CLINICAL STUDY

Predictive Factors of Postoperative Blood Pressure Abnormalities Following a Minor-to-Moderate Surgery

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Summary

Myocardial ischemic events after non-cardiac surgery is still a serious problem, especially in older, high-risk patients. However, the prevalence and risk factors of blood pressure (BP) abnormalities, which may possibly lead to myocardial ischemic attack, have not been reported. Our aim is to elucidate predictive factors of postoperative BP abnormalities following a minor-to-moderate surgery, employing preoperative left ventricular diastolic function. Patients who underwent cardiac echocardiogram examination and received oral and maxillofacial surgery under general anesthesia were enrolled. The echocardiographic parameters of diastolic function were compared between patients who had postoperative BP abnormalities (hypertension-systolic blood pressure [SBP] ≥ 170 mmHg-or hypotension-SBP < 80 mmHg-episode) that required therapeutic interventions until 7 days after surgery and those who had no BP abnormalities. Of the 173 patients analyzed, 25 (14.4%) had BP abnormalities. BP abnormalities patients were older, having a larger proportion of diabetes mellitus, lower E/A ratio and e', and larger E/e' and left atrial dimension than those without BP abnormalities. Subanalyses revealed that the independent risk factors responsible for hypertension episodes (14 patients) were the mean e' (odd ratio [OR]: 0.434; 95% confidence interval [CI]: 0.229-0.824), diabetes mellitus (OR: 5.018; 95% CI: 1.030-24.436), SBP at hospitalization (OR: 1.099; 95% CI: 1.036-1.165), and operation time (hour; OR: 1.326; 95%CI: 1.109-1.586), while hypotension episodes (11 patients) were associated solely with operation time (OR: 1.206; 95% CI: 1.046-1.391). In conclusion, left ventricular diastolic dysfunction, increased insulin resistance, boosted SBP at hospitalization, and prolonged operation should be taken into consideration as risk factors of postoperative BP abnormalities, especially hypertension, following minor-to-moderate surgery.

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Key words: Diastolic function, Diastolic dysfunction, Echocardiography, Non-cardiac surgery, Atherosclerotic risk factors

The percentage of population aged ≥ 65 years in Japan is rapidly increasing to up to 33.8 million (26.6%) according to the 2015 National Population Census. Accordingly, a greater number of patients is receiving non-cardiac surgery, and the impact of cardiovascular diseases in these patients is potentially significant than in those receiving cardiac surgery. An early postoperative myocardial ischemia after non-cardiac surgery is a potent risk factor of adverse cardiac outcomes. Furthermore, myocardial ischemic attack after non-cardiac surgery independently predicts 30-day mortality, especially in older, high-risk patients.3,4)

Recently, symptomatic heart failure caused by diastolic dysfunction, keeping the left ventricular ejection fraction (LVEF) normal or preserved, is rapidly increasing. Diastolic dysfunction is characterized by stiffness of the left ventricle (LV), which impairs the active relaxation of the LV to aspirate blood from the left atrium (LA), leading to elevation of the left ventricular end-diastolic pressure (LVEDP). An acute elevation of the blood pressure (BP) or heart rate, or cardiac arrhythmia in such condition is easily able to induce symptoms of heart failure such as exertional dyspnea, fluid retention, and pulmonary edema.5) It has been reported that hypertension, diabetes mellitus, coronary artery disease, and myocardial infarction are associated with diastolic dysfunction.6) The prevalence of diastolic dysfunction is 44.8% at the age of 65-74 years and as much as 70.8% at the age of ≥ 75 years in the general population; it was further reported that the prevalence of mild diastolic dysfunction is 47.6% and that of moderate-to-severe diastolic dysfunction is 16.5% in a population with an age of ≥ 65 years having hypertension...
or coronary artery disease.\(^6\)

With regard to the perioperative safety of elderly patients, informing non-cardiologists of the prevalence and risk factors of postoperative BP abnormalities, i.e., hypertension ([SBP] \(\geq 170\) mmHg) and hypotension (SBP < 80 mmHg), which may possibly lead to myocardial ischemic attack unless appropriate therapeutic interventions are provided, is important. In this study, we investigated predicting factors of postoperative BP abnormalities in patients receiving oral and maxillofacial surgery, employing preoperative diastolic function of the LV.

**Methods**

Approval by the Clinical Ethical Committee of Kagoshima University Hospital, which waived the requirement of informed consent due to the minimal risk to the subjects, was obtained. We performed a retrospective, single-institution, observational, case-control study in patients with no functional limitations aged \(\geq 18\) years who had undergone cardiac echocardiogram examination and received oral and maxillofacial surgery under general anesthesia between June 2013 and June 2015. We included patients with hypertension, coronary artery disease, valvular heart disease, or cerebrovascular diseases, and with cardiovascular risk factors such as dyslipidemia (LDL-cholesterol \(\geq 140\) mg/dL, HDL-cholesterol < 40 mg/dL, or triglycerides \(\geq 150\) mg/dL), obesity (BMI \(\geq 25\) kg/m\(^2\)), hypertension, diabetes mellitus (HbA1c \(\geq 6.5\) % [NGSP value]), current/past smoking habits, and LV hypertrophy. Patients with peripheral artery disease and coronary artery disease were also included in the analysis.

A preoperative echocardiogram examination was performed in patients with hypertension, coronary artery disease, valvular heart disease, or cerebrovascular diseases, and in patients who had prognostic risk factors for cardiovascular diseases other than BP, e.g., age of \(\geq 65\) years, obesity, smoking habits, diabetes mellitus, dyslipidemia, a family history of cardiovascular disease arising in the adolescence, history of cardiovascular and cerebrovascular disease, chronic kidney disease, or peripheral vascular disease, which were described in the Guidelines for the Management of Hypertension 2014 by the Japanese Society of Hypertension.\(^5\) Preoperative echocardiogram examination was also performed in patients with the age of < 65 years having cardiac arrhythmias, congenital heart diseases, or a history of cardiac surgery.

Routine antihypertensive medications were continued until the day of surgery; however, angiotensin II receptor blockers and angiotensin-converting enzyme inhibitors were discontinued on the day of surgery to minimize hypotension during anesthesia.\(^7\) Sevoflurane- or propofol-based anesthesia, which was supplemented by an opioid analgesic remifentanil (0.1-0.3 \(\mu\)g/kg/minute), was performed. Tracheal intubation was facilitated by intravenous rocuronium administration (1 mg/kg). To minimize postoperative pain, fentanyl (1-2 \(\mu\)g/kg) and acetaminophen (15 mg/kg) were administered until the end of the surgery.

Postoperative BP abnormalities (hypertension [SBP \(\geq 170\) mmHg] and hypotension [SBP < 80 mmHg]) that required therapeutic interventions until 7 days after surgery were retrospectively picked out from the electric medical records.

The echocardiogram parameters analyzed were the left ventricular end-diastolic dimension (LVDd), left ventricular end-systolic dimension (LVDs), left atrial dimension (LAD), interventricular septum thickness (IVS), posterior wall thickness (PWT), relative wall thickness (RWT), left ventricular ejection fraction (LVEF), percent fractional shortening (%FS), left ventricular mass index (LVMI), and speculated right ventricle pressure (RVsp). The parameters of diastolic function (the peak mitral flow velocity of the early [E] to the late [A] diastolic flow [E/A ratio], the early diastolic septal and lateral annular velocity measured from tissue Doppler imaging [e’], the ratio of E to e’ [E/e’], the deceleration time of early diastolic mitral flow velocity [DcT], and the LAD) were also compared between patients who experienced postoperative BP abnormalities and those who did not.

In order to examine the relationships between performed surgery and postoperative BP abnormalities, the surgeries were divided into three categories; (1) tooth extraction, cysts, benign tumors, or implants, (2) maxillofacial injuries, osteomyelitis, or infection of plates/implants, and (3) malignant tumors. Distribution of BP abnormalities were compared between the hypertension episode and hypotension episode groups.

**Statistical analysis:** Data are expressed as means with SD. One-way analysis of variance was performed for the numerical data including preoperative blood examination data and echocardiogram parameters between the BP abnormalities (−) and the BP abnormalities (+) groups. Tukey-Kramer’s HSD test was used in such numerical data between the BP abnormalities (−), the hypertension episode, and the hypotension episode groups. The chi-squared test was used for examining the differences in the sex, distribution of hypertension, dyslipidemia, diabetes mellitus, current smoking habit, proportion of antihypertensive and lipid-lowering medication use, or category of surgery performed, between the BP abnormalities (−) and the BP abnormalities (+) groups or between combinations of each of two groups within the three groups of postoperative BP abnormalities. Receiver operating characteristic (ROC) curve analysis was performed to identify cutoff values of the echocardiogram parameters for optimal discrimination of patients having postoperative BP abnormalities. Multinomial logistic regression analysis was performed to estimate the dependence of cardiovascular risk factors, echocardiogram parameters of diastolic function, or operation time on the development of postoperative BP abnormalities. Receiver operating characteristic (ROC) curve analysis was performed to identify cutoff values of the echocardiogram parameters for optimal discrimination of patients having postoperative BP abnormalities. Logistic regression analyses were performed using JMP 13.0 software (SAS Institute Japan, Tokyo, Japan).

**Results**

The total number of patients enrolled was 181. Eight patients were excluded from the data analysis due to lack of echocardiogram data with regard to diastolic function. Thus, the total number of patients analyzed was 173. Twenty-five patients had postoperative BP abnormalities (BP abnormalities (+) group), while 148 were uneventful
were a hypertension episode of SBP level of 170 mmHg (14 patients) and a hypotension episode of SBP < 80 mmHg (11 patients). One patient with a hypertension episode also revealed chest pain and ST depression, which was relieved by nitroglycerin, on the day of surgery. The baseline characteristics of the patients in both groups are shown in Table I. BP abnormalities (+) patients were significantly older, had larger proportion of diabetes mellitus, and experienced a longer operation time as compared with BP abnormalities (−) patients. However, there was no difference in the hemoglobin concentration, intraoperative blood loss, or systolic parameters of the echocardiogram like LVEF or %FS between the two groups (Table II). BP abnormalities (+) patients had a significantly lower E/A ratio, longer D+T, and larger LAD. The e' of the BP abnormalities (+) patients was significantly higher both at the ventricular septum and the lateral wall; the E/e' was significantly higher both at the ventricular septum and the lateral wall.

The results of the multinomial logistic regression analysis are shown in Table III. The risk factors responsible for developing postoperative BP abnormalities were analyzed using age, sex, SBP at hospitalization, history of hypertension, diabetes mellitus or dyslipidemia, current smoking habit, LAD, mean e', and operation time as independent variables. The analysis revealed that mean e', SBP at hospitalization, and operation time were independent risk factors for developing postoperative BP abnormalities.

Second, in order to elucidate the risk factors of postoperative hypertension and hypotension episodes, subanalyses were performed. BP abnormalities (+) patients were classified into the hypertension episode subgroup (14 patients) and the hypotension episode subgroup (11 patients). The baseline characteristics of patients in the BP abnormalities (−), hypertension episode, and hypotension episode subgroups (11 patients) was significantly lower both at the ventricular septum and the lateral wall; the E/e' was significantly higher both at the ventricular septum and the lateral wall.

The details of the postoperative BP abnormalities were a hypertension episode of SBP ≥ 170 mmHg (14 patients) and a hypotension episode of SBP < 80 mmHg (11 patients). One patient with a hypertension episode also revealed chest pain and ST depression, which was relieved by nitroglycerin, on the day of surgery. The baseline characteristics of the patients in both groups are shown in Table I. BP abnormalities (+) patients were significantly older, had larger proportion of diabetes mellitus, and experienced a longer operation time as compared with BP abnormalities (−) patients. However, there was no difference in the hemoglobin concentration, intraoperative blood loss, or systolic parameters of the echocardiogram like LVEF or %FS between the two groups (Table II). BP abnormalities (+) patients had a significantly lower E/A ratio, longer D+T, and larger LAD. The e' of the BP abnormalities (+) patients was significantly higher both at the ventricular septum and the lateral wall; the E/e' was significantly higher both at the ventricular septum and the lateral wall.

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tension episode groups, and between the hypertension and the hypotension episode groups. The operation time in the hypertensive hypertension episodes were mean e’, diabetes mellitus, SBP at hospitalization, and operation time, and that affecting the development of hypotension episodes was solely the operation time (Table VI).

The ROC curves of the e’ of the lateral wall (A), the E/e’ of the lateral wall (B), the A-wave (C), and the E/A ratio (D) to estimate overall BP abnormalities (in order of area under the ROC curve [AUC]) are shown in Figure 1. The results of the ROC curve analysis with a peak discriminating sensitivity and specificity as well as a cutoff point for each parameter are also included. Figure 2 shows the ROC curves of the IVS (A), the e’ of the lateral wall (B), the RWT (C), and the E/e’ of the lateral wall (D) to estimate a hypertension episode (in order of AUC), along with the results of the ROC curve analysis. Similarly, the ROC curves of the E/A ratio (E), the DcT (F), the e’ of the ventricular septum (G), and the mean e’ (H) to estimate a hypotension episode (in order of AUC), along with the results of the ROC curve analysis, are also shown in Figure 2.

Table VII shows the distribution of BP abnormalities classified by the category of the oral and maxillofacial surgery performed. There were significant differences in the distribution of BP abnormalities between the hypertension and hypotension episode groups (P = 0.033). A post-operative hypertension episode occurred mainly following surgeries for malignant tumors (50.0%), and surgeries for tooth extraction, cysts, benign tumors, or implants (35.7%). In contrast, a hypotension episode occurred mostly following surgeries for malignant tumors (81.8%).

Table II. Echocardiogram Parameters

| Variables       | Total n = 173 | BP abnormalities (-) n = 148 | BP abnormalities (+) n = 25 | P value |
|-----------------|--------------|------------------------------|-----------------------------|---------|
| LVDd (mm)       | 44.2 ± 4.5   | 44.3 ± 4.6                   | 43.6 ± 4.4                  | 0.4912  |
| LVDs (mm)       | 26.7 ± 3.6   | 26.8 ± 3.6                   | 26.4 ± 3.9                  | 0.6072  |
| LAD (mm)        | 35.9 ± 5.4   | 35.5 ± 5.3                   | 38.0 ± 5.7                  | 0.0328* |
| IVS (mm)        | 10.7 ± 1.7   | 10.6 ± 1.6                   | 11.2 ± 1.8                  | 0.1164  |
| PWT (mm)        | 10.4 ± 1.5   | 10.3 ± 1.4                   | 10.9 ± 1.9                  | 0.0857  |
| RWT             | 0.47 ± 0.07  | 0.47 ± 0.07                  | 0.50 ± 0.08                 | 0.0548  |
| LVEF (%)        | 69.6 ± 6.4   | 69.5 ± 6.5                   | 70.1 ± 5.5                  | 0.6648  |
| %FS             | 39.5 ± 5.0   | 39.4 ± 5.0                   | 39.5 ± 5.0                  | 0.9352  |
| LVMI            | 106.8 ± 28.2 | 105.9 ± 27.7                 | 112.2 ± 31.3                | 0.3014  |
| RVsp (mmHg)     | 29.8 ± 4.1   | 29.6 ± 4.3                   | 31.1 ± 4.7                  | 0.0898  |
| E (cm/s)        | 63.7 ± 17.1  | 63.7 ± 17.0                  | 63.5 ± 18.4                 | 0.9429  |
| A (cm/s)        | 76.6 ± 18.3  | 74.8 ± 17.4                  | 87.5 ± 20.3                 | 0.0015* |
| E/A ratio       | 0.86 ± 0.31  | 0.88 ± 0.33                  | 0.72 ± 0.13                 | 0.0193* |
| DcT (s)         | 219.5 ± 46.6 | 215.4 ± 45.2                 | 243.6 ± 48.6                | 0.0048* |
| e’ septal (cm/s)| 6.6 ± 2.1    | 6.8 ± 2.2                    | 5.7 ± 1.2                   | 0.0150* |
| e’ lateral (cm/s)| 8.8 ± 3.2  | 9.0 ± 3.3                    | 7.2 ± 1.5                   | 0.0082* |
| Mean e’ (cm/s)  | 7.7 ± 2.5    | 7.9 ± 2.6                    | 6.4 ± 1.0                   | 0.0059* |
| E/e’ ratio septal| 10.0 ± 3.2 | 9.8 ± 2.9                    | 11.6 ± 4.4                  | 0.0088* |
| E/e’ ratio lateral| 7.8 ± 3.1 | 7.6 ± 2.9                    | 9.2 ± 3.5                   | 0.0185* |

BP indicates blood pressure; LVDd, left ventricular end-diastolic dimension; LVDs, left ventricular end-systolic dimension; LAD, left atrial dimension; IVS, interventricular septum thickness; PWT, posterior wall thickness; RWT, relative wall thickness; LVEF, left ventricular ejection fraction; %FS, percent fractional shortening; LVMI, left ventricular mass index; RVsp, speculated right ventricle pressure; E, the peak mitral velocity of the early diastolic flow; A, the peak mitral velocity of the late diastolic flow; e’, the early diastolic annular velocity measured from tissue Doppler imaging; and E/A ratio, the peak mitral velocities of the early [E] to the late [A] diastolic flow. *P < 0.01 compared between the groups.

Table III. Multinomial Logistic Regression Analysis

| Variables          | OR    | 95% CI             | P value |
|--------------------|-------|--------------------|---------|
| Age (years)        | 1.020 | 0.960-1.083        | 0.5102  |
| Female sex         | 0.784 | 0.272-2.263        | 0.6538  |
| SBP at hospitalization (mmHg) | 1.034 | 1.001-1.067        | 0.0358* |
| Hypertension       | 0.551 | 0.163-1.863        | 0.3368  |
| Diabetes mellitus  | 2.659 | 0.849-8.327        | 0.0954  |
| Dyslipidemia       | 1.095 | 0.406-2.957        | 0.8566  |
| Current smoking habit | 0.294 | 0.046-1.855        | 0.1639  |
| LAD (mm)           | 1.055 | 0.958-1.161        | 0.2724  |
| Mean e’ (cm/second)| 0.695 | 0.496-0.972        | 0.0222* |
| Operation time (hours) | 1.272 | 1.097-1.373        | 0.0003* |

OR indicates odds ratio; CI, confidence interval; SBP, systolic blood pressure; and LAD, left atrial dimension. *P < 0.05
Indeed, parameters of cardiac hypertrophy, i.e., decreased afterload of the LV and myocardial oxygen deprivation, were associated with postoperative hypertension episodes. These parameters are considered to be useful to predict hypertension episodes in clinical practice. Furthermore, postoperative hypertension episodes occurred mainly following surgeries for malignant tumors (81.8%), and surgeries for tooth extraction, cysts, benign tumors, or implants (35.7%). This implies that evaluating atherosclerotic risk factors is important regardless of the surgical stress or implant.

### Discussion

The results of the current study showed that diastolic dysfunction of the LV, SBP at hospitalization, and operation time should be considered as independent risk factors of BP abnormalities following oral and maxillofacial surgery. Further subanalyses revealed that diastolic dysfunction, increased insulin resistance, boosted SBP at hospitalization, and prolonged operation are independent risk factors for developing postoperative hypertension. It has been reported that part of the ejected blood flow reflects backward when pressure waves encounter arterial bifurcations, returning to the heart as early as at late systole in atherosclerotic conduit vessels. The backward waves increase afterload of the LV and myocardial oxygen demand, leading to cardiac hypertrophy and diastolic dysfunction. Indeed, parameters of cardiac hypertrophy, i.e., the IVS (cutoff value of 10.4 mm) and the RWT (cutoff value of 0.50), and parameters of diastolic function, i.e., the e’ of the lateral wall (cutoff value of 8.8 cm/s), were associated with postoperative hypertension episodes. These parameters are considered to be useful to predict hypertension episodes in clinical practice. Furthermore, postoperative hypertension episodes occurred mostly following surgeries for malignant tumors (50.0%), and surgeries for tooth extraction, cysts, benign tumors, or implants (35.7%). This implies that evaluating atherosclerotic risk factors is important regardless of the surgical stress or operation time. In contrast, hypertension episodes occurred mostly following surgeries for malignant tumors (81.8%) and were associated with prolonged operation time but not with atherosclerotic risk factors. Therefore, we should rather put emphasis on the surgical stress and maintaining the circulating blood volume.

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### Table IV. Baseline Characteristics of the Patients According to Two BP Abnormalities (+) Categories

| BP abnormalities (+) | BP abnormalities (+) Categories |
|----------------------|---------------------------------|
| **Age (years)**      | 68.0 ± 12.5 n = 148             |
| Gender (M/F)         | 82/66                           |
| Height (cm)          | 157.3 ± 10.5 n = 148            |
| Weight (kg)          | 56.5 ± 12.6 n = 148             |
| BMI (kg/m²)          | 22.6 ± 3.5 n = 148              |
| SBP (mmHg)           | 127.0 ± 17.6 n = 148            |
| DBP (mmHg)           | 75.3 ± 12.1 n = 148             |
| HR (minute)          | 72.2 ± 12.3 n = 148             |
| Hypertension         | 93 (62.8%) n = 148              |
| Diabetes Mellitus    | 22 (14.8%) n = 148              |
| Dyslipidemia         | 53 (35.8%) n = 148              |
| Coronary artery disease | 10 (6.7%) n = 148              |
| Current smoker       | 32 (21.6%) n = 148              |
| Fasting plasma glucose (g/dL) | 102.6 ± 22.7 n = 148 |
| HbA1c (%)            | 5.98 ± 0.66 n = 148             |
| Triglyceride (mg/dL) | 121.1 ± 89.0 n = 148            |
| Total cholesterol (mg/dL) | 198.2 ± 35.9 n = 148 |
| BUN (mg/dL)          | 16.4 ± 16.2 n = 148             |
| Serum creatinine (mg/dL) | 0.78 ± 0.22 n = 148            |
| Serum uric acid (mg/dL) | 5.7 ± 4.7 n = 148              |
| eGFR (mL/minute/1.73m²) | 70.9 ± 16.8 n = 148           |
| Antihypertensive medication use (%) | 79 (53.3%) n = 148 |
| ARBs                 | 45 (30.4%) n = 148              |
| Ca antagonists       | 55 (37.1%) n = 148              |
| Diuretics            | 9 (6.0%) n = 148                |
| β-blockers           | 6 (4.0%) n = 148                |
| ACE inhibitors       | 5 (3.3%) n = 148                |
| Lipid-lowering medication use (%) | 29 (19.5%) n = 148 |
| Hemoglobin (g/dL)    | 13.4 ± 1.8 n = 148              |
| Intraoperative blood loss (g) | 91.7 ± 185 n = 148 |
| Operation time (minutes) | 205 ± 224 n = 148              |

ACE indicates angiotensin-converting enzyme; ARBs, angiotensin II receptor blockers; BMI, body mass index; BP, blood pressure; BUN, blood urea nitrogen; DBP, diastolic blood pressure; eGFR, estimated glomerular filtration rate; SBP, systolic blood pressure; and NS, not applicable to any statistical significance. SBP, DBP, HR were measured at hospitalization. A P < 0.05 between the BP abnormalities (+) and the hypertension episode groups. †P < 0.05 between the BP abnormalities (+) and the hypotension episode groups. ‡P < 0.05 between the hypertension episode and the hypotension episode groups.
In the dentistry field, it has been reported that 989 out of 3811 dental outpatients at a university hospital, aged ≥ 20 years, were classified as hypertensive, among which 694 had not been previously diagnosed as hypertension. Furthermore, the record of medical emergency call system of our dental hospital revealed that approximately one-third of 210 medical emergency cases in these 20 years represented cardiovascular symptoms, e.g., acute hypertension (57 cases), chest pain or angina pectoris (six cases), and tachycardia or arrhythmias (six cases), among which two patients died later of myocardial infarction. These findings suggested that stimulation of the cardiac sympathetic nerve in response to acute dental stress predominantly causes cardiovascular symptoms in patients.
with hypertension or undiagnosed hypertension, though patients who suffered myocardial infarction or cardiac death were exceptional. Meanwhile, dental patients also show cardiovascular symptoms after surgery performed under general anesthesia, one of the independent risk factors for developing BP abnormalities is diastolic dysfunction. The BP abnormalities that occurred in this study did not affect mortality nor caused serious physical disabilities. However, they may have led to irreversible myocardial ischemia or cerebrovascular disorders if the appropriate therapeutic interventions had not been provided. Spasms of a coronary artery might have occurred in the patient with chest pain and ST depression as well as hypertension on the day of surgery. With regard to perioperative safety of elderly patients, these risk factors for BP abnormalities should be alerted to non-cardiologists.

It is supposed that one of the mechanisms of postoperative hypertension in diastolic dysfunction is mediated by the sympathetic nervous system. Postoperative patients are vulnerable to induce sympathetic hyperactivity due to acute inflammation of the surgical site and/or postoperative pain. Sympathetic hyperactivity induces vasoconstriction of the peripheral resistance arteries, which increases the afterload of the LV. However, patients with diastolic dysfunction are not able to augment the stroke volume by means of the Frank-Starling mechanism in response to vasoconstriction of the peripheral resistance arteries. A further increase in the afterload of the LV leads to eleva-
tion of the LVEDP and internal pressure of the LA, thereby inducing pulmonary congestion. Simultaneously, sympathetic hyperactivity induces constriction of the splanchnic capacitance veins through the α1 and α2 adrenergic receptors, which in turn shifts the intravascular volume of the splanchnic venous reservoir acutely to the effective circulatory volume.14 Increased effective circulatory volume rapidly returns to the stiff heart, which contributes to elevation of the preload of the LV.

In contrast, in situations in which the peripheral veins are dilated by remaining general anesthetics and/or opioid analgesics, or warming body surface after surgery, the intravascular volume shifts to the periphery, while the stiff heart is not able to eject enough blood volume due to the decreased cardiac output, which in turn decreases the venous return to the heart. In the present study, the proportion of patients with concentric hypertrophy, where the internal LV capacity is reduced by hypertropy, was higher (eight out of 14 cases; 57.1%) in the hypertension episode group as compared with the BP abnormalities (−) group (55 out of 148 cases; 37.1%).

We have already observed that endothelial function as evaluated by the reactive hyperemia index (RHI) is severely suppressed on the day of a minor-to-moderate surgery; suppressed RHI improves until the 4th postoperative day in average; however, recovery of the endothelial function is impaired by diabetes mellitus, obesity, hyperuricemia, and sevoflurane-based anesthesia, possibly due to oxidative stress.14 As diastolic dysfunction is associated with hypertension, diabetes mellitus, chronic kidney diseases, obesity, and coronary heart disease,6,15 we cannot exclude the possibility that recovery of endothelial function in patients with diastolic dysfunction after surgery is delayed. Because endothelial dysfunction is associated with impaired anticoagulatory potential of the endothelium, such patients are susceptible to postoperative ischemic heart disease.

Recently, it has been recognized in the anesthesia field that diastolic dysfunction is sensitive to hypovolemia, that it is further impaired by myocardial ischemia leading to heart failure, or that it precipitates subendocardial myocardial ischemia due to chronic LV wall stress by increased LVEDP.17 With regard to major postoperative complications after surgery, it has been reported that diastolic dysfunction is associated with cardiac events shortly after coronary artery bypass grafting,13 congestive heart failure and prolonged hospital stay after major vascular surgery,19 and pulmonary edema after renal transplantation.20 However, we should carefully interpret these results because a study evaluated diastolic function after induc-
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