

Original**Evaluation of Heart Rate Variability as a Predictor of Hypotension after Induction of General Anesthesia**

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Abstract

Purpose. To investigate specific criteria of parameters of heart rate variability (HRV) to predict hypotension after induction of general anesthesia.

Methods. We studied 57 patients who were scheduled for either total knee arthroplasty ($n = 42$) or anterior cruciate ligament reconstruction ($n = 15$) under general anesthesia. Patients with rhythm other than sinus, major cardiovascular, pulmonary, neurologic, endocrine, or metabolic disorder or recent exposure to medications affecting heart rate were excluded from the study. After HRV analysis, anesthesia was induced with propofol, 1.5mg/kg, fentanyl, 3 μ g/kg, and vecuronium, 1.5mg/kg. We analyzed 256 R-R intervals immediately before induction of anesthesia. Power spectrum densities were calculated for total power (TP), low frequency (LF) power (0.04–0.15Hz) and high frequency (HF) power (0.15–0.4Hz). Non-invasive blood pressure was measured every 2.5 minutes from 5 min before anesthetic induction until 10 min after intubation. A decrease in systolic blood pressure (SBP) greater than 30% of the control value or SBP less than 90mmHg was defined as hypotension. A receiver operating characteristic curve (ROC) was constructed for each of the significant HRV measures.

Results. Forty patients developed hypotension during induction of general anesthesia. Amongst HRV measures, LF and TP were significantly lower in the hypotensive (HYPO) group. ROC curve analysis revealed a sensitivity of 33% and a specificity of 94% for $LF < 90\text{ms}^2/\text{Hz}$ (area: 0.73, likelihood ratio: 5.5). The sensitivity and specificity of $TP < 500\text{ms}^2/\text{Hz}$ were 33%, and 95%, respectively (area 0.71, likelihood ratio: 5.5).

Conclusion. Preoperative $LF < 90\text{ms}^2/\text{Hz}$ and $TP < 500\text{ms}^2/\text{Hz}$ significantly correlated with hypotension after induction of general anesthesia. We suggest that preoperative measurement of LF and TP is useful for the prediction of hypotension during induction of general anesthesia.

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—Key words—

heart rate variability, hypotension, general anesthesia

Introduction

Hypotension after induction of general anesthesia is common¹⁾. It has been recognized that perioperative hypotension is associated with adverse outcome^{2,3)}.

Heart rate variability (HRV), the variation over time of the period between consecutive heart beats, is a useful parameter for understanding the status of the autonomic nervous system^{4~6)}. HRV measures provided by power spectral analysis include low frequency (LF) power (0.04–0.15Hz) and high frequency (HF) power (0.15–0.4Hz), where LF reflects sympathetic and parasympathetic influences, and HF represents vagal nerve activity. The ratio of LF to HF (LF/HF) correlates with sympathovagal balance.

Recently, several investigators have reported that HRV can predict the incidence of hypotension caused by the induction of general anesthesia^{7~9)} or spinal anesthesia^{10~13)}. It would be very beneficial in improving outcome to predict the patients predisposed to develop hypotension before the induction of general anesthesia or

spinal anesthesia. Indeed, Hanss et al.¹⁰ reported that they successfully managed the patients at high risk for hypotension during spinal anesthesia by prophylactic treatment.

We hypothesized that prediction with HRV of hypotension after the induction of general anesthesia could be applicable to various anesthetic combinations other than those reported previously⁷⁻⁹. To date, hypotension elicited by an anesthetic combination of bolus-administered propofol and fentanyl has not been investigated. The objectives of this study were to confirm that HRV could predict hypotension associated with an anesthetic combination of bolus-administered propofol and fentanyl, and to determine specific criteria of parameters of HRV to predict hypotension.

Materials and Methods

Patients

After approval of Institutional Research Committee, informed consent was obtained from each patient. We studied 57 patients who were scheduled for either total knee arthroplasty (n = 42) or anterior cruciate ligament reconstruction (n = 15) under general anesthesia.

Patients with rhythm other than sinus, major cardiovascular, pulmonary, neurologic, endocrine, or metabolic disorder or recent exposure to medications affecting heart rate (e.g., beta-adrenergic blockers or agonists, antiarrhythmic drugs) were excluded from the study.

Anesthesia

All patients were allowed to take food until midnight, and clear fluid until 10 : 00 a.m. Patients received no premedication, and received 500ml of acetate Ringer solution before entering the operating room. The lower limb surgery started at 1 : 00 p.m.

Anesthesia was induced with propofol, 1.5mg/kg, fentanyl, 3 μ /kg, and vecuronium, 1.5mg/kg. Three minutes later, tracheal intubation was performed. Anesthesia was maintained with sevoflurane in 40% oxygen in air and sevoflurane concentration was adjusted to maintain bispectral (BIS) index at 40–60 [approximately 0.5 minimum alveolar concentration (MAC)]. Incidentally, the BIS index is the most validated measure of depth of anesthesia, where 0 represents an isoelectric electroencephalographic and 100 an awake status. The MAC implies anesthetic potency; 1 MAC of an anesthetic agent abolishes response to surgical incision. The inhalation of sevoflurane was started just after the intubation. Ventilation was controlled to maintain end-tidal CO₂ at 30–35mmHg. Non-invasive blood pressure was measured every 2.5 minutes from 5 min before anesthetic induction until 10 min after intubation. A decrease in systolic blood pressure (SBP) greater than 30% of the control value or SBP less than 90mmHg was defined as hypotension. Accordingly, subjects were classified into either hypotensive (HYPO) or non-hypotensive (NON-HYPO) group.

HRV measurement

Subsequent to a 10-min stabilization period, we recorded 256 R-R intervals using FM-150 device (Fukuda Denshi, Tokyo, Japan) immediately before induction of general anesthesia with a sampling rate of 1,024Hz. We conformed to the Task Force recommendation⁹. During the HRV measurement, participants were resting in a supine position and breathing was controlled at a rate of 12–15 breathes per minute. Frequency domain analysis was based on fast Fourier transformation. Power spectrum densities were calculated for total power (TP), LF (0.04–0.15Hz) and HF (0.15–0.4Hz) by use of a PC-based analysis system (HPS-RRA, Fukuda Denshi, Tokyo, Japan). Artifacts were eliminated by computer-based artifact detection.

Statistical analysis

Intergroup comparisons were performed using Mann-Whitney-U test or χ^2 test. A $p < 0.05$ was considered significant. Data were expressed as median (interquartile range). A receiver operating characteristic curve (ROC) was constructed for each of the significant HRV measures, and the areas under the ROC curves (AUR) were determined. StatFlex version 5.0 (Arteck inc., Osaka, Japan) was used for the statistical analysis.

Results

Fifty-seven patients were enrolled, and all patients completed the study. Demographic data are shown in Table 1. Forty patients developed hypotension during induction of general anesthesia. Two groups were not

Table 1 Demographic data of the HYPO and NON-HYPO groups.

	HYPO (n = 40)	NON-HYPO (n = 17)	P
Age	77 (72, 80)	44 (30, 77)	< 0.01
Sex (m/f)	7/33	4/13	< 0.001
ASA physical status (I/II)	2/38	10/7	< 0.001
Hypertension	28	4	< 0.01
Height (cm)	152 (148, 156)	165 (157, 172)	< 0.05
Weight (kg)	57 (49, 64)	63 (59, 73)	< 0.05
Baseline SBP (mmHg)	153 (147, 165)	133 (123, 142)	< 0.001
Baseline HR(/min)	67 (59, 73)	64 (59, 73)	0.94
LF (ms ² /Hz)	115.3 (57.7, 294.2)	387.5 (132.4, 814.4)	< 0.01
HF (ms ² /Hz)	145.0 (60.5, 463.8)	347.2 (147.7, 475.6)	0.12
LF/HF	0.77 (0.42, 1.85)	1.41 (0.83, 1.83)	0.12
TP (ms ² /Hz)	894.9 (346.0, 1,945.1)	1,823.1 (971.4, 3,228.6)	< 0.05

Values are expressed as median (interquartile range). SBP, systolic blood pressure; HR, heart rate; LF, low frequency; HF, high frequency; TP, total power

Table 2 Characteristics of HRV measures as predictors of hypotension.

	AUR (95% CI)	Threshold value	Sensitivity (95% CI)	Specificity (95% CI)	Likelihood ratio
LF (ms ² /Hz)	0.73 (0.61–0.85)	90	33 (21–45)	94 (88–100)	5.5 (4.21–7.25)
TP (ms ² /Hz)	0.71 (0.59–0.83)	500	33 (21–45)	94 (88–100)	5.5 (4.21–7.25)

LF, low frequency; TP, total power

comparable with respect to demographic data. The HYPO group was older and had a higher percentage of individuals with hypertension and a higher percentage of individuals classified with ASA class II. With regard to the American Society of Anesthesiologists physical status classification system, it is for assessing the fitness of patients before surgery, in which 6 categories are comprised. Class I refers to a normal healthy patient, class II a patient with mild systemic disease and so forth. Amongst HRV measures, LF and TP were significantly lower in the HYPO group. Table 2 compares the threshold value, sensitivity, specificity and likelihood ratio of LF and TP. ROC curve analysis revealed a sensitivity of 33% [95% confidence interval (CI), 21–45] and a specificity of 94% (95% CI, 88–100) for LF < 90ms²/Hz [area:0.73 (95% CI, 0.61–0.85), likelihood ratio:5.5 (95% CI, 4.21–7.25)] (Fig. 1). The sensitivity and specificity of TP < 500ms²/Hz were 33% (95% CI, 21–45), and 94% (95% CI, 88–100), respectively [area 0.71 (95%CI, 0.59–0.83), likelihood ratio:5.5 (95% CI, 4.21–7.25)] (Fig. 2). ROC curves showed the following AURs for other variables; age [0.77 (95%CI, 0.66–0.92)], ASA physical status [0.77 (95%CI, 0.66–0.92)], hypertension [0.73 (95%CI, 0.61–0.85)].

Discussion

In the present study, heart rate variability was analyzed in patients scheduled to undergo lower limb surgery. LF < 90ms²/Hz and TP < 500ms²/Hz significantly predicted the development of hypotension during induction of general anesthesia. Our findings are in agreement with previous findings^{8,9)}.

Recently, Reich et al.¹⁾ demonstrated that postinduction hypotension is significantly correlated with age ≥ 50 years, baseline hypotension, use of propofol for induction of anesthesia and increasing induction dosage of fentanyl (>1.5μ/kg). However, total avoidance of propofol and fentanyl is presumably impractical. These drugs are indispensable for patients with bronchial asthma or limited coronary reserve. HRV as a predictor of perioperative hypotension has been investigated in various anesthetic combinations, e.g., propofol and fentanyl⁷⁾, midazolam and fentanyl⁸⁾, and propofol and remifentanyl⁹⁾. With respect to the combination of propofol and fentanyl, propofol was continuously infused in the previous study⁷⁾. Thus, hypotension elicited by an anesthetic combination of bolus-administered propofol and fentanyl was investigated for the first time by the present study.

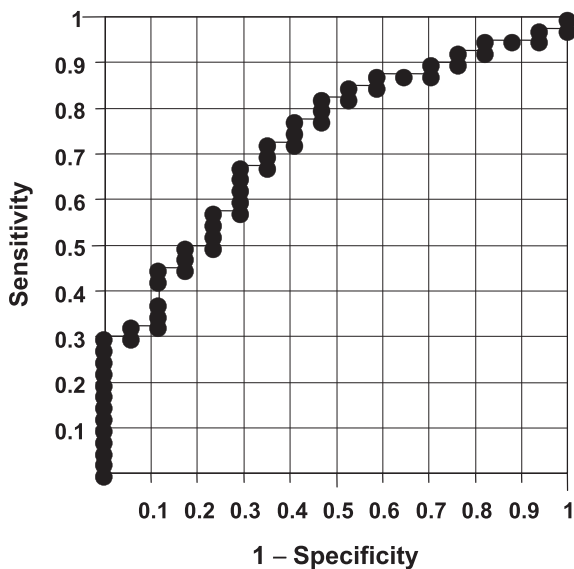


Fig.1 Receiver operator characteristic curve of low frequency (LF) for prediction of hypotension during induction of general anesthesia.

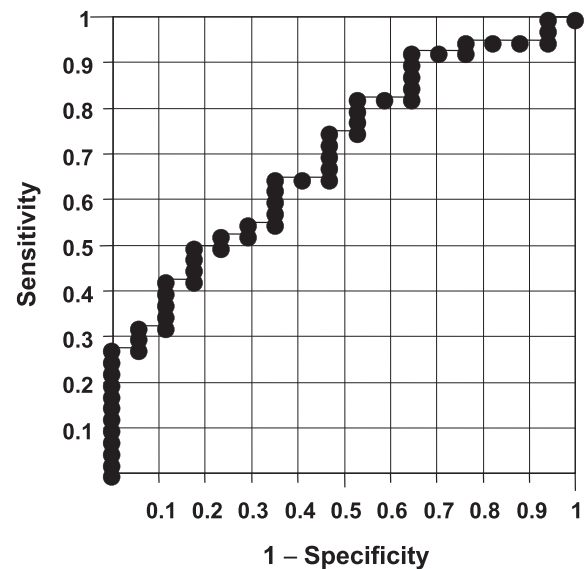


Fig.2 Receiver operator characteristic curve of total power (TP) for prediction of hypotension during induction of general anesthesia.

Fujiwara et al.⁷⁾ reported that a nonlinear index of heart rate variability, ultra short term entropy (UsEn), is correlated with blood pressure fluctuation during induction of general anesthesia. In their study, blood pressure fluctuations were significantly greater in patients with low LF. Huang et al.⁸⁾ found that LF, HF and TP were significantly lower in the patients whose intraoperative blood pressure was instable, and concluded that TP independently predicts the incidence of hypotension. Moreover, Hanss et al.⁹⁾ investigated whether HRV predicts hemodynamic events in high risk patients, and demonstrated a greater incidence of hypotension and bradycardia in the patients with $TP < 500 \text{ms}^2/\text{Hz}$.

Our study has some limitations. There were significant differences between HYPO and NON-HYPO group in demographic data. Namely, HYPO group was older, and had a higher percentage of individuals with hypertension and a higher percentage of individuals classified as ASA class II compared with NON-HYPO group. The results would reflect the evidence that HRV decreases with age^{5,14)}. Actually, HRV is not independent of age, and accompanying hypertension or ASA status.

In summary, we investigated the value of HRV for prediction of hypotension in patients undergoing lower limb surgery. Preoperative $LF < 90 \text{ms}^2/\text{Hz}$ and $TP < 500 \text{ms}^2/\text{Hz}$ significantly correlated with hypotension after induction of general anesthesia. We suggest that preoperative measurement of LF and TP is useful for the prediction of hypotension during induction of general anesthesia.

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全身麻酔導入後の低血圧発生の予測因子としての心拍変動解析の検討

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—キーワード—

心拍変動, 全身麻酔, 低血圧

近年, 心拍変動解析により周術期の低血圧を予測することが可能であるとの報告が散見される. 全身麻酔下に整形外科下肢手術(膝関節全置換術および靭帯断裂形成術)が予定された成人 57 名を対象に心拍変動解析を行い, 全身麻酔導入時の低血圧の発生との関連を検討したので報告する.

手術室入室後, 256 心拍の心拍変動の測定を行った. low frequency (LF : 0.04~0.15Hz), high frequency (HF : 0.15~0.40Hz), LF/HF を測定した. 全身麻酔の導入は, プロポフォール 1.5mg/kg, フェンタニル 3 μ g/kg を用いた. 全身麻酔導入後から気管挿管 10 分後までの血圧を評価し, 導入直前に比し 30% 以上の収縮期血圧の低下もしくは収縮期血圧 90mmHg 以下への低下をみたものを低血圧とした. 数値は中央値(四分位数間領域)で示した. 有意差のみられた心拍変動解析のパラメータについて受診者動作特性 (Receiver Operating Characteristic : ROC) 曲線を構築し, その曲線下面積 (Area under curve ; AUC) をもとに解析し, それぞれについて, 閾値, 感度, 特異度, 尤度比を求めた. 57 名中 40 名で低血圧を認めた. 非低血圧群, 低血圧群でそれぞれ LF は, 387.5 (132.4, 814.4), 115.3 (57.7, 294.2), LF/HF は, 1.41 (0.83, 1.83), 0.77 (0.42, 1.85) であった. LF < 90ms²/Hz の感度は 33%, 特異度は 94% であった (面積 : 0.73, 尤度比 : 5.5). TP < 500ms²/Hz の感度は 33%, 特異度は 95% であった (面積 : 0.71, 尤度比 : 5.5).

術前の心拍変動解析により全身麻酔導入後の低血圧の発生を予測しうる可能性が示唆された.

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