Usefulness of Surgical Parameters as Predictors of Postoperative Cardiac Events in Patients Undergoing Non-Cardiac Surgery

Myung Hwan Bae, MD; Jang Hoon Lee, MD; Dong Heon Yang, MD; Hun Sik Park, MD; Yongkeun Cho, MD; Shung Chull Chae, MD

Background: Postoperative cardiac events are an important cause of morbidity and mortality in patients undergoing non-cardiac surgery. Predictive values of surgical parameters with respect to development of postoperative cardiac events have not been well investigated.

Methods and Results: This study included 1,016 consecutive patients who underwent cardiac consultation prior to elective non-cardiac surgery. A major adverse cardiac event (MACE) was defined as a composite of all-cause death, non-fatal myocardial infarction, and pulmonary edema within 30 days of surgery. There were 95 postoperative MACEs (9.4%). Patients with postoperative MACE were significantly older, and had significantly higher revised cardiac risk index than those without. ST-T change on electrocardiogram (ECG) was significantly higher in patients with postoperative MACE. Of the surgical parameters, significant differences in surgery time (317±211 min vs. 189±112 min, $P<0.001$), postoperative hemoglobin (10.7±1.9 g/dl vs. 11.3±1.8 g/dl, $P=0.007$), risk of surgery ($P<0.001$), and transfusion (37.6% vs. 6.6%, $P<0.001$) were observed between the 2 groups. On multivariate logistic regression analysis, surgery time (odds ratio [OR], 1.004; 95% confidence interval [CI]: 1.003–1.006, $P<0.001$) and need for transfusion (OR, 4.578; 95% CI: 2.599–8.065, $P<0.001$), as well as age and ST-T change on ECG were independent predictors of postoperative MACE.

Conclusions: Surgical parameters, including surgery time and transfusion, can strongly predict development of postoperative MACE in patients undergoing non-cardiac surgery. (Circ J 2014; 78: 718–723)

Key Words: Myocardial infarction; Pulmonary edema; Surgery
Surgical Indicators of Postoperative Cardiac Events

low-risk surgery, endoscopic procedures, superficial procedures, cataract surgery, breast surgery, and ambulatory surgery. Surgical parameters, including type of anesthesia, surgery time, need for transfusion during surgery, and level of postoperative hemoglobin were also evaluated.

A major adverse cardiac event (MACE) was defined as a composite of all-cause death, non-fatal MI, and pulmonary edema within 30 days after surgery. MI was diagnosed on characteristic clinical presentation, serial changes on ECG suggesting infarction, and increases in cardiac enzymes. Postoperative pulmonary edema was defined as new rales noted during clini-

CVD; and vascular surgery. Echocardiography was performed before surgery at the discretion of the attending physicians. Prehospital medications, including aspirin, β-blocker, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker, statin, and diuretics were also entered into the analysis.

Risk of surgical procedures was based on the American College of Cardiology (ACC)/American Heart Association (AHA) guidelines, as follows: high-risk surgery, aortic and other major or peripheral vascular surgery; intermediate-risk surgery, intraperitoneal and intrathoracic surgery, carotid endarterectomy, head and neck surgery, orthopedic and prostatic surgery; and vascular surgery. Echocardiography was performed before surgery at the discretion of the attending physicians. Prehospital medications, including aspirin, β-blocker, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker, statin, and diuretics were also entered into the analysis.

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tical examination, with a chest X-ray showing worsening peripheral vascular congestion or edema.¹²

**Statistical Analysis**

Data are expressed as mean±SD for continuous variables and as percentages for categorical variables. For comparisons between baseline variables, Student’s t-test was used for continuous variables and Pearson’s Chi-squared test was used for categorical variables. A multivariate logistic regression model was used for identification of independent predictors of postoperative MACE.

Receiver operating characteristic (ROC) curve analysis was performed for determination of cut-off values for prediction of postoperative MACE. For all analyses, 2-sided P<0.05 was considered statistically significant. Statistical analysis was performed using SPSS® version 15.0 for Windows® (SPSS, Chicago, IL, USA).

**Results**

Baseline characteristics of the 1,016 patients are listed in Table 1. Mean patient age was 66.6±12.5 years and 578 (56.9%) were male. History of IHD, diabetes, CHF, CVD, and renal insufficiency were noted in 25.4% (n=258), 24.3% (n=247), 12.1% (n=123), 7.6% (n=77), and 4.9% (n=50), respectively. Mean RCRI was 0.81±0.96, and RCRI was 0, 1, 2, and ≥3 in 47.6% (n=484), 31.4% (n=319), 15.2% (n=154), and 5.8% (n=59), respectively. Echocardiography was performed in 891 patients. Mean left ventricular ejection fraction (LVEF) and E/E’ were 56.8±9.3% and 12.4±4.7, respectively, and LVEF was ≤50% in 14.2% (n=126), and E/E’ was >15 in 21.9% (n=178). Among ECG parameters, pathological Q wave, atrial fibrillation (AF), and ST-T changes were present in 9.8% (n=99), 12.3% (n=124), and 24.3% (n=245), respectively.

Table 2 lists the surgical characteristics of the study subjects. Intermediate-risk surgery (n=859) and general anesthesia (n=840) were performed most often. Mean surgery time was 201±130 min and 93 patients (9.5%) received transfusion during the operation. There were 95 (9.4%) postoperative MACEs; 8 (0.8%) all-cause deaths, 13 (1.3%) non-fatal MIs, and 74 (7.3%) pulmonary edemas not caused by acute MI (Table 3). Five deaths were attributed to cardiovascular events (MI, n=1; infective endocarditis, n=1; aggravated CHF, n=1; pulmonary embolism, n=1; and sudden cardiac death, n=1), and the other 3 deaths to postoperative complications. Aggravation of the previous CHF, stress and/or tachycardia-induced cardiomyopathy, diastolic dysfunction, AF, and underlying valvular disease were found to be common causes of postoperative pulmonary edema.

Patients with a postoperative MACE were older (Table 1). No difference in gender, BMI, current smoking status, previous history of hypertension, diabetes, hyperlipidemia, IHD, or CHF was observed between the 2 groups. Previous CVD was
more common, and mean RCRI was significantly higher in patients with postoperative MACE. No difference in preoperative hemoglobin and creatinine was observed between the 2 groups. No significant intergroup differences were found in the mean LVEF or E/E’ or the prevalence of LVEF ≤50% and E/E’ >15. For ECG parameters, ST-T change was more common in patients with postoperative MACE. No significant intergroup differences were observed, however, in QRS duration, or prevalence of pathological Q wave, left ventricular hypertrophy, AF, and right or left bundle branch block. No differences in preoperative medications were observed between the 2 groups.

Patients with postoperative MACE underwent high-risk surgery more often (13.7% vs. 5.9%, P=0.003) and underwent low-risk surgery less often (2.1% vs. 9.6%, P=0.015). These patients had a significantly longer mean surgery time (317±211 min vs. 189±112 min, P<0.001), and more of them underwent transfusion during surgery (37.6% vs. 6.6%, P<0.001). In addition, their postoperative hemoglobin was significantly lower (10.7±1.9 g/dl vs. 11.3±1.8 g/dl, P=0.008).

On multivariate logistic regression analysis, surgery time (odds ratio [OR], 1.004; 95% confidence interval [CI]: 1.003–1.006, P<0.001), transfusion during surgery (OR, 4.578; 95% CI: 2.599–8.065, P<0.001), age (OR, 1.042; 95% CI: 1.016–1.067, P=0.001), and ST-T change on ECG (OR, 1.766; 95% CI: 1.048–2.977, P=0.033) were independent predictors of postoperative MACE (Table 4).

The area under the ROC curve for prediction of postoperative MACE was 0.693 (95% CI: 0.631–0.755) for surgery time (Figure 1), and sensitivity and specificity for prediction of postoperative MACE using the optimal cut-off for surgery time (235 min) were 59.3% and 73.3%, respectively.

Significantly higher prevalence of high-risk surgery (14.8% vs. 2.9%, P<0.001) and general anesthesia (92.4% vs. 79.1%, P<0.001), and transfusion during surgery (20.8% vs. 5.2%, P<0.001) were observed in patients with longer surgery times. When patients with surgery time ≤235 min were analyzed separately, age was significantly older and RCRI was significantly higher in patients with MACE. Among echocardiographic parameters, LVEF was significantly lower and E/E’ ≥15 was more common in patients with MACE. In addition, ST-T change on ECG and transfusion during surgery were more common in patients with MACE. In patients with surgery time ≥235 min, however, no significant differences in age, RCRI, ECG, and echocardiographic findings (including LVEF and E/E’) were observed between patients with and without postoperative MACE (Figure 2).

### Discussion

The main finding of this study is that surgical parameters, such as surgery time and blood transfusion during surgery, were independent predictors of postoperative MACE in patients undergoing non-cardiac surgery. When they were included in the predictive model, conventional risk factors such as RCRI and echocardiographic parameters did not have predictive value. These conventional risk factors may have predictive value only in patients with a relatively short surgery time.

Postoperative cardiac events such as acute coronary syndrome, heart failure, or serious arrhythmias are the main causes of morbidity and mortality in patients undergoing non-cardiac surgery. Clinical and echocardiographic parameters as well as biomarkers have been suggested for prediction of postoperative cardiac events. The RCRI is composed of clinical and laboratory findings, including diabetes, IHD, CVD, CHF, and renal insufficiency, and has been used in stratification of cardiac risk before surgery. In the clinical setting, however, RCRI is limited in terms of its ability to identify patients with a high cardiac risk; therefore, several authors have suggested modifications. In a recent study, it was suggested that the predictive power of RCRI would be strengthened by the addition of NT-proBNP and C-reactive protein. In our previous study, we also found that the combination of RCRI and fragmented QRS on ECG was more powerful than RCRI itself for cardiac risk stratification in patients undergoing non-cardiac vascular surgery. Echocardiography is commonly performed for cardiac evaluation before surgery, and several studies have reported that LVEF and/or E/E’ were predictive of postoperative heart failure and death. The majority of these studies, however,

### Table 4. Predictors of Postoperative MACE

<table>
<thead>
<tr>
<th>Predictor</th>
<th>OR</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (per year)</td>
<td>1.042</td>
<td>1.016–1.067</td>
<td>0.001</td>
</tr>
<tr>
<td>Revised cardiac risk index</td>
<td>1.191</td>
<td>0.942–1.504</td>
<td>0.144</td>
</tr>
<tr>
<td>ST-T change on ECG</td>
<td>1.766</td>
<td>1.048–2.977</td>
<td>0.033</td>
</tr>
<tr>
<td>Surgery time (per min)</td>
<td>1.004</td>
<td>1.003–1.006</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Transfusion during surgery</td>
<td>4.578</td>
<td>2.599–8.065</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

CI, confidence interval; ECG, electrocardiogram; OR, odds ratio. Other abbreviation as in Table 1.

![Figure 1. Receiver operating characteristic curve analysis of surgery time for prediction of postoperative major adverse cardiac event. AUC, area under the curve; CI, confidence interval.](image-url)
operative MACE. These results suggest that if a patient has poor surgical factors, such as a large amount of surgical bleeding and subsequent blood transfusion or a long surgery time, he/she is at risk of a postoperative cardiac event, regardless of the results of preoperative evaluation. Conversely, it is possible that efforts by surgeons to decrease surgery time and blood loss would reduce the risk of postoperative cardiac events in patients at high risk.

The current study has several limitations that warrant consideration. First, we did not have data on hemoglobin level immediately before blood transfusion or on precise amount of surgical blood loss. In addition, because blood specimens might be sampled after blood transfusion in some patients, postoperative hemoglobin level suggested in this study is likely to be higher than in real patients. For this reason, postoperative hemoglobin was not included in the multivariate analysis. We believe, however, that it does not affect the present conclusions. Second, we did not evaluate cardiac biomarkers such as NT-proBNP, a recently identified predictor of postoperative cardiac events. This, however, is a prohibitively expensive laboratory test and has not been used routinely for preoperative cardiac evaluation. Third, only approximately 40% of patients with postoperative cardiac MACE underwent echocardiography; thus, we were unable to determine the precise etiology of newly developed CHF in some patients.

Conclusions

Surgical parameters, including surgery time and blood transfusion during surgery, were found to be independent predictors of postoperative MACE in patients undergoing non-cardiac surgery.

References

2. JCS Joint Working Group. Guidelines for perioperative cardiovascu-
lar evaluation and management for noncardiac surgery (JCS 2008): 

M, et al. Significance of coronary vasospasm in the perioperative 

4. Healy KO, Waksmenson CA, Alman RK, Stetson PD, Reyetovich A, 
Maurer MS. Perioperative outcome and long-term mortality for heart 
failure patients undergoing intermediate- and high-risk noncardiac sur-
gery: Impact of left ventricular ejection fraction. Congest Heart Fail 
2010; 16: 45–49.

5. Lee TH, Marcantonio ER, Mangione CM, Thomas EJ, Polanczyk CA, 
et al. Derivation and prospective validation of a simple index for 
prediction of cardiac risk of major noncardiac surgery. Circulation 
1999; 100: 1043–1049.

6. Schouten O, Bax JJ, Poldermans D. Preoperative cardiac risk assess-
ment in vascular surgery patients: Seeing beyond the perioperative 

7. Choi JH, Cho DK, Song YB, Hahn JY, Choi S, Gwon HC, et al. Pre-
operative NT-proBNP and CRP predict perioperative major cardio-

parison of transthoracic echocardiography with N-terminal pro-brain 
natriuretic peptide as a tool for risk stratification of patients undergo-

J, et al. Impact of ejection fraction on long-term outcome after elec-
tive aortic valve replacement in octogenarians with aortic stenosis. 

10. Fleisher LA, Beckman JA, Brown KA, Calkins H, Chaikof E, 
Fleischmann KE, et al; ACC/AHA Task Force Members. ACC/AHA 
2007 Guidelines on Perioperative Cardiovascular Evaluation and 
Care for Noncardiac Surgery: Executive Summary: A report of the 
American College of Cardiology/American Heart Association Task 
Force on Practice Guidelines (Writing Committee to Revise the 2002 
Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac 
Surgery): Developed in collaboration with the American Society of 
Echocardiography, American Society of Nuclear Cardiology, Heart 
Rhythm Society, Society of Cardiovascular Anesthesiologists, Society 
for Cardiovascular Angiography and Interventions, Society for Vascular 

the diagnosis of acute myocardial infarction: Implications for prac-


13. Kim SE, Park DG, Lee JH, Han KR, Oh DJ. Utility of B-type natri-
uretic peptide for predicting perioperative cardiovascular events in 
patients without history of cardiovascular disease undergoing major 

14. Parmar CD, Torella F. Prediction of major adverse cardiac events in 
vascular surgery. Are cardiac risk scores of any practical value? Vasc 
Endovasc Surg 2010; 44: 14–19.

implications of a fragmented QRS complex and newly reclassified 
revised cardiac risk index including fragmented QRS in patients un-
dergoing non-cardiac vascular surgery. Int J Cardiol 2012; 157: 276– 
278.

R, et al. Association between intraoperative blood transfusion and 
mortality and morbidity in patients undergoing noncardiac surgery. 
Anesthesiology 2011; 114: 283–292.

17. Kuduvalli M, Oo AY, Newall N, Grayson AD, Jackson M, Desmond 
MJ, et al. Effect of peri-operative red blood cell transfusion on 30-day 
and 1-year mortality following coronary artery bypass surgery. Eur J 

Limit to cardiac compensation during acute isovolemic hemodilution: 


DP, Wisselink W, et al. Effect of fluid loading with saline or colloids 
on pulmonary permeability, oedema and lung injury score after car-

21. Aman J, Groeneveld AB, van Nieuw Amerongen GP. Predictors of 
pulmonary edema formation during fluid loading in the critically ill 

22. Bainbridge D, Martin J, Arango M, Cheng D; Evidence-based Peri-
operative Clinical Outcomes Research (EPiCOR) Group. Periopera-
tive and anaesthetic-related mortality in developed and developing 
countries: A systematic review and meta-analysis. Lancet 2012; 380: 
1075–1081.

23. Pedersen T. Complications and death following anaesthesia. A prospec-
tive study with special reference to the influence of patient-, anaes-
thesia-, and surgery-related risk factors. Dan Med Bull 1994; 41: 
319–331.

24. Leppo JA. Preoperative cardiac risk assessment for noncardiac sur-
gery. Am J Cardiol 1995; 75: 42D–51D.