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# Prediction of Atrial Fibrillation After Off-Pump Coronary Artery Bypass Grafting Using Preoperative Total Atrial Conduction Time Determined on Tissue Doppler Imaging

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***Background:*** Postoperative atrial fibrillation (POAF) is a common complication of cardiac surgery and results in increased health-care utilization. This study identified new transthoracic echocardiographic predictors of POAF using an index of the total atrial conduction time derived on tissue Doppler imaging (PA-TDI duration) in patients undergoing off-pump coronary artery bypass grafting (OPCAB).

***Methods and Results:*** A total of 88 patients undergoing isolated OPCAB were enrolled. They were examined preoperatively on transthoracic echocardiography with tissue Doppler evaluations and monitored postoperatively with continuous electrocardiographic telemetry for 7 days. POAF occurred in 35 patients (39.8%). Patients with POAF had a significantly longer duration of hospital stay than those without (44.9±6.2 vs. 37.3±3.3 days, P=0.04). Multivariate analysis showed that PA-TDI duration (odds ratio [OR], 1.11; 95% confidence interval [CI]: 1.06–1.16; P=0.0001) and left atrial volume index (LAVI; OR, 1.11; 95% CI: 1.02–1.20; P=0.01) were independent predictors of POAF. Moreover, PA-TDI duration was more reliable, given an area under the receiver operating characteristic curve of 0.85 (sensitivity, 74.3%; specificity, 86.8%).

***Conclusions:*** PA-TDI duration was an independent predictor of POAF following OPCAB. Awareness of risk of POAF may lead to the prevention of POAF, a rapid response to POAF, shortened hospital stay, and improved prognosis. (*Circ J* 2014; **78:** 345–352)

**Key Words:** Atrial fibrillation; Off-pump coronary artery bypass grafting; PA-TDI duration

Atrial fibrillation (AF) after elective coronary artery bypass grafting (CABG) is the most common cardiac arrhythmia, occurring in 30–50% of patients.[1] Although postoperative AF (POAF) after on-pump CABG is benign and self-limiting in most cases, in some cases, it can cause stroke or congestive heart failure and may lead to prolonged hospital stay, increased cost, additional concomitant treatment, and worsened prognosis.[2–4] Therefore, prophylactic therapies with $\beta$-blockers, amiodarone, or atrial pacing have been used in order to reduce POAF and accompanying complications.[5–8] These prophylactic treatments, however, are not always effective in all patients undergoing CABG and may cause unfavorable side-effects. Identifying patients at high risk of developing POAF before they undergo off-pump CABG (OPCAB) and intervening with POAF therapy would be very valuable for improving the prognosis in these patients. OPCAB is a valuable skill-set and technique for performing coronary revascularization. Its benefits are most apparent in patients with a higher risk of complications from cardiopulmonary bypass and aortic manipulation.[9] More than half of isolated CABG procedures have been performed in Japan.

Recently, an easy and non-invasive echocardiographic parameter based on tissue Doppler imaging (TDI) has been reported to provide an estimation of total atrial conduction time

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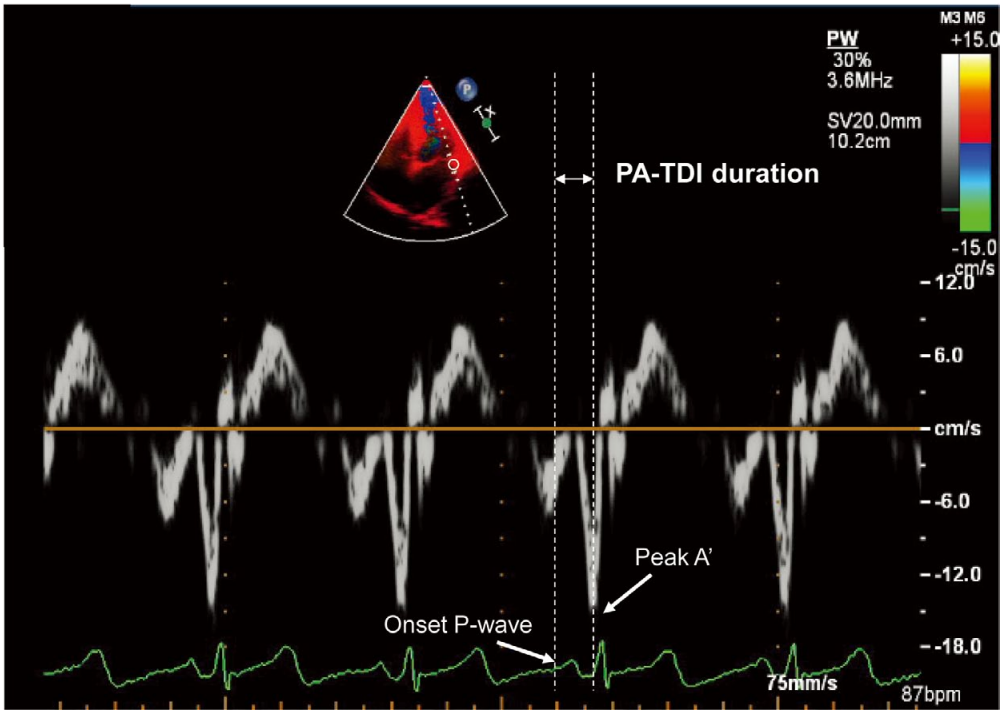


**Figure 1.** Measurement of total atrial conduction time (PA-TDI duration). A sample volume is placed on the lateral wall of the left atrium just above the mitral valve. PA-TDI duration is the time from the onset of the P wave on surface electrocardiogram to the peak of the A' wave on the velocity graph (white arrow).

(TACT). Merckx et al showed that the time interval from the beginning of the P wave on electrocardiogram (ECG) to the peak of the A' lateral wave on TDI (PA-TDI duration) provided a good estimation of TACT.[10] In addition, de Vos et al found a strong association between PA-TDI duration and new-onset AF.[11] The efficiency of PA-TDI duration in predicting POAF in patients undergoing OPCAB, however, remains unknown. The aim of the present study was to investigate the prognostic value of PA-TDI duration in predicting AF after OPCAB.

## Methods

### Subjects

Patients undergoing their first elective isolated OPCAB without concurrent valve surgery at Hiroshima University between February 2009 and January 2012 were enrolled. The exclusion criteria were as follows: prior cardiac surgery; emergency surgical procedure; acute coronary syndrome; prior myocardial infarction; congestive heart failure; significant valvular heart disease; prior implantation of a permanent pacemaker, implantable cardioverter defibrillator, or cardiac resynchronization therapy defibrillator converted to a standard on-pump procedure; and use of class I or class III anti-arrhythmic agents. The patients were also excluded if they were not in sinus rhythm during echocardiography. As a result, a total of 88 patients were retrospectively studied. The institutional review board approved the study to retrospectively use the data of the patients. All patients underwent 12-lead ECG, transthoracic echocardiography, and coronary angiography before OPCAB. All patients were monitored with continuous ECG telemetry and underwent 12-lead ECG every day for 1 week following OPCAB. A patient was determined to have AF when it lasted >5 min. Cardiologists in the cardiovascular intensive care unit, who were not informed of the study, confirmed the diagnosis of AF and initiated prompt treatment. We retrospectively compared several clinical, ECG, and echocardiographic parameters in patients with and without POAF.

### Echocardiography

Transthoracic echocardiography, including 2-D, M-mode, pulsed wave, continuous wave, color flow, and TDI, were performed in all patients using iE33 (Philips Medical Systems, Best, The Netherlands) equipped with a 3.5-MHz transducer at a depth of 16 cm. All patients were imaged in the left lateral decubitus position. 2-D and color Doppler data were obtained in the parasternal short- and long-axis views and the apical 2- and 4-chamber views according to the American Society of Echocardiography guidelines.[12] The left ventricular (LV) diameter and wall thickness were measured on 2-D echocardiography. The parameters of the mitral valve inflow pattern (E wave, A wave, E wave deceleration time, and E/A ratio) were measured on pulsed wave Doppler. LV ejection fraction was calculated from the apical 2- and 4-chamber views at end-diastole and end-systole using Simpson's method.[12] The left atrial (LA) volumes were measured during 2 phases of the cardiac cycle: LA maximum volume during the end-systolic phase (just before mitral valve opening) and LA minimum volume during the end-diastolic phase (just before mitral valve closure), and were then calculated using the method of disks.[12] The LA volume index (LAVI) was calculated by dividing the maximum LA volume by the body surface area (calculated

**Table 1. Baseline Patient Characteristics vs. Presence of POAF**

| | POAF+ (n=35) | POAF– (n=53) | P-value |
|---|---|---|---|
| **Clinical Characteristics** | | | |
| Age (years) | 68.5±9.6 | 66.2±9.9 | 0.27 |
| Male gender | 14 (89) | 45 (85) | 0.62 |
| BSA ($m^2$) | 1.62±0.17 | 1.67±0.23 | 0.30 |
| BMI ($kg/m^2$) | 22.4±3.8 | 24.3±4.3 | 0.04 |
| History of PAF | 4 (11) | 7 (13) | 0.81 |
| Hypertension | 28 (80) | 39 (73) | 0.49 |
| Diabetes | 20 (57) | 32 (60) | 0.76 |
| COPD | 3 (9) | 3 (6) | 0.60 |
| Hemodialysis | 4 (11) | 7 (13) | 0.81 |
| Hyperlipidemia | 20 (57) | 35 (66) | 0.40 |
| Smoker | 12 (34) | 29 (29) | 0.06 |
| Grafts, n | 2.9±0.8 | 3.0±1.1 | 0.55 |
| Right atrial pacing after the operation | 14 (40) | 18 (34) | 0.65 |
| **Medications** | | | |
| **Preoperative medications** | | | |
| ACEI/ARB | 28 (80) | 13 (25) | 0.11 |
| Calcium channel blocker | 6 (17) | 10 (19) | 0.84 |
| $\beta$-blocker | 8 (23) | 13 (25) | 0.86 |
| Statins | 23 (66) | 34 (64) | 0.88 |
| **Intraoperative medications** | | | |
| Dopamine | 31 (89) | 51 (96) | 0.16 |
| Dobutamine | 8 (23) | 7 (13) | 0.24 |
| Noradrenaline | 34 (97) | 48 (91) | 0.23 |
| Efedorin | 28 (80) | 45 (85) | 0.99 |
| Mirislol | 35 (100) | 53 (100) | NS |
| Diltiazem | 23 (66) | 37 (70) | 0.69 |
| Nicorandil | 1 (3) | 0 (0) | 0.22 |
| Landiolol | 12 (34) | 22 (42) | 0.50 |
| Nicardipine | 14 (40) | 31 (58) | 0.09 |
| Carperitide | 3 (9) | 2 (4) | 0.34 |
| Olprinone | 1 (3) | 0 (0) | 0.22 |
| **Postoperative medications** | | | |
| Dopamine | 35 (100) | 53 (100) | NS |
| Dobutamine | 11 (31) | 18 (34) | 0.81 |
| Mirislol | 34 (97) | 52 (98) | 0.77 |
| Diltiazem | 4 (11) | 7 (13) | 0.85 |
| Nicorandil | 3 (9) | 6 (11) | 0.68 |
| Nicardipine | 17 (49) | 11 (21) | 0.006 |
| Carperitide | 10 (29) | 13 (25) | 0.67 |
| Prostaglandin | 3 (9) | 2 (4) | 0.34 |

Data given as mean ± SD or n (%).
POAF, postoperative atrial fibrillation; BSA, body surface area; BMI, body mass index; PAF, paroxysmal atrial fibrillation; COPD, chronic obstructive pulmonary disease; ACEI, angiotensin-converting enzyme inhibitor; ARB, angiotensin-II receptor blocker.

using the Fujimoto formula using body height and weight). LV mass was measured using the area-length formula.[12] The LV mass was indexed to the body surface area. Mitral regurgitation severity was graded on a 0–4 scale.[13] TDI was performed with transducer frequencies of 3.5–4.0 MHz by adjusting the spectral pulsed Doppler signal filters to acquire the Nyquist limit of 15–20 cm/s and using the minimal optimal gain. Spectral pulsed Doppler was used to measure myocardial TDI velocities (early diastolic [Em] and late diastolic velocities [Am]) for the LV lateral wall from the apical 4-chamber view. The PA-TDI interval was defined as the time interval from the initiation of the ECG P wave recorded by the echo machine (lead II) to the peak of the A' wave of atrial tissue Doppler tracing (**Figure 1**).[10] The PA-TDI interval was measured in the 3 other cardiac cycles and averaged. Clinical echocardiographic evaluation on transthoracic echocardiography and transesophageal echocardiography was performed <5 days before surgery. Experienced echocardiographers conducted all echocardiographic examinations and analyzed the echocardiographic parameters. The independent of investigators who analyzed the clinical information performed the echocardiogram. We assessed the reproducibility of PA-TDI measurements. Twenty patients were randomly selected to determine intraclass correlation coefficients (ICC) for PA-TDI duration measurements. ICC (2,1) in

**Table 2. Electro/Echocardiographic Parameters vs. Presence of POAF**

| | POAF+ (n=35) | POAF– (n=53) | P-value |
|---|---|---|---|
| **Electrocardiogram** | | | |
| P duration (ms) | 114.9±13.3 | 112.2±11.0 | 0.29 |
| **Echocardiography** | | | |
| Aorta diameter (mm) | 31.9±3.7 | 30.7±3.9 | 0.15 |
| LA dimension (mm) | 40.8±6.7 | 38.0±6.3 | 0.05 |
| LV end-diastolic dimension (mm) | 50.7±7.7 | 49.2±5.9 | 0.32 |
| LV end-systolic dimension (mm) | 36.7±9.7 | 34.5±6.9 | 0.26 |
| Interventricular septum thickness (mm) | 9.6±1.8 | 9.6±1.7 | 0.99 |
| Posterior wall thickness (mm) | 9.7±1.6 | 9.6±2.0 | 0.80 |
| E wave (m/s) | 70.7±22.2 | 66.2±16.0 | 0.28 |
| A wave (m/s) | 78.1±22.1 | 81.7±22.0 | 0.46 |
| E/A ratio | 0.91±0.27 | 0.89±0.29 | 0.47 |
| Deceleration time (ms) | 230.9±57.7 | 222.8±53.3 | 0.51 |
| LA volume (ml) | 64.6±26.1 | 51.2±17.6 | 0.006 |
| LAVI (ml/m$^2$) | 41.1±16.4 | 31.8±10.6 | 0.005 |
| LV ejection fraction (%) | 56.8±20.8 | 56.7±10.9 | 0.99 |
| LV mass index (g/m$^2$) | 87.0±28.1 | 86.1±29.2 | 0.90 |
| MR | | | 0.17 |
| Grade 0 | 5 (14) | 14 (26) | |
| Grade 1 | 27 (77) | 38 (72) | |
| Grade 2 | 3 (9) | 1 (2) | |
| **Doppler tissue imaging** | | | |
| e' wave (cm/s) | 7.3±2.6 | 7.2±2.8 | 0.87 |
| A' wave (cm/s) | 9.2±2.7 | 10.6±1.8 | 0.03 |
| E/e' ratio (septal) | 14.6±5.6 | 12.7±5.6 | 0.14 |
| E/e' ratio (lateral) | 10.5±4.4 | 10.4±5.4 | 0.90 |

Data given as mean±SD or n (%).
LA, left atrial; LV, left ventricular; LAVI, left atrial volume index; MR, mitral regurgitation. Other abbreviations as in Table 1.

this study was 0.93.

## Surgical Technique: OPCAB

All preoperative cardiac medications including $\beta$-blockers, calcium antagonists, angiotensin receptor blockers, and angiotensin-converting enzyme inhibitors (except for non-steroidal anti-inflammatory drugs) were continued until 1 day before surgery. The patients underwent OPCAB, which was performed using a standard surgical technique. General anesthesia was induced and maintained by i.v. infusion of fentanyl and propofol. Muscle relaxation was achieved with pancuronium. The patients routinely received nitroglycerin (0.1–0.3 $\mu g \cdot kg^{-1} \cdot min^{-1}$) for the dilation of the coronary arteries and the prevention of perioperative left internal thoracic artery (LITA) spasms. Heparin (150 IU/kg) was given, and the activated clotting time was maintained above 250 s. All patients underwent median sternotomy. Using a skeletonized technique, the LITA/right internal thoracic artery (RITA), gastroepiploic artery (GEA), and radial artery (RA) were harvested with an ultrasonic scalpel. Distal ends of LITA, RITA and GEA were cut off and olprinone was injected into graft lumens. Olprinone was also injected into the proximal end of RA. A heart positioner and stabilizer were applied to lift and stabilize the heart (Starfish and Octopus; Medtronic, Minneapolis, MN, USA).

After adequate exposure and stabilization, the target vessel was then exposed and snared above the anastomotic site with 4-0 elastic suture and a soft plastic snugger to prevent coronary injury. The coronary artery was then opened, and an incision of 7–8 mm was made. LITA-left anterior descending coronary artery anastomosis was performed using the intracoronary shunt tube (diameter, 1.75–2.0 mm) with 8-0 prolene at first. Then, anastomosis of the left circumflex and right coronary arteries was completed with 8-0 or 7-0 prolene suture. Visualization was enhanced using echocardiography. For the prevention of arterial spasms, a continuous i.v. infusion of diltiazem (0.5–1.0 $\mu g \cdot kg^{-1} \cdot min^{-1}$) or nicardipine (2 mg/h) was used intraoperatively and during the first 24 h after operation. Anesthetic techniques and medications for the intraoperative and postoperative periods were almost the same in all patients. Low-dose aspirin was given to all patients following the procedure, and warfarin was used in patients with saphenous vein grafts in addition to low-dose aspirin. If necessary, inotropic drugs were used during the stay in the intensive care unit.

## Statistical Analysis

Data are presented as mean±SD. Continuous variables between different subgroups were analyzed using Mann-Whitney U-test. Chi-squared test and Fisher's exact test were used to evaluate the differences in categorical variables between subgroups. Student's t-test or Mann-Whitney U-test was used to compare continuous variables. Multivariate logistic regression analysis was used for assessing association with PA-TDI duration. Multivariate stepwise logistic regression analysis was used to identify the independent predictors of POAF. Odds ratio (OR) and 95% confidence interval (CI) were calculated. Variables with $P<0.05$ on univariate analysis were included

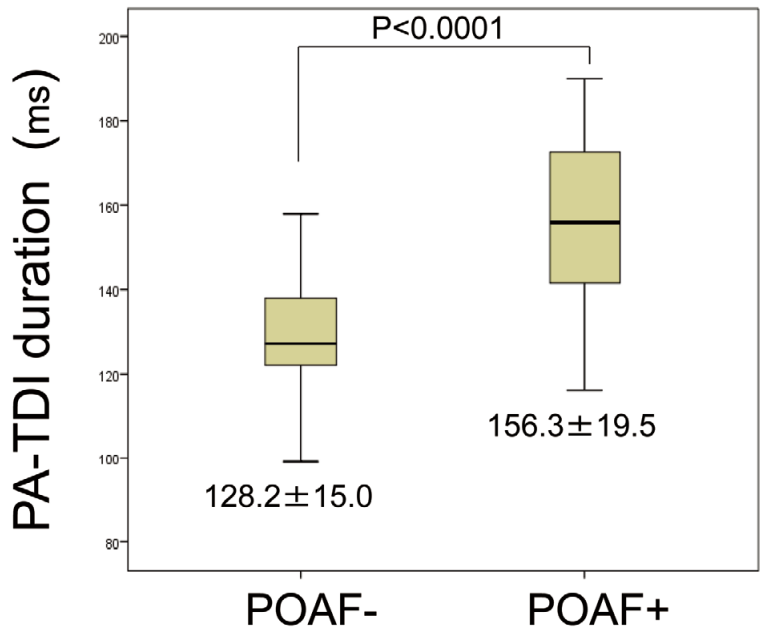


**Figure 2.** Comparison of total atrial conduction time (PA-TDI) duration in patients with and without postoperative atrial fibrillation (POAF). The PA-TDI duration in patients with POAF was significantly longer than that in patients without POAF (156.3±19.5 vs. 128.2±15.0 ms, P<0.0001).

in multivariate analysis. The receiver operating characteristic (ROC) curve was calculated to evaluate the performance of the strongest independent predictors of POAF obtained on multivariate analysis. All statistical analysis was performed using SPSS version 18.0 (SPSS, Chicago, IL, USA). P<0.05 was considered significant.

## Results

### Patient Characteristics

Table 1 lists the patient characteristics. Of a total of 88 patients, 35 patients (39.8%) developed POAF. The majority of these patients (65.7%, 23/35) developed POAF 2–3 days after surgery. The mean duration from OPCAB to the onset of POAF was 3.0±0.3 days. Patients with POAF had a significantly lower body mass index (BMI) than those without POAF (22.4±3.8 vs. 24.3±4.3 kg/m$^2$, P=0.04). The other clinical characteristics were similar in patients with and without POAF, including a history of prior paroxysmal AF. The perioperative medications were similar in patients with and without POAF, except for use of postoperative nicardipine. The treatment strategies for patients with POAF were not standardized because each intensive care unit doctor or anesthesiologist initiated a discretionary approach to therapy. Patients with POAF had a significantly longer duration of hospital stay than those without (44.9±6.2 vs. 37.3±3.3 days, P=0.04). The reasons why hospital stay was prolonged in the POAF group were as follows. We had to adjust the anti-arrhythmic drugs in patients in the POAF group and, in some cases, cardioversion was required to terminate AF. Although no patient developed heart failure in the non-POAF group, 5 patients in the POAF group developed severe heart failure after OPCAB, and their hospital stay was prolonged in order to control heart failure. In addition, all of the patients who underwent OPCAB at Hiroshima University were provided with cardiac rehabilitation after the procedure, with patients in the POAF group having a delay in the start of cardiac rehabilitation. Hospital mortality (<30 days) was 2.9% (1/35) in patients with POAF and 0% (0/53) in those without (P=0.22). No patients in the study suffered a stroke or perioperative myocardial infarction during hospitalization. Moreover, no patients were treated with perioperative i.v. amiodarone.

### Echocardiographic Variables

Table 2 lists preoperative echocardiographic parameters between patients with and without POAF. LA volume (64.6±26.1 vs. 51.2±17.6 ml, P=0.006) and LAVI (41.1±16.4 vs. 31.8±10.6 ml/m$^2$, P=0.005) were greater in patients with POAF than in those without POAF. No significant difference was observed in preoperative LV ejection fraction, E wave, or A wave between patients with and without POAF. A' wave velocity was significantly lower in patients with POAF than in those without (9.2±2.7 vs. 10.6±1.8 ms, P=0.03). As shown in Figure 2, PA-TDI duration was significantly longer in patients with POAF than in those without (156.3±19.5 vs. 128.2±15.0 ms, P<0.0001).

### Clinical Predictors of AF After OPCAB

A modest positive correlation was seen between PA-TDI duration and LAVI (r=0.278; P=0.01) and between PA-TDI duration and age (r=0.233; P=0.03), but no correlation was observed between A' wave velocity and PA-TDI duration. Table 3 lists predictors of POAF on univariate and multivariate analysis. On univariate analysis, PA-TDI duration and LAVI were significant predictors of POAF (PA-TDI duration: OR, 1.10; 95% CI: 1.06–1.15; P=0.0001; LAVI: OR, 1.06; 95% CI: 1.02–1.10; P=0.005). On multivariate stepwise logistic regression analysis, PA-TDI duration (OR, 1.11; 95% CI: 1.06–1.16; P=0.0001) and LAVI (OR, 1.11; 95% CI: 1.02–1.20; P=0.01) remained as independent determinants of POAF. The discriminative performance of these variables for predicting POAF was determined on ROC curve analysis (Figure 3). The area under the ROC curve (index of discrimination) for LAVI was 0.67 (95% CI: 0.55–0.79; P<0.01) and that for PA-TDI duration was 0.85 (95% CI: 0.77–0.93; P<0.0001), indicating a higher degree of discrimination than that for LAVI. PA-TDI duration >141 ms was found to be a predictor of POAF, fol-

**Table 3. Predictors of AF After OPCAB**

| | Univariate analysis | | Multivariate analysis | |
|---|---|---|---|---|
| | OR (95% CI) | P-value | OR (95% CI) | P-value |
| HT | 1.44 (0.51–4.02) | 0.49 | 3.03 (0.56–16.51) | 0.20 |
| COPD | 1.56 (0.30–8.22) | 0.60 | 3.77 (0.14–103.42) | 0.43 |
| BMI (m/kg$^2$) | 0.89 (0.79–0.99) | 0.04 | 0.87 (0.72–1.05) | 0.14 |
| P duration (ms) | 1.02 (0.98–1.06) | 0.29 | 0.96 (0.90–1.02) | 0.16 |
| A' velocity (m/s) | 0.86 (0.70–1.05) | 0.13 | 0.86 (0.63–1.17) | 0.34 |
| LVMI (g/m$^2$) | 1.00 (0.99–1.02) | 0.90 | 0.97 (0.95–1.00) | 0.07 |
| PA-TDI duration (ms) | 1.10 (1.06–1.15) | 0.0001 | 1.11 (1.06–1.16) | 0.0001 |
| LAVI (ml/m$^2$) | 1.06 (1.02–1.10) | 0.005 | 1.11 (1.02–1.20) | 0.01 |

OPCAB, off-pump coronary artery bypass grafting; AF, atrial fibrillation; CI, confidence interval; HT, hypertension; LVMI, left ventricular mass index; OR, odds ratio; PA-TDI, beginning of the P wave on ECG to the peak of the A' lateral wave on tissue Doppler imaging. Other abbreviations as in Tables 1,2.

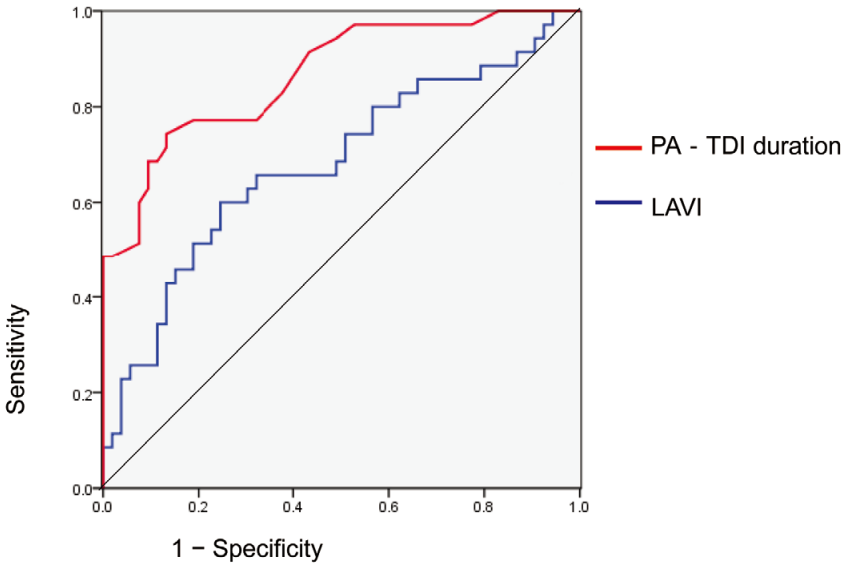


**Figure 3.** The area under the receiver operating characteristic (ROC) curve (index of discrimination) for left atrial volume index (LAVI) was 0.67 (95% CI: 0.55–0.79; P<0.01) and that for PA-TDI duration was 0.85 (95% CI: 0.77–0.93; P<0.0001), indicating a higher degree of discrimination than that for LAVI.

lowing OPCAB with a sensitivity of 74.3% and specificity of 86.8%. LAVI >33 ml/m$^2$ was found to be a predictor of POAF after OPCAB, with a sensitivity of 65.7% and specificity of 67.9%.

## Discussion

To the best of our knowledge, this is the first report to show that PA-TDI duration is the most reliable independent predictor of POAF in patients undergoing OPCAB. AF is the most common arrhythmia in the perioperative phase. Although perioperative management has improved in recent years, the proportion of patients with POAF has not decreased.[1] AF after on-pump CABG is reported to be benign in most cases, but in some cases it causes stroke or congestive heart failure and leads to a prolonged hospital stay and worsened prognosis.[2–4]

In this study, among 88 patients who underwent OPCAB, 35 (39.8%) developed POAF, and it prolonged the length of hospitalization. If patients at high risk of developing POAF are identified preoperatively and intervention with POAF therapy is applied in the early phase of surgery, it would be very valuable for improving the prognosis in these patients.

For more than 2 decades, researchers have attempted to identify predictors of AF after cardiac surgery. The use of signal-averaged P wave duration to predict POAF has been evaluated, and it was found that patients with AF have a prolonged P wave duration.[14] A previous study found that a larger preoperative LA volume is associated with the occurrence of POAF.[15] In addition, studies have shown that older age, body surface area, white ethnicity, larger preoperative LA volume, lower postoperative atrial filling fraction, LV hypertrophy, hypertension, preoperative digoxin use, obstructive lung disease, postoperative LV diastolic dysfunction, and use of adrenergic drugs following cardiac surgery were all indicators of POAF.[1,2,8,15–17] These parameters, however, were inadequate for predicting POAF because most of them did not have clear cut-offs, the sensitivity or specificity of these factors were not sufficiently high, and some of the parameters were postoperative factors. Reliable parameters would allow investigators to identify the most significant contributing factors and help develop a novel strategy for the prophylaxis of POAF. In the present study, we could not predict the probability of POAF on the basis of some of these reported factors (eg, greater age, BMI, LV hypertrophy, hypertension, preoperative medication, and use of adren-

ergic drugs after cardiac surgery). Instead, we were able to predict POAF using PA-TDI duration more efficiently than LAVI, and found that PA-TDI duration was the most reliable preoperative independent predictor of POAF.

PA-TDI duration has recently been introduced as a non-invasive method of assessment of TACT because PA-TDI duration measurement is easy, fast, and reliable. P wave determination on SA-ECG is also useful for estimating TACT, but, because it requires special hardware and is time-consuming, the use of SA-ECG in clinical practice is limited.[10,14] This novel echocardiographic parameter has been validated against P wave duration using signal-averaged ECG.[10,19]

LA size reflects the extent of atrial structural remodeling. TACT is related to the atrial dimensions and conduction speed. PA-TDI duration reflects both electrical and structural remodeling changes in the LA.[19] Electrical remodeling has been known to appear in an earlier phase than structural remodeling.[20,21] de Vos et al showed that prolonged PA-TDI is the most important predictor of new-onset AF.[11] Another report suggested that prolonged PA-TDI was associated with the recurrence of AF after catheter ablation.[19] Bertini et al found that PA-TDI duration may be useful to stratify the risk of AF occurrence in heart failure patients with and without a history of AF.[22]

Recently, Özlü et al showed that LA maximum volume and PA-TDI duration were independent predictors of POAF development after conventional CABG.[23] The new information provided in the present study is that PA-TDI duration is also an independent predictor of POAF in patients undergoing OPCAB.

Consistent with a previous report, the extent of fibrosis of the right atrial appendages in the present study was higher in patients with AF after cardiac surgery than in those without POAF.[24] A number of factors have been reported to play roles in the genesis of POAF, including ischemic myocardial damage during the procedure, perioperative pericarditis and myocarditis, the chemical and metabolic milieu, the increase in adrenergic tone, and hypoglycemia. Hence, these possible factors may synergistically promote latent electrical or anatomical LA remodeling that lead to AF occurrence in the settings of the postoperative period.

There have been many reports of prophylactic therapy to reduce inflammation, oxidative stress, and eventually POAF.[1,8,25] Prophylactic high doses of oral-*N*-acetylcysteine (NAC), statins, $\omega$-3 fatty acids, $\beta$-blockers, sotalol, amiodarone, magnesium, and use of atrial pacing have all been reported to be candidates for preventive POAF therapy.[1,5–8,25–28] A large meta-analysis of randomized controlled studies by Crystal et al reported that the incidence of POAF was 33% in controls, whereas patients receiving $\beta$-blockers had only a 19% incidence of POAF.[28] Baker et al reported a meta-analysis on use of NAC, and it was found that the use of NAC significantly lowered the odds of developing POAF by 36% (95% CI: 2–58).[25] If we can identify the patients at high risk of developing POAF using preoperative PA-TDI duration, preventive treatment for POAF can be made available to these patients.

### Clinical Implications

Using PA-TDI duration, we can easily and non-invasively identify patients at high risk of developing POAF. Identifying candidates for the development of POAF may be important in the primary prevention of POAF and prove to be a cost-effective means of reducing the number of patients requiring treatment.

### Study Limitations

There were several limitations of the present study. We examined a small number of patients in a single institution in a non-randomized, retrospective manner. Therefore, the present findings and the prognosis of patients undergoing OPCAB need to be validated in a larger prospective study with a longer follow-up period. We excluded high-risk patients with cardiac disease. The potential of PA-TDI duration in a consecutive series may be more meaningful in the clinical setting. Further, the assessment of PA-TDI duration might be an overestimation of TACT. In addition, PA-TDI duration can be assessed only during sinus rhythm. We did not examine other parameters of electrical remodeling, such as SA-ECG, or electrophysiological studies. In this study, the number of patients with POAF was a little higher than that in previous studies. One reason may be that the definition of AF differed from that in the other studies. The other reason was that we included patients with a history of paroxysmal AF. Finally, we assessed POAF only in patients who had undergone OPCAB and excluded on-pump CABG. There are few previous reports examining the predictors of AF after OPCAB, in contrast to the many reports dealing with on-pump CABG. Moreover, to the best of our knowledge, this is the first report demonstrating a quantitative predictor of POAF in patients undergoing OPCAB.

## Conclusion

Increased PA-TDI duration may be an independent predictor of AF after OPCAB. Triage of patients at high risk of developing POAF may lead to the prevention of POAF, shortening of hospital stay, and improvement of prognosis.

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