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Effect of performing preoperative echocardiography in patients with cardiovascular risk on intraoperative anesthetic management and postoperative outcomes

A retrospective study

Jae Hong Park, MD[a], Yei Heum Park, MD[a], Byeongcheol Lee, MD[a], Sung Hyun Shin, MD[a], Daeseok Oh, MD[a], Sung Ho Moon, MD[a], Myoung Jin Ko, MD[a,*]

Abstract

Although echocardiography is widely used for preoperative cardiac risk evaluation, few studies have analyzed the effect of performing preoperative echocardiography on intraoperative anesthetic management and postoperative outcomes. We investigated the effect of performing echocardiography on intraoperative anesthetic management and postoperative outcomes in patients with cardiovascular risk. We retrospectively evaluated patients who had undergone major abdominal surgery and satisfied 2 or more of the following criteria: hypertension, diabetes mellitus, age ≥70 years, and previous cardiac disease. Patients were categorized into a group in which preoperative echocardiography was performed (echo) and a group in which it was not (non-echo). The primary outcomes were postoperative 30-day mortality and incidence of cardiovascular complications. Secondary outcomes were length of hospital stay, intraoperative incidence of hypotension, use of vasopressors, and findings on intraoperative invasive hemodynamic monitoring. There were no differences in 30-day mortality, incidence of postoperative cardiovascular complications, length of hospital stay, and intraoperative events between the groups. Only the incidence of cardiac output monitoring was lower in the echo group than in the non-echo group (59.6% vs 73.9%). Preoperative echocardiography does not affect postoperative outcomes, but it has the potential to affect intraoperative anesthetic management such as invasive hemodynamic monitoring during surgery.

Abbreviations: ASA = American Society of Anesthesiologists, BMI = body mass index, CO = cardiac output, DM = diabetes mellitus, LVEF = left ventricular ejection fraction, TTE = thoracic echocardiography.

Keywords: anesthesia, complication, echocardiography

1. Introduction

Several unexpected complications may occur in the perioperative period of any procedure. Therefore, a preoperative evaluation is performed to prevent or predict these complications. Preoperative evaluation of the cardiovascular system is particularly important because cardiovascular complications that may occur in the perioperative period can sometimes be fatal. Transthoracic echocardiography (TTE) is one of the most widely used methods for preoperative cardiac risk stratification, because it can safely evaluate cardiac function and structure. Although several guidelines recommending preoperative echocardiography have been published previously,[1–3] hospitals in South Korea have their own clinical protocol for performing preoperative echocardiography before non-cardiac surgery.[4] Our hospital has recently established criteria for preoperative cardiac evaluation of patients in collaboration with cardiologists and anesthesiologists. The patients who satisfy 2 or more of the following 4 criteria have to undergo preoperative echocardiography in our hospital (history of hypertension, history of diabetes mellitus [DM], over 70 years of age, previous cardiac disease).

Echocardiography is an excellent diagnostic tool for preoperative cardiac risk evaluation. However, it requires considerable time, cost, and labor. Therefore, it is important to determine how performing echocardiography affects the results in the perioperative period. Although some studies have evaluated the effect of echocardiographic parameters on postoperative outcomes,[5–7] few studies have analyzed the effect of performing echocardiography on intraoperative anesthetic management or

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

[a] *Department of Anesthesiology and Pain Medicine, Haeundae Paik Hospital of Inje University, Busan, Republic of Korea.*

**Correspondence: Myoung Jin Ko, Department of Anesthesiology and Pain Medicine, Haeundae Paik Hospital of Inje University, 875 Haeundae-ro, Haeundae-gu, Busan 48108, Republic of Korea (e-mail: h00319@paik.ac.kr).*

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postoperative outcomes. This study investigated the differences in intraoperative managements, intraoperative and postoperative outcomes between groups of patients with cardiovascular risks that underwent or did not undergo preoperative echocardiography.

2. Materials and Methods

2.1. Patients

This retrospective study was approved by the Institutional Review Board of Haeundae Paik Hospital and registered with the Clinical Research Information Service (cris.nih.go.kr; registration number: KCT0006772). The requirement of informed consent was waived by the institutional review board. Patients aged ≥19 years who underwent elective major abdominal surgery under general anesthesia at Haeundae Paik Hospital between March 2010 and October 2021 were included in this study. Patients were included in the study when 2 or more of the following 4 criteria were satisfied: history of hypertension, history of DM, over 70 years of age, and previous diagnosis of cardiac disease (angina, arrhythmia, heart failure, or ischemic heart disease). Major abdominal surgeries included gastrointestinal (gastrectomy, colectomy, hepatectomy, and rectal and sigmoid resection) and urologic (prostatectomy and nephrectomy) surgeries. The included patients were categorized into 2 groups (echo and non-echo groups) according to whether echocardiography was performed. Patients who had undergone echocardiography within 3 months of surgery were classified into the echo group. Cases where the medical records lacked important data and could not be used for research were excluded from the study.

2.2. Data collection

Basic demographic data pertaining to sex, age, height, weight, body mass index, and American Society of Anesthesiologists (ASA) physical status class of the patients included in the study were collected. The patients' diagnosis, operation name, medical history, and electrocardiogram results were investigated. The cardiovascular risk score was determined for all patients, and it was determined as 2 when 2 of the 4 inclusion criteria of the study (hypertension, DM, age ≥70 years, cardiac disease) were satisfied, 3 when 3 of the 4 inclusion criteria were satisfied, and 4 when all 4 inclusion criteria were satisfied. Intraoperative anesthesia-related information (operative time, amount of bleeding, hypotension, use of vasopressors, and invasive hemodynamic monitoring) was obtained through anesthesia records, and length of hospital stay, 30-day mortality after surgery, and incidence of other postoperative cardiovascular complications were also determined. Intraoperative hypotension was defined as a mean blood pressure <60 mm Hg. Vasopressor use was defined as a continuous infusion of norepinephrine or epinephrine or vasopressin during surgery. Intraoperative invasive hemodynamic monitoring included arterial blood pressure, central venous pressure, and cardiac output (CO). In this study, CO was measured with a minimally invasive method using FloTracTM (VigileoTM, Edwards LifeSciences, Irvine, CA) or the NICOM® system (Cheetah Medical Inc., Portland, OR). All data were anonymized to protect patient information.

2.3. Echocardiography

In this study, patients who had and had not undergone echocardiography (echo and non-echo groups, respectively) were compared. The echo group included patients who had undergone echocardiography within 3 months of surgery using a suitable instrument for TTE (Vivid E95 ultrasound system; GE Healthcare, Milwaukee, WI). The left ventricular ejection fraction (LVEF), valvular heart disease, presence of relaxation abnormality, and presence of regional wall motion abnormality were investigated as echocardiographic parameters. Valvular heart disease was defined as mild or more valvular dysfunction as a result of echocardiography.

2.4. Endpoints

The primary outcomes were postoperative 30-day mortality and incidence of cardiovascular complications. All included patients were followed up for 30 days after surgery. Postoperative cardiovascular complications analyzed were pulmonary thromboembolism, severe arrhythmia, uncontrolled hypertension, acute coronary syndrome, acute heart failure, nonfatal cardiac arrest, and cardiac death. The presence of these complications was confirmed by a cardiologist. Severe arrhythmia was defined as paroxysmal supraventricular tachycardia or new-onset atrial fibrillation with a rapid ventricular response or ventricular tachycardia requiring treatment. Uncontrolled hypertension was defined as hypertension (systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg) that persisted despite appropriate medical treatment. The secondary outcomes were variables in intraoperative anesthetic management including use of vasopressor and findings on intraoperative invasive hemodynamic monitoring.

2.5. Sample size calculation

To compare 30-day mortality between the echo group and non-echo group, chi-square test was used. The required sample size, which assumed incidence of 0.4% and 2.3%, under the 2-tailed significance level of 0.05 and 80% power was 1156 patients.[8]

2.6. Statistical analysis

The data are presented frequency and percentage for categorical variables and mean ± standard deviation for continuous variables. Considering the differences in the baseline characteristics between patients in echo and non-echo groups, propensity score matching was used to reduce selection bias. Matching was performed using of a 1:1 nearest neighbor matching without replacement on a propensity score estimated using a logistic regression model. The covariates used for matching included age, sex, height, weight, body mass index, ASA, hypertension, DM, previous cardiac disease, operation name, BUN, Cr, operation type, amount of bleeding, and operative time. The standardized difference was used to assess group balance after propensity score matching, and absolute standardized differences <0.1 indicated a relatively small imbalance. Differences in study participants' characteristics were compared across subgroups with chi-square test or Fisher exact test for categorical variables and Mann–Whitney *U* test for continuous variables as appropriate. To check if its distribution is normal, we used Shapiro–Wilk test.

All statistical analyses were carried out using R 4.1.2, SPSS 25.0 and *P* values <.05 were considered statistically significant.

3. Results

We reviewed the medical records of 1532 patients who satisfied the inclusion criteria. After propensity score matching, 1188 patients were statistically analyzed (Fig. 1). Patients were categorized into 2 groups: echo (n = 594) and non-echo (n = 594; Table 1). There were no statistically significant differences in the primary outcomes (postoperative 30-day mortality, length of hospital stay, incidence of intraoperative hypotension, and use of vasopressors). However, the CO monitored during surgery was statistically lower in the echo group (59.1%) than in the non-echo group (73.4%; Table 2). Table 3 demonstrates that the overall incidence of postoperative cardiovascular complications was 3.9% in the echo group and 3.5% in non-echo group, but there was no difference between the 2 groups in the incidence

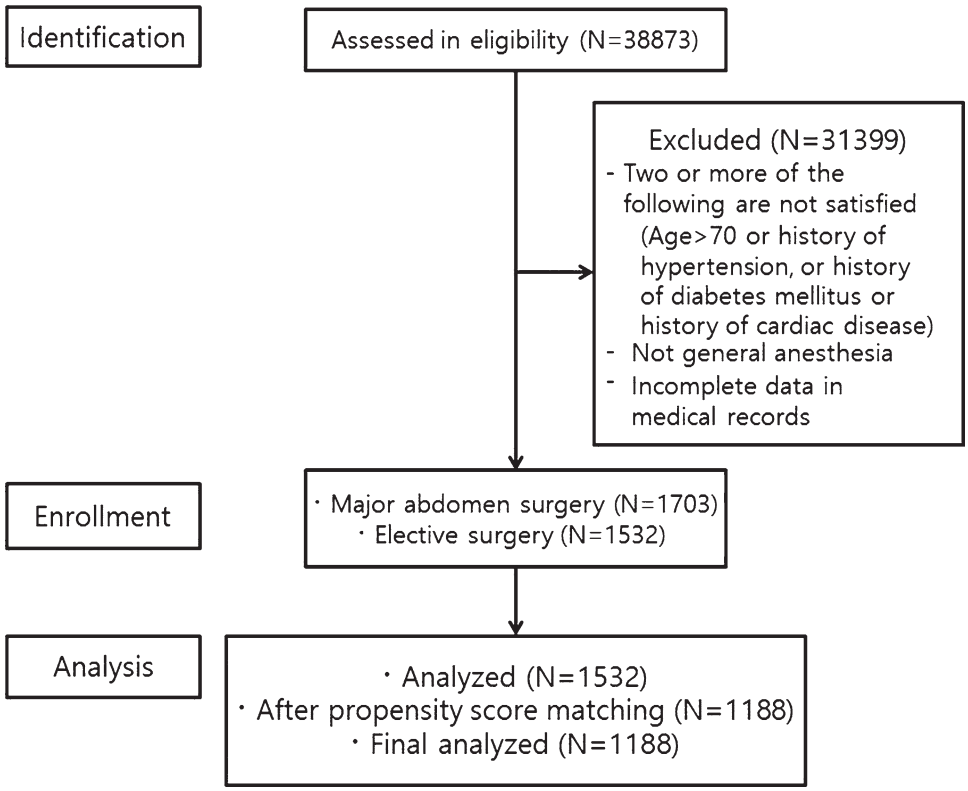

Figure 1. Patient selection as per STROBE flowchart. STROBE = Strengthening the Reporting of Observational Studies in Epidemiology.

Table 1

Patients' baseline demographic data.

	Before propensity score matching			After propensity score matching		
	Echo group (n = 594)	Non-echo group (n = 938)	Standardized difference	Echo group (n = 594)	Non-echo group (n = 594)	Standardized difference
Age	73.04 ± 7.78	71.96 ± 8.21	0.135	73.04 ± 7.78	72.89 ± 8.14	0.018
Sex			0.121			0.017
F	234 (39.4)	315 (33.6)		234 (39.4)	229 (38.6)	
M	360 (60.6)	623 (66.4)		360 (60.6)	365 (61.4)	
Height (cm)	159.98 ± 9.19	161.56 ± 9.07	0.172	159.98 ± 9.19	160.36 ± 9.41	0.041
Weight (kg)	62.63 ± 11.89	64.46 ± 11.59	0.156	62.63 ± 11.89	62.96 ± 11.56	0.029
BMI (weight [kg]/height [m^2])	24.38 ± 3.57	24.62 ± 3.42	0.069	24.38 ± 3.57	24.40 ± 3.43	0.006
ASA class	2.41 ± 0.51	2.35 ± 0.51	0.120	2.41 ± .51	2.41 ± .54	0.006
Operation name			0.158			0.009
Gastrointestinal surgery	498 (83.8)	728 (77.6)		498 (83.8)	496 (83.5)	
Urologic surgery	96 (16.2)	210 (22.4)		96 (16.2)	98 (16.5)	
Hypertension	497 (83.7)	801 (85.4)	0.048	497 (83.7)	501 (84.3)	0.018
DM	290 (48.8)	471 (50.2)	0.028	290 (48.8)	292 (49.2)	0.007
Previous cardiac disease	106 (17.8)	191 (20.4)	0.064	106 (17.8)	107 (18.0)	0.004
Operation type			0.032			0.026
Hepatectomy/prostatectomy	106 (17.8)	179 (19.1)		106 (17.8)	112 (18.9)	
Gastrectomy/colectomy/nephrectomy/ rectal and sigmoid resection	488 (82.2)	759 (80.9)		488 (82.2)	482 (81.1)	
BUN	16.12 ± 6.36	16.91 ± 8.08	0.109	16.12 ± 6.36	15.97 ± 6.88	0.022
Cr	1.05 ± .66	1.14 ± .88	0.118	1.05 ± .66	1.04 ± .55	0.014
Amount of bleeding	422.93 ± 517.01	400.84 ± 685.91	0.036	422.93 ± 517.01	392.00 ± 475.24	0.062
Operative time	243.01 ± 101.55	242.11 ± 94.05	0.009	243.01 ± 101.55	244.89 ± 96.45	0.019

Values are presented as either n (%) or mean ± standard deviation.

ASA = American Society of Anesthesiologists, BMI = body mass index, DM = diabetes mellitus.

of general postoperative complications. Subgroup analysis was performed in the echo group, which was divided into the CO monitor (n = 351) and without CO monitor (n = 243) groups; significant differences were evident between the subgroups in LVEF, valvular heart disease, relaxation abnormality, regional wall motion abnormality, age, ASA class, history of hypertension, history of cardiac disease, and cardiovascular risk score (Table 4).

Table 2

Perioperative outcomes.

	Echo group (n = 594)	Non-echo group (n = 594)	*P* value
Intraoperative hypotension	73 (12.3)	62 (10.4)	.315*
Use of vasopressor	22 (3.7)	31 (5.2)	.206*
Arterial blood pressure monitoring	583 (98.1)	588 (99.0)	.222*
Central venous pressure monitoring	450 (75.8)	435 (73.2)	.318*
Cardiac output monitoring	351 (59.1)	436 (73.4)	<.001*
Length of hospital stay	14.88 ± 8.89	15.66 ± 13.86	.589†
Postoperative 30-d mortality	5 (0.8)	5 (0.8)	1.000*
Cardiovascular risk score‡	2.29 ± .51	2.29 ± .52	.680†

Values are presented as either n (%) or mean ± standard deviation.

*Chi-square test.

†Mann-Whitney *U* test.

‡Cardiovascular risk score = number of conditions shown by the patient among 4 inclusion criteria (hypertension, diabetes mellitus, age >70 yr, cardiac disease).

Table 3

Postoperative complications.

	Echo group (n = 594)	Non-echo group (n = 594)	*P* value
Overall	23 (3.9)	21 (3.5)	.759*
Uncontrolled hypertension	1 (0.2)	5 (0.8)	.218†
Severe arrhythmia	9 (1.5)	5 (0.8)	.282*
Acute heart failure	2 (0.3)	2 (0.3)	1.000†
Acute coronary syndrome	2 (0.3)	3 (0.5)	1.000†
Pulmonary thromboembolism	3 (0.5)	0 (0.0)	.249†
Nonfatal cardiac arrest	1 (0.2)	1 (0.2)	1.000†
Cardiac death	5 (0.8)	5 (0.8)	1.000*

Values are presented as n (%).

*Chi-square test.

†Fisher exact test.

Table 4

Subgroup analysis of the echo group with CO monitor versus without CO monitor.

	With CO monitor (n = 351)	Without CO monitor (n = 243)	*P* value
Left ventricular ejection fraction	62.59 ± 6.74	64.28 ± 4.15	.007*
Valvular heart disease	239 (40.2)	130 (21.9)	<.001†
Regional wall motion abnormality	25 (4.2)	3 (0.5)	.001‡
Relaxation abnormality	275 (46.3)	164 (27.6)	.003†
Age	74.23 ± 7.52	71.32 ± 7.84	<.001*
Sex			.828†
F	137 (39.0)	97 (39.9)	
M	214 (61.0)	146 (60.1)	
Height (cm)	160.11 ± 9.13	159.80 ± 9.29	.684*
Weight (kg)	62.50 ± 11.94	62.80 ± 11.83	.719*
BMI (kg/m^2)	24.30 ± 3.62	24.49 ± 3.51	.386*
ASA class	2.49 ± .53	2.30 ± .46	<.001*
Operation name			.061†
Gastrointestinal surgery	286 (81.5)	212 (87.2)	
Urologic surgery	65 (18.5)	31 (12.8)	
Hypertension	283 (80.6)	214 (88.1)	.016†
DM	162 (46.2)	128 (52.7)	.118†
Previous cardiac disease	81 (23.1)	25 (10.3)	<.001†
Intraoperative hypotension	47 (7.9)	26 (4.4)	.326†
Use of vasopressor	13 (2.2)	9 (1.5)	1.00†
Cardiovascular risk score§	2.33 ± .53	2.24 ± .48	.036*

Values are presented as either n (%) or mean ± standard deviation.

ASA = American Society of Anesthesiologists, BMI = body mass index, CO = cardiac output, DM = diabetes mellitus.

*Mann-Whitney *U* test.

†Chi-square test.

‡Fisher exact test.

§Cardiovascular risk score = number of conditions shown by the patient among 4 inclusion criteria (hypertension, DM, age > 70 years, cardiac disease).

4. Discussion

In this retrospective study, the effect of performing preoperative echocardiography on intraoperative anesthetic management and postoperative outcomes was investigated in patients expected to have a relatively high perioperative cardiovascular risk. Each hospital may have different standards for performing preoperative echocardiography. Many hospitals may also conduct tests without any clear criterion. In 2013, the British Society of Echocardiography guidelines clarified the following 4 indications of echocardiography for elective and semi-urgent surgery[1]: documented ischemic heart disease with reduced functional capacity, unexplained shortness of breath in the absence of clinical signs of heart failure and abnormal electrocardiogram and/or chest radiography findings, murmur in the presence of cardiac or respiratory symptoms, and murmur in an asymptomatic individual in whom clinical features or other investigations suggest severe structural heart disease. The more recent guidelines published in 2014 by the American College of Cardiology/American Heart Association recommend echocardiography for patients with clinically suspected moderate or greater degrees of valvular stenosis or regurgitation.[3] Importantly, in previous studies, authors have pointed out that routine preoperative echocardiography should not be recommended.[1–3] This was also considered in this study; therefore, patients who were expected to have a high risk of cardiac events were included and analyzed. However, to understand all the risk factors of patients suggested in previous guidelines, detailed recording of patient history and physical examination by an experienced doctor are essential. In hospitals where the number of doctors is less than needed, diagnosis of such patients is difficult. Therefore, in our hospital, through consultation with cardiologists, the criteria for performing echocardiography before surgery have been simplified to satisfy 2 or more of the following: age ≥70 years, hypertension, DM, and history of cardiac disease.

Previous studies have demonstrated that these criteria increase the risk of cardiovascular complications after surgery.[9,10]

We expected that there would be a significant difference in the postoperative results between the 2 groups according to whether preoperative echocardiography was performed, because we thought that preoperative echocardiography would enable better treatment provision to patients with similar cardiac risks and lead to better postoperative outcomes. However, contrary to expectations, there were no significant differences in outcomes such as postoperative 30-day mortality, incidence of postoperative complications, and length of hospital stay. In addition, there was no difference between the 2 groups in the incidence of hypotension and the use of vasopressors during surgery. However, these results cannot be the basis for determining whether preoperative echocardiography is meaningless. Perhaps, the 4 considered inclusion criteria were insufficient to determine the need of preoperative echocardiography. Echocardiographic parameters have been known to influence postoperative outcomes. However, studies have shown that echocardiographic parameters do not have any additional effect on prognosis after surgery in patients with known or low cardiac risk. Halm et al[11] demonstrated that echocardiographic measurements do

not add any prognostic value to known clinical risk factors. Another study examined 570 and 3745 patients in whom preoperative TTE was and was not performed, respectively. In this study, if systolic dysfunction, moderate-to-severe hypertrophy or mitral regurgitation, or aortic stenosis was detected in moderate-to-high-risk patients, such patients were found to exhibit a 4-fold increase in the incidence of cardiac events. However, echocardiography did not add any value in low-risk patients.[12] Therefore, preoperative echocardiography is important because it can detect those cardiac abnormalities that were not detected before surgery, and the associated risks can be explained to patient beforehand, rather than reducing the risk after surgery.

Interestingly, this study showed that more extensive intraoperative CO monitoring was performed in the non-echo group than in the echo group. This result contrasts with our expectations that the echo group would have better outcomes and more extensive interventions during surgery. Intraoperative CO monitoring is mainly used for stable hemodynamic monitoring during surgery in high-risk patients.[13,14] The reason for these paradoxical results could be that cardiac risk during surgery could not be adequately determined in the non-echo group. Therefore, detailed monitoring was performed to ensure patient safety during surgery. For investigating these data in detail, the echo group was divided into 2 subgroups according to whether CO monitoring was performed. The result showed that LVEF was significantly lower in the group with CO monitoring. LVEF is an index that reflects the contractility of the left ventricle, which can be measured using echocardiography. It is the most basic index when evaluating cardiac function and also used to predict cardiovascular risk.[15] Patients with a reduced LVEF on preoperative echocardiography may have an increased risk of perioperative complications.[16,17] Additionally, the incidence of valvular dysfunction, regional wall motion abnormality, and relaxation abnormality of LV was significantly higher in the group with CO monitoring. These results can probably be interpreted as an anesthesiologists tended to attempt additional monitoring when the LVEF was lower or other echocardiographic findings were poor. Although it is difficult to determine whether each one is significant as an independent cause of CO monitoring since they often present together with more than one, it seems to be clear that factors influence the decisions of anesthesiologists. Intraoperative hypotension and use of vasopressor increased slightly in the CO monitoring group, but there was no statistically significant difference. This suggests that decisions on CO monitoring were made based on information obtained before surgery rather than secondary to intraoperative events. Although performing preoperative echocardiography does not directly improve postoperative results, changes in intraoperative anesthetic management may be required based on the results of echocardiography. Previous studies have shown that, for patients diagnosed with uncorrected severe aortic stenosis, doctors put more effort into invasive hemodynamic monitoring, prompt hypotension treatment, volume status optimization, and sinus rhythm maintenance during surgery.[18]

Our study has several limitations. First, this is a retrospective study. Therapeutic intervention can have a specific effect on outcomes such as patient mortality and morbidity, whereas diagnostic tests yield unexpected results for each examined patient. Therefore, it is not easy to prove the effect of preoperative echocardiography, a diagnostic test, performed during or after surgery through a randomized controlled study.[19] Therefore, we retrospectively analyzed the echo and non-echo groups, both including patients with cardiovascular risk, to investigate the effect on postoperative outcomes. The quality of the study was improved by adding propensity score matching to the retrospectively obtained data.[20] Second, only patients who had undergone abdominal surgery were enrolled in this study. Vascular surgery has the highest cardiovascular risk of >5% among all non-cardiac surgeries.[21] However, abdominal surgery also has a moderate-to-high cardiovascular risk (1%–5%). Since abdominal surgery accounts for most surgeries in our hospital, we expected that most patient complications could be analyzed. Third, we did not conduct detailed analysis of results according to echocardiographic findings. Because this study did not intend to find the difference in outcomes according to echocardiographic findings. Finally, it was impossible to select patients by assessing all patient histories and physical examinations. The factors that increase perioperative cardiovascular risk are diverse. Therefore, it is almost impossible to consider all these factors, and therefore, the inclusion criteria of this study were established after considerable simplification. Efforts to identify the indications of preoperative echocardiography for better risk stratification should continue.

This study aimed to determine the difference in intraoperative anesthetic management and postoperative outcomes between the groups that did and did not undergo echocardiography, both including patients with cardiovascular risks, in an actual clinical environment. We found that preoperative echocardiography did not affect postoperative outcomes such as 30-day mortality and incidence of postoperative cardiovascular complications. However, we found that preoperative echocardiography could affect intraoperative anesthetic management and findings on intraoperative invasive hemodynamic monitoring such as CO monitoring. Further research is needed to determine how these behavioral changes might affect postoperative outcomes.

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