL of plasmalyte, and 500 mL of 5% albumin. Residual neuromuscular blockade was reversed by sugammadex 200 mg. The endotracheal tube was removed when the patient was able to follow verbal commands to open her eyes and there was an adequate recovery of neuromuscular blockade. The patient was then transferred to the post anesthesia care unit.

During operation, the hemodynamic parameters were monitored by HPI software (Edwards Lifesciences, USA; ***Fig. 1***). The system generates an alert to clinicians when HPI reaches or exceeds 85. Hemodynamic data were presented in ***Fig. 2***. Intraoperative mean arterial pressure (MAP) was lower than 65 mmHg for 108 minutes, and HPI was higher than 85 for 209 minutes. No vasopressor was administered. The rSO_2 baseline values were 75 on the left (L) and 74 on the right (R). The rSO_2 values were maintained at 72-81 (L) and 71-82 (R) during surgery. There were no adverse perioperative outcomes. Patient's preoperative serum creatinine (SCr) was 0.53 mg/dL and was 0.70, 0.59, and 0.51 mg/dL on postoperative day (POD) 1, 2, and 3, respectively. Patient's preoperative estimated glomerular filtration rate was greater than 100 mL/(minute·1.73 m^2) and was greater than 100 mL/(minute·1.73 m^2) on POD 1, 2, and 3, respectively. There were no ST changes on electrocardiogram from the preoperative baseline during the entire surgery. The patient started liquid diet on POD 1 and passed flatus on POD 2 and had moderate soft formed stool in the morning of POD 3. The patient was discharged home in the afternoon of POD 3. No long-term effects were noted 3 months after discharge from the hospital.

Discussion

Although intraoperative hypotension is poorly defined, the incidence of intraoperative hypotension is common[1]. A large cohort study based on 138 021 patients undergoing noncardiac surgery demonstrated that up to 44% of patients experienced at least one absolute hypotension (MAP less than 65 mmHg) episode of more than 10 minutes, and 68% experienced more than 10 minutes of relative intraoperative hypotension (relative MAP values greater than 20% below pre-induction baseline)[5]. Studies have suggested that intraoperative hypo-

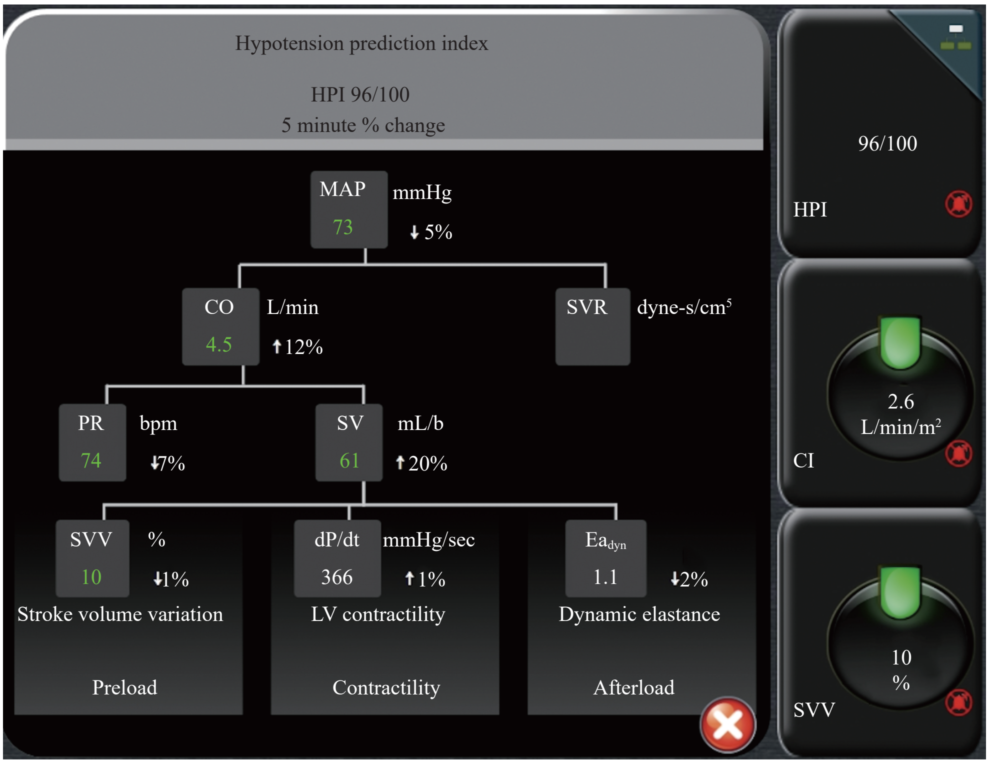

Fig. 1 **Sample screenshot of hypotension prediction index (HPI) monitor with hemodynamic variables including stroke volume variation (SVV), rate of contractility (dP/dt), and dynamic elastance (Eadyn) reflect preload, contractility, and afterload.** MAP: mean arterial pressure; CO: cardiac output; PR: pulse rate; SV: strokevolume; LV: left ventricle; SVR: systemic vascular resistance; CI: cardiac index.

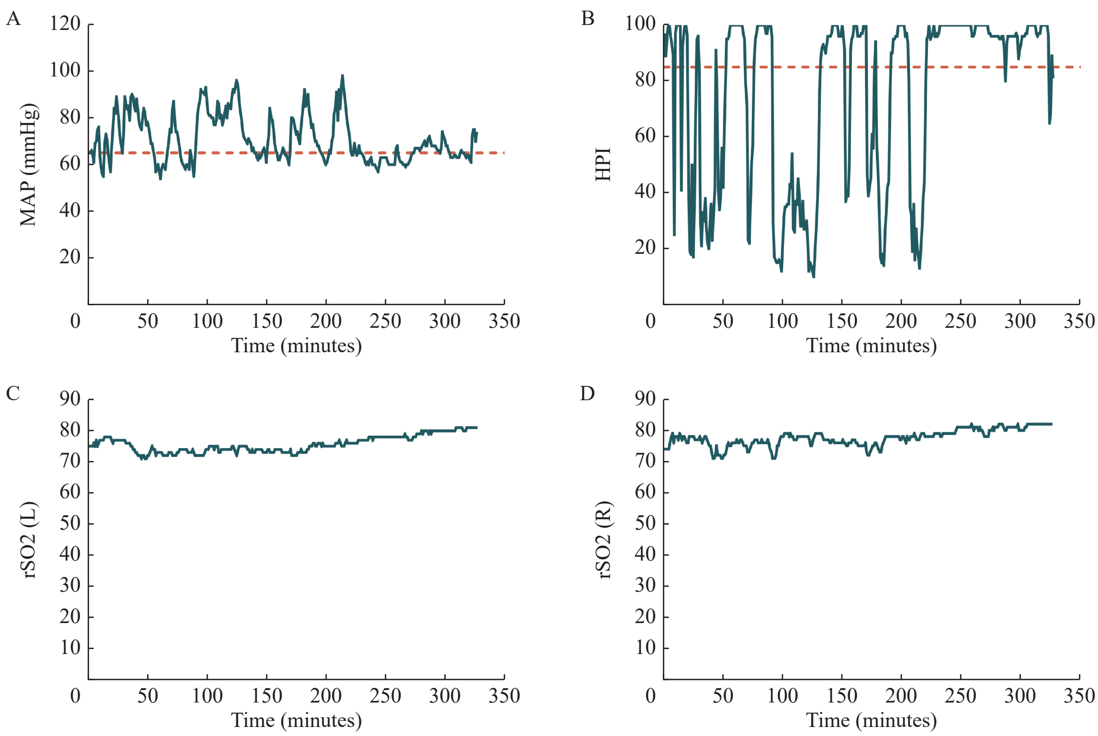

Fig. 2 **Intraoperative mean arterial pressure and regional cerebral oxygen saturation of the patient.** A: Patient's mean arterial pressure (MAP), the dotted line represents the MAP of 65 mmHg; B: Patient's hypotension prediction index (HPI), the dotted line represents the HPI of 85; C and D: Patient's regional cerebral oxygen saturation (rSO_2). L: left; R: right.

tension is associated with unfavorable outcomes[2]. Recently, a large cohort study in noncardiac surgical patients, aiming to examine the relationship between hypotension and AKI factoring in underlying patient and procedural risks, found that patients with the highest baseline risk demonstrated an association between even mild absolute intraoperative hypotension and AKI, whereas patients with low risk demonstrated no associated increased risk of AKI across all BP ranges[5]. Although our patient experienced 108 minutes of hypotension, the postoperative kidney function was normal and postoperative gastrointestinal function recovery was not affected.

During hypotension, organ-specific pressure autoregulation plays an important role in maintaining stable blood flow for organ perfusion within certain limits and provides some protection against hypotension-induced hypoperfusion. However, different organs have different autoregulatory capacities[4]. Furthermore, the pressure autoregulation of specific organs is affected by multiple factors. It is known that pressure autoregulation is compromised in chronic hypertensive patients with decreased elasticity of the arterial wall and the lower limit of organ-specific autoregulation threshold shift rightward. Other variables such as anesthesia, changes in the autonomic nervous system, or vasodilatation by medication may also affect pressure autoregulation. Elderly patients, especially with coexisting hypertension, diabetes, history of tobacco use, hypercapnia, or obstructive sleep apnea, are more likely to have impaired pressure autoregulation and result in right-shifted pressure autoregulation curves[4]. The implication related to right shifts of autoregulation curves means poor tolerance of hypotension. Consequently, patients with weak or weakened pressure autoregulation are at increased risk of organ injury during hypotension. Recently the Perioperative Quality Initiative-3 workgroup presented a consensus statement on intraoperative BP, and recommended that maintaining systolic arterial pressure above 100 mmHg and MAP above 60–70 mmHg may reduce risk during noncardiac surgery[6]. However, much of the evidence arises from large retrospective cohort analyses of data obtained from electronic medical records, and it cannot be extrapolated to be optimal for all cases, or "one size does not fit all". The challenge for anesthesia is how to translate population data to the care of individuals with heterogeneity and variability since organ-specific thresholds for autoregulation likely differ and are affected by the types of anesthesia and surgery. In this case, the patient experienced an accumulated duration of intraoperative hypotension (MAP <65 mmHg) of more than 100 minutes, where there were no adverse perioperative outcomes. This might be explainable by the robust ability of pressure autoregulation to maintain the organ blood flow.

It may be beneficial to use pre-emptive treatment by early identification or even prediction of intraoperative hypotension before it occurs. HPI, based on machine-learning derived algorithm, was established to predict hypotension (MAP <65 mmHg for more than 1 minute) and to warn clinicians. The HPI algorithm was created by applying machine-learning arterial pressure waveforms and was trained with a large data sources. The sensitivity and specificity of HPI for predicting hypotension is 88% and 87% 15 minutes before a hypotensive event, 89% and 90% 10 minutes before, 92% and 92% 5 minutes before, respectively[3].

The HPI parameter displays a unitless value ranging from 0 to 100. The HPI value represents the probability of hypotensive event, and it is updated every 20 seconds. The HPI system will generate an alarm once the HPI value reaches or exceeds 85. A decision tree with advanced hemodynamic information comes along with the HPI value in the second screen (***Fig. 2***). Hemodynamic variables include stroke volume variation (SVV), rate of contractility (dP/dt), and dynamic elastance (Eadyn) reflect preload, contractility, and afterload. Additionally, pulse rate (PR), cardiac output (CO), and stroke volume (SV) are also shown. The hemodynamic variables offered by the second screen may help the clinician identify the probable causes underlying the hypotensive event, and let the clinician proceed with proactive treatments to optimize hemodynamics. Schneck and colleagues evaluated the value of HPI in minimizing the incidence and duration of intraoperative hypotension in patients undergoing total hip arthroplasty under general anesthesia[7]. The authors found that a significant reduction of the incidence and duration of hypotensive events in patients with goal directed therapy guided by HPI, but did not affect the hospital or intensive care unit length of stay. The effect of HPI-based treatment on patient's outcomes in terms of postoperative morbidity and mortality remains unknown and warrants further evaluation.

Hemodynamics can be regarded as a ladder construct, and it is composed of multiple interrelated steps, such as intravascular volume, preload, CO, BP, organ perfusion, and tissue oxygenation. Tissue oxygenation, a step situated upward on the ladder, describes the balance between tissue oxygen supply and consumption. BP is a step situated in the middle[4]. Tissue oxygen supply is determined by multiple downward steps on the ladder, and BP is just one of the determinants to drive blood flow for organ perfusion and tissue oxygen supply[4]. In our case, the patient was monitored by HPI combined with cerebral rSO_2 which is based on near-infrared spectroscopy, measured regional tissue oxygen saturation with sensors applied to the forehead. We can continuously assess the balance between cerebral tissue oxygen consumption and supply, estimate cerebral perfusion and early detect cerebral hypoperfusion[8]. Several studies have demonstrated the importance of rSO_2 to monitor the brain as an index organ during intraoperative hypotension[9]. Brandon and colleagues found that rSO_2 increased even though MAP decreased during controlled hypotension while using nitroglycerin, and illustrated that BP alone was not a reliable marker of tissue perfusion[10]. Similarly, the decrease of rSO_2 remained within 5% baseline value during intraoperative hypotension in our case.

In summary, the case illustrates that HPI alone does not provide beneficial impact on patient outcome although it presents reliable prediction of intraoperative hypotension. HPI combined with end-organ oxygenation monitoring may facilitate individualized BP management. The MAP used in HPI should be individualized and the clinicians should be allowed to set the value to provide individualized hemodynamic management.

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