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Predicting Long-Term Mortality After First Coronary Revascularization

– The Kyoto Model –

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Background: We explored the determinants of mortality in order to develop and validate the Kyoto model, which predicts outcomes after percutaneous coronary intervention (PCI) and coronary artery bypass grafting (CABG).

Methods and Results: A total of 9,393 patients who underwent their first coronary revascularization without concomitant valvular, left ventricular, or major vascular surgery were followed over a median follow-up of 3.5 years in the CREDO-Kyoto Registry. We fitted separate Cox regression to mortality after PCI and CABG. The best-fitting model was internally validated by 10-fold cross-validation. The Cox regression identified the following predictors: age, sex, body mass index, ejection fraction, atrial fibrillation, diabetes mellitus, hyperlipidemia, current smoker, stroke, peripheral vascular disease, chronic obstructive pulmonary disease, malignancy, kidney disease, anemia, liver cirrhosis, diseased vessel, left main disease, proximal left anterior descending artery disease, and total occlusion. This model simulated that the 3-year mortality for a hypothetical 70-year-old man with 2-vessel disease is 2.0% after PCI and 2.6% after CABG, or 4.2% and 5.1% if he has diabetes and chronic kidney disease. The Hosmer-Lemeshow test showed no significant deviations between the observed and predicted events. The C statistics were greater than 0.78.

Conclusions: The Kyoto model can assist clinicians and patients in adherence to medication and lifestyle changes after revascularization and in individualized decision making. A web application is available at http://www.biostatistics.jp/prediction/kyoto-model. (*Circ J* 2012; **76:** 328–334)

Key Words: Coronary artery bypass grafting; Percutaneous coronary intervention (PCI); Risk factors

Mathematical models for predicting outcomes after coronary revascularization on the basis of patient preoperative characteristics are valuable tools for patients, clinicians and healthcare providers. To date, numerous models have been developed for predicting operative or in-hospital mortality[1–13] or middle-term outcome (ie, 6–18 months)[14–16] after percutaneous coronary intervention (PCI). However, given the low operative and in-hospital mortality in state-of-the-art of coronary revascularization, risk assessment for long-term mortality appears to be valuable. We previously reported a strong association between metabolic syndrome-like risk factor accumulation and major cardiovascular events in long-term follow-up after coronary revascularization,[17] and inclusion of cardiovascular risk factors into prediction models would aid in comprehension of a patient's risk and the intensity of subsequent management after the intervention. Further, the most frequently referenced models for coronary artery bypass grafting (CABG) are based on data from Europe[18] or from the USA,[19] which may not be reflective of outcomes in Asian populations.[20] To date, no validated measure for predicting outcomes of Asian patients who undergo CABG is available, except for the model of the Japan Adult Cardiovascular Surgery Database, which focuses on 30-day and operative mortality.[21]

The present study therefore had 2 main aims. First, we explored the determinants of long-term mortality in patients who underwent their first isolated CAGB or PCI in the bare-metal stent era. This was done using data from the CREDO-Kyoto Registry, a nationwide multicenter registry in Japan.[22] Second, we aimed to develop and validate a mathematical model, the Kyoto model, which predicts mortality after PCI and CABG separately. Here, we fitted Cox regression models, which allows risk assessment of mortality at an arbitrary time point, and validated the model using a cross-validation strategy.

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Table 1. Baseline Characteristics of 9,393 Patients Undergoing First Coronary Revascularization

	PCI (n=6,878)	CABG (n=2,515)
Age (years)	67.2±10.3 (0.0%)	67.3±9.5 (0.0%)
Female (%)	29.7 (0.0%)	28.0 (0.0%)
BMI (kg/m²)	23.7±3.3 (2.3%)	23.5±3.2 (2.3%)
LVEF (%)	63.4±12.7 (11.3%)	59.9±14.4 (6.0%)
<40%	6.1 (11.3%)	11.2 (6.0%)
HF (%)	11.9 (0.3%)	25.1 (0.6%)
Functional class 3/4 (%)	4.0 (0.2%)	6.4 (0.7%)
Prior MI (%)	22.5 (0.3%)	33.7 (0.1%)
Atrial fibrillation (%)	6.7 (0.0%)	5.8 (0.1%)
DM (%)	36.4 (0.2%)	46.0 (0.1%)
Hypertension (%)	69.0 (0.1%)	70.3 (0.0%)
SBP (mmHg)	137.2±21.7 (0.5%)	131.5±20.1 (0.5%)
DBP (mmHg)	75.7±13.2 (0.6%)	71.5±12.1 (0.6%)
Hyperlipidemia (%)	49.8 (0.3%)	53.5 (0.1%)
Current smoker (%)	29.2 (1.8%)	25.3 (2.3%)
Stroke (%)	13.0 (0.1%)	21.2 (0.1%)
PVD* (%)	8.0 (0.1%)	19.6 (0.1%)
COPD (%)	2.4 (0.1%)	2.2 (0.1%)
Malignancy (%)	7.1 (0.1%)	6.5 (0.1%)
Kidney disease (%)		
CKD†	38.2 (3.7%)	44.5 (1.2%)
Dialysis	3.6 (0.0%)	5.0 (0.0%)
Anemia‡ (%)	22.5 (2.3%)	33.8 (2.5%)
Liver cirrhosis (%)	3.4 (0.1%)	3.2 (0.2%)
Extracardiac arteriopathy (%)	22.0 (0.1%)	38.1 (0.1%)
Ventricular tachycardia (%)	0.3 (0.1%)	0.3 (0.1%)
Emergency procedure (%)	5.4 (0.0%)	6.1 (0.1%)
No. of diseased vessels (%)		
1	44.3 (0.0%)	8.0 (0.0%)
2	34.2 (0.0%)	22.9 (0.0%)
3	21.2 (0.0%)	66.2 (0.0%)
LMD (%)	2.4 (0.0%)	29.5 (0.0%)
Proximal LAD disease (%)	36.3 (0.0%)	58.9 (0.0%)
Total occlusion (%)		
None	75.5 (0.0%)	55.1 (0.0%)
1	21.1 (0.0%)	32.9 (0.0%)
2	3.2 (0.0%)	10.7 (0.0%)
3	0.2 (0.0%)	1.3 (0.0%)

Mean ± SD for continuous variables, percentage for categorical variables. Percentages in parentheses are the proportion of missing data.
PCI, percutaneous coronary intervention; CAGB, coronary-artery bypass grafting surgery; BMI, body mass index; LVEF, left ventricular ejection fraction; HF, heart failure; MI, myocardial infarction; DM, diabetes mellitus; SBP, systolic blood pressure; DBP, diastolic blood pressure; PVD, peripheral vascular disease; COPD, chronic pulmonary disease; CKD, chronic kidney disease; LMD, left main disease; LAD, left anterior descending artery.
*PVD was defined as being present when the patients were being treated for carotid, aortic and/or other PVD or scheduled for surgical or endovascular intervention.
†CKD was defined as an estimated glomerular filtration rate <60 ml/min.
‡Anemia was defined as blood hemoglobin level <12 g/dl.

Methods

Study Design

Details of the CREDO-Kyoto Registry have been described elsewhere.[22] In brief, this nationwide observational study of 30 institutions in Japan enrolled a total of 9,877 patients who underwent their first coronary revascularization between January 2000 and December 2002. We did not register those patients with acute myocardial infarction (MI) within 1 week of the index procedure. Exclusion criteria for the present analysis were concomitant valvular, left ventricular, or major vascular operation. Demographic, angiographic, and procedural data were collected from hospital charts or databases in each center by independent clinical research coordinators according to prespecified definitions. Diabetes mellitus (DM) diagnosis was made by each physician and based on the Expert Committee on the Diagnosis and Classification of Diabetes Mellitus.[23] Chronic kidney disease (CKD) was defined as a glomerular filtration rate <60 ml/min estimated by the Cockcroft-Gault formula. Anemia was defined as a blood hemoglobin level

Table 2. Best-Fitting Cox Regression Models for Prediction of All-Cause Mortality After First PCI or CABG

	PCI			CABG			P for interaction
	HR	95%CI	P value	HR	95%CI	P value	
Age, +10 years	1.74	1.55–1.96	<0.01	1.96	1.63–2.36	<0.01	0.33
Sex, F/M	1.34	1.10–1.64	<0.01	1.30	0.96–1.75	0.09	0.77
BMI							
18.5–25/<18.5 kg/m^2	0.77	0.59–1.00	0.05	0.92	0.60–1.39	0.68	0.54
≥25/<18.5 kg/m^2	0.60	0.43–0.83	<0.01	0.79	0.48–1.32	0.37	0.43
LVEF, –10%	1.20	1.13–1.27	<0.01	1.09	1.00–1.19	0.05	0.09
Atrial fibrillation, yes/no	1.38	1.07–1.79	0.01	1.67	1.10–2.56	0.02	0.43
DM, yes/no	1.43	1.20–1.70	<0.01	1.21	0.94–1.55	0.15	0.29
Hyperlipidemia, yes/no	1.02	0.85–1.23	0.79	0.82	0.64–1.06	0.14	0.18
Current smoker, yes/no	1.18	0.96–1.44	0.11	1.32	0.99–1.77	0.06	0.59
Stroke, yes/no	1.20	0.98–1.48	0.08	1.35	1.02–1.77	0.03	0.42
PVD, yes/no	1.80	1.44–2.25	<0.01	0.97	0.72–1.30	0.84	<0.01
COPD, yes/no	1.60	1.12–2.29	0.01	1.42	0.77–2.61	0.27	0.71
Malignancy, yes/no	2.07	1.65–2.59	<0.01	1.53	1.03–2.27	0.03	0.20
Kidney disease							
CKD/normal	1.48	1.18–1.85	<0.01	1.69	1.22–2.34	<0.01	0.51
Dialysis/normal	5.23	3.84–7.13	<0.01	8.31	5.36–12.88	<0.01	0.07
Anemia, yes/no	1.94	1.59–2.36	<0.01	1.26	0.95–1.69	0.11	0.02
Liver cirrhosis, yes/no	1.94	1.39–2.72	<0.01	1.60	0.98–2.60	0.06	0.49
No. of diseased vessels							
2/1	1.27	1.03–1.56	0.03	1.10	0.67–1.82	0.70	0.63
3/1	1.38	1.09–1.73	0.01	1.34	0.84–2.14	0.22	0.99
LMD, yes/no	1.22	0.80–1.84	0.36	1.27	0.95–1.69	0.10	0.96
Proximal LAD disease, yes/no	1.13	0.95–1.34	0.18	0.93	0.73–1.20	0.59	0.18
Total occlusion							
1/0	1.22	1.00–1.49	0.05	1.19	0.90–1.57	0.23	0.75
≥2/0	1.52	1.04–2.22	0.03	1.06	0.70–1.61	0.78	0.16

HR, hazard ratio; CI, confidence interval. Other abbreviations see in Table 1.

<12 g/dl. Peripheral vascular disease (PVD) was defined as present if the patient was being treated for carotid, aortic and/or other PVD or was scheduled for surgical or endovascular intervention. Heart failure (HF) was defined by The New York Heart Association functional classification or a history of hospitalization for HF. Follow-up data were obtained from hospital charts, or by contacting patients or referring investigators and the date of closure was November 2006. Because it was retrospective enrollment, written informed consent was not obtained from the patients, in accordance with the guidelines for epidemiological studies issued by the Ministry of Health, Labour and Welfare of Japan.[22]

Statistical Analysis

The endpoint for the present analysis was the time from first coronary revascularization to all-cause mortality. To explore determinants of mortality, we stratified patients according to CABG or PCI and fitted separate Cox regression models. The following prespecified variables were screened via backward variable selection with a critical value of P=0.2: age, sex, body mass index (BMI), left ventricular ejection fraction (LVEF), emergency procedure, prior MI, stroke, PVD, atrial fibrillation, chronic obstructive pulmonary disease (COPD), malignancy, hypertension, hyperlipidemia, DM, dialysis, CKD, anemia, current smoking status, liver cirrhosis, extracardiac arteriopathy, ventricular tachycardia, total occlusion, proximal left anterior descending artery (LAD) disease, left main disease (LMD), and the number of diseased vessels. Among these, kidney disease (dialysis and CKD), number of diseased vessels, and total occlusion were treated as dummy variables representing 3 categories. Hazard ratios estimated by the best-fitting Cox regression models were reported with 95% confidence intervals (CI) and P values. Finally, the Kyoto model was developed using the following formula:

$$\mathrm{Prob}(t) = \exp[-\int_0^t \lambda_0(s)\exp(\mathrm{X}\beta)ds]$$

where β is a vector of log-hazard ratios for covariate X, and $\lambda_0(s)$ denotes baseline hazard function estimated by the Breslow estimator. Note that this formula allows for the calculation of probabilities at any time point.

We assessed the predictive accuracy of the Kyoto model using 10-fold cross-validation in terms of calibration and discrimination.[24] Calibration, namely how closely the prediction reflected observed events, was assessed by the Hosmer-Lemeshow test and a calibration plot. Discrimination, which is the ability to distinguish between those who experienced the event and those who did not, was evaluated using a receiver-operating characteristic curve and Harrell's C statistic, the latter calculated as the proportion of all patient pairs in which the predictions of the model and observed events were concordant. The difference in the C statistics from 2 models, namely the Kyoto model and the logistic EuroSCORE,[25] was compared by a contrast test.

Missing data for LVEF were substituted using the multiple imputation method in which age, sex and HF were used as predictors. All the other missing variables were treated by com-

Table 3. Cumulative Proportion of 3-Year Mortality Calculated From the Kyoto Model and Mean Number of Risk Factors of Patients in Each Stratum

Calculated 3-year mortality	No. of patients	Cumulative proportion	No. of deaths (%)	Mean no. of risk factors*
<1%	473	5.89%	3 (0.63%)	2.99
1–3%	2,504	37.06%	55 (2.20%)	3.71
3–5%	1,480	55.48%	81 (5.47%)	4.61
5–10%	1,811	78.03%	151 (8.34%)	5.66
10–15%	720	86.99%	118 (16.39%)	6.71
15–20%	359	91.46%	72 (20.06%)	7.20
≥20%	686	100.00%	246 (35.86%)	8.13
Total	8,033†	100.00%	726 (9.04%)	5.08

*The following cutoff values were used for counting continuous risk factors: age ≥75 years, body mass index <18.5 kg/m^2, and ejection fraction <40%.
†Three-year mortality was not calculated for 1,360 patients because of missing data.

Table 4. Predictive Accuracy of the Kyoto Model Evaluated by 10-Fold Cross-Validation

	Calibration, observed/predicted events (P value*)	Discrimination, C statistics† (95%CI)
30-day mortality	62/62.3 (0.56)	0.788 (0.737–0.840)
1-year mortality	261/264.1 (0.10)	0.805 (0.779–0.830)
3-year mortality	589/626.6 (0.29)	0.794 (0.775–0.812)
The logistic EuroScore‡	– (–)	0.731 (0.712–0.750)

CI, confidence interval.
*Hosmer-Lemeshow test with 8 degree of freedom, P<0.05 indicates a significant deviation between the observed and predicted event frequencies.
†Proportion of all patient pairs in which predictions from the Kyoto model and observed occurrence of event are concordant.
‡Discriminatory power of the logistic EuroSCORE for prediction of 3-year mortality. The contrast test for difference in the C statistics between the Kyoto model and the logistic EuroSCORE was significant (P<0.01).

plete-case analysis.

All analyses were conducted by a biostatistician (S.T.) using SAS software version 9.2 (SAS Institute, Cary, NC, USA). The authors had full access to the data and take responsibility for its integrity. All reported P values for statistical tests are 2-tailed, and P<0.05 was taken to indicate statistical significance.

Results

Baseline Characteristics and Follow-up

The baseline characteristics of the 9,393 patients are summarized in Table 1. All the patients were Japanese. The proportion of missing baseline data was less than 4%, except for LVEF. In the PCI group, bare-metal stents were used in 85% of patients, and none received a drug-eluting stent. In the CABG group, a left or right internal mammary artery graft was used in 92% and 30%, respectively, and 60% of operations included an additional saphenous vein graft. Clinical follow-up was completed in 98% at 1 year, and 96% at 2 years. Over a median follow-up of 3.5 years (range 0.0–6.8 years), 638 patients in the PCI group died (9.3%: 32 in-hospital deaths, 170 cardiac deaths other than sudden death, 84 sudden deaths, 83 non-cardiac vascular deaths, 269 non-cardiovascular deaths), and 286 in the CABG group (11.4%: 58 in-hospital deaths, 48 cardiac deaths other than sudden death, 39 sudden deaths, 45 non-cardiac vascular deaths, 96 non-cardiovascular deaths).

Development of the Kyoto Model

The backward variable selection identified 19 predictive factors for long-term mortality, namely age, sex, BMI, LVEF, atrial fibrillation, DM, hyperlipidemia, current smoker, stroke, PVD, COPD, malignancy, kidney disease, anemia, liver cirrhosis, diseased vessel, LMD, proximal LAD disease, total occlusion (Table 2). On the whole, determinants of mortality after PCI and CABG were similar, but some factors had differential effects on mortality. Specifically, PVD and anemia increased mortality in the PCI group only and these differences in hazard ratios between groups were significant in tests for treatment-covariate interactions (Table 2). All the predictive factors that were retained through the variable selection procedure were incorporated into the final prediction model, the Kyoto model. If we added medications into the Kyoto model as a sensitivity analysis, the hazard ratios (95%CI) for renin–angiotensin system inhibitors, statins and β-blockers were 1.17 (0.96–1.43, P=0.13), 0.81 (0.61–1.07, P=0.14), and 0.98 (0.76–1.27, P=0.88) in the PCI group and 0.85 (0.58–1.26, P=0.42), 1.06 (0.66–1.70, P=0.82), and 1.49 (0.95–2.34, P=0.09) in the CABG group.

Validation of the Kyoto Model

The 3-year mortality data of CREDO-Kyoto participants calculated by the Kyoto model are shown in Table 3. As shown, more than 75% of patients had a 3-year mortality <10%, but some had mortality >20%. Patients with a calculated 3-year mortality <3% had markedly low actual mortality and had ≤4 risk factors, whereas high-risk patients (ie, 3-year mortality ≥10%) had 6 or more risk factors. Predictive accuracy of the Kyoto model by 10-fold cross-validation is shown in Table 4 and Figures 1,2. The Hosmer-Lemeshow test and the calibration plot showed no significant deviation between the observed and predicted events for 30-day, 1-year or 3-year mortality.

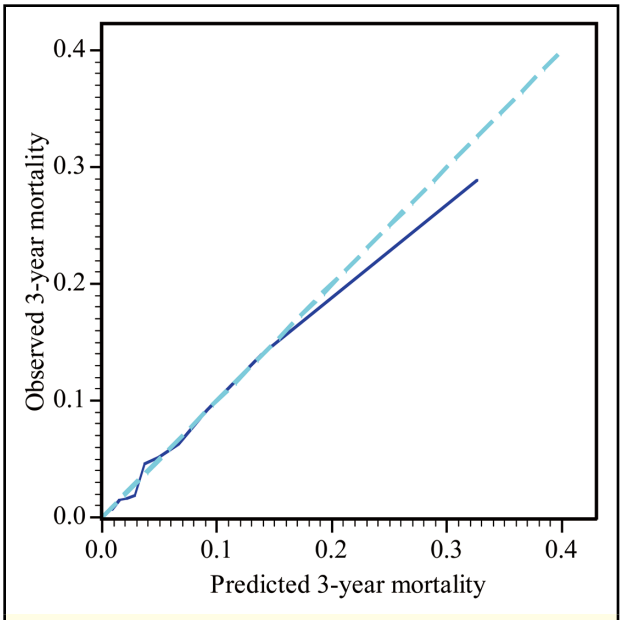

Figure 1. Calibration plot for the prediction of 3-year mortality. The Kyoto model predicted the observed 3-year mortality almost accurately in 10 strata used for the Hosmer-Lemeshow test.

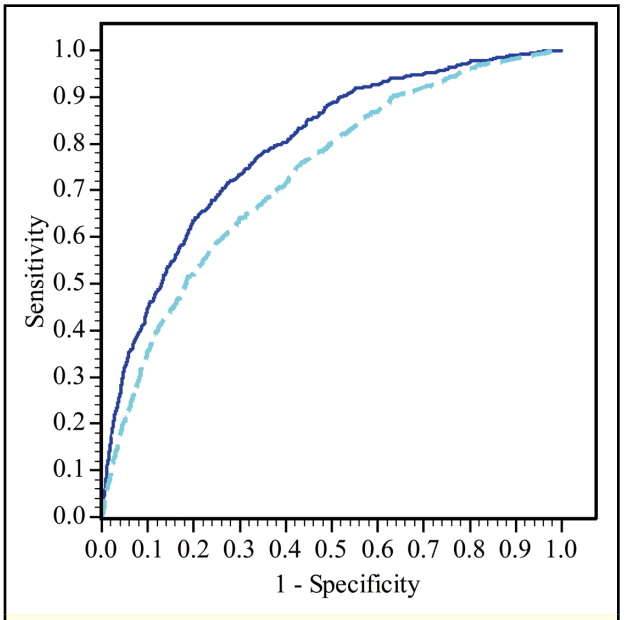

Figure 2. Receiver-operating characteristic curves for the prediction of 3-year mortality. The Kyoto model performed well (solid curve) and the discriminatory power was significantly better than the logistic EuroSCORE (dashed curve).

Table 5. Clinical Example of a Hypothetical 70-Year-Old Man Without Comorbidities Other Than Those Simulated

Diabetes	Kidney disease	No. of diseased vessels	Total occlusion	Outcome after first PCI			Outcome after first CABG		
				30-day mortality (%)	1-year mortality (%)	3-year mortality (%)	30-day mortality (%)	1-year mortality (%)	3-year mortality (%)
No	Normal	2	None	0.1	0.7	2.0	0.4	1.2	2.6
Yes	Normal	2	None	0.2	1.0	2.8	0.5	1.5	3.1
Yes	CKD	2	None	0.2	1.5	4.2	0.8	2.5	5.1
Yes	Dialysis	2	None	0.9	5.4	14.0	4.0	11.6	23.1
No	Normal	3	None	0.1	0.8	2.2	0.5	1.5	3.2
Yes	Normal	3	None	0.2	1.1	3.1	0.6	1.8	3.8
Yes	CKD	3	None	0.3	1.7	4.5	1.0	3.0	6.3
Yes	Dialysis	3	None	0.9	5.8	15.1	4.9	14.2	27.8
No	Normal	3	≥2	0.2	1.2	3.3	0.5	1.6	3.3
Yes	Normal	3	≥2	0.3	1.7	4.7	0.6	1.9	3.9
Yes	CKD	3	≥2	0.4	2.5	6.8	1.0	3.1	6.5
Yes	Dialysis	3	≥2	1.4	8.7	22.2	5.0	14.6	28.5

Abbreviations see in Table 1.

The C statistics for all time points were more than 0.78, suggesting excellent discriminatory power of the Kyoto model.

Further, we compared the performance of the Kyoto model with the logistic EuroSCORE,[25] a major previously developed risk score (Table 4). The C statistics of the logistic EuroSCORE were 0.731 in the CREDO-Kyoto Registry and the improvement of the Kyoto model from the logistic EuroSCORE was significant (P<0.01). Figure 2 compares the receiver-operating characteristic curves for the Kyoto model and logistic EuroSCORE.

Clinical Examples

As a practical example, Table 5 lists the probabilities of 30-day, 1-year and 3-year mortality calculated by the Kyoto model for a 70-year-old man without comorbidities other than those simulated here. As shown, 30-day mortality would be consistently low. In contrast, the 3-year mortality increased from a low of 2.0% to a high of 28.5% as the number of risk factors accumulated. If this hypothetical patient did not receive dialysis, mortality for the 2 procedures would be remarkably similar at any time. This numerical example also suggests that the long-term prognosis is determined not only cardiac- or operation-related factors but also medical condition such as DM and renal function.

Discussion

We developed and validated a novel model for predicting mortality after PCI using long-term follow-up data from the CREDO-Kyoto Registry. The Kyoto model enables (1) risk assessment of short-, middle- and long-term mortality and (2) comparison of simulated outcomes after PCI and CABG, and

this richer and more flexible output is the major advantage over previous prediction models. The arbitrariness of the time point is by virtue of the Cox regression models; in contrast, the logistic regression models and additive scoring systems allow prediction at a single time point only. We confirmed by internal validation that the Kyoto SCORE allows accurate prediction of 30-day, 1-year, and 3-year mortality in terms of both calibration and discrimination. The calculated mortalities were comparable to those in previous studies in Asia.[26–28] A web application for the Kyoto model, which works in both Windows and Macintosh environments, is available at http://www.biostatistics.jp/prediction/kyoto-model.

Importance of Cardiovascular Risk Factors

It is well-known that age, LVEF, multivessel disease, renal failure, PVD and anemia are important predictive factors of operative or in-hospital mortality after PCI.[29] The present analysis showed that, in addition to these factors, cardiovascular risk factors such as atrial fibrillation, DM, hyperlipidemia, current smoker and CKD are associated with long-term mortality. This observation is consistent with both a previous study from the CREDO-Kyoto Registry and a Japanese retrospective study,[30] which reported a strong association between metabolic syndrome-like risk factor accumulation and major cardiovascular events.[17] Importantly, among the conventional cardiovascular risk factors, the effect of obesity on mortality was entirely different between the CREDO-Kyoto Registry, and US and European populations; mortality of patients with BMI ≥25 kg/m^2 was similar to patients with normal BMI and, in contrast, BMI <18.5 kg/m^2 was associated with higher mortality in the PCI group. In contrast, the effects of renin–angiotensin system inhibitors, statins and β-blockers in this analysis were relatively small and thus we did not include the medications in the Kyoto model for easy interpretability. This does not mean a lack of efficacy of the medications, because this was an observational study.

Can Prediction Models for Mortality After PCI and CAGB Be Used to Select a Better Coronary Revascularization Strategy?

The Kyoto model is potentially useful for 2 purposes. First, it provides a convenient measure for stratifying patients according to a given characteristic. Second, it enables comparison between PCI and CABG of the calculated mortality of a patient with various risk profiles and thus selection of the best coronary revascularization strategy. Regarding the issue of individualized treatment selection, a subgroup analysis that pooled individual patient data suggested that CABG might be better for patients with DM and for those aged 65 years or older.[31–33] That result indicates that a better coronary revascularization strategy is possible in theory if individual risk profiles are taken into account.

Study Limitations

Decision making based solely on prediction models is subject to various uncertainties. First, given the CREDO-Kyoto Registry was not randomized, potential confounding factors that could not be adjusted for may be present. This residual confounding would make it difficult to directly compare outcomes between PCI and CABG in a specific subset of patients. The second problem is that we did not validate the Kyoto model in an external population. Given the rapid change in both PCI and CABG, there is no guarantee that the present CREDO-Kyoto population and future patient populations in Japan will remain comparable. Evaluation of the transportability of Kyoto model to other recent registries or clinical trials is therefore warranted. Given these 2 difficulties, decision making about coronary revascularization strategy should not be based solely on prediction models.

Other limitations of this study are as follows. We included total occlusion, proximal LAD disease, LMD, and diseased vessels in the variable selection procedure, but further complexity of disease was not taken into account. Quantification of the complexity of disease, such as the SYNTAX score,[34] is thus worth investigating in future research. We acknowledge that some of the previous prediction models for operative or in-hospital mortality[1–13] have better discrimination than the Kyoto model with regard to 30-day mortality. The C statistics of these models ranged from 0.648 to 0.900,[29] compared with 0.794 for the Kyoto model. Rapid technical and technological improvements make it difficult to develop up-to-date prediction models for long-term outcomes, which require follow-up for a couple of years. Unfortunately, drug-eluting stents were not used in the CREDO-Kyoto Registry, but contemporary PCI procedures have already shifted from bare-metal to drug-eluting stents. However, a pooled analysis of 4 randomized trial suggested that long-term mortality (ie, 2–5 years) with a sirolimus-eluting stent is similar to bare-metal stents[35] and therefore the Kyoto model appears to be still useful in current practice. Finally, we performed only cross-validation, and external validation in other populations is necessary.

Conclusions

These limitations notwithstanding, the Kyoto model provides a flexible and accurate measure for prediction. The calculated mortality aids patients in better comprehending their risk and in adhering to medication and lifestyle changes after coronary revascularization, because the cardiovascular risk factors in the Kyoto model are modifiable, and possibly the clinician in individualized decision making about coronary revascularization strategies.

Disclosures

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