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# Validation of Scoring Systems That Predict Outcomes in Patients With Coronary Artery Disease Undergoing Coronary Artery Bypass Grafting Surgery

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**Abstract:** Several risk stratification scores, based on angiographic or clinical parameters, have been developed to evaluate outcomes in patients with left main coronary artery disease (LMCAD) who undergo coronary artery bypass grafting (CABG). This study aims to validate the predictive ability of different risk scoring systems with regard to long-term outcomes after CABG.

This single-center study retrospectively re-evaluated the Synergy Between PCI with TAXUS and Cardiac Surgery (SYNTAX) score; EuroSCORE; age, creatinine, and ejection fraction (ACEF) score; modified ACEF score; clinical SYNTAX; logistic clinical SYNTAX score (logistic CSS); and Parsonnet scores for 305 patients with LMCAD who underwent CABG. The endpoints were 5-year rate of all-cause death and major adverse cardio-cerebral events (MACCEs), including cardiovascular (CV) death, myocardial infarction (MI), and stroke and target vessel revascularization (TVR).

Compared with the SYNTAX score, other scores were significantly higher in discriminative ability for all-cause death (SYNTAX vs others: $P<0.01$). The EuroSCORE $\geq 6$ showed significant outcome difference on all-cause death, CV death, MI, and MACCE ($P<.01$). Multivariate analysis indicated the SYNTAX score was a non-significant predictor for different outcomes. Adjusted multivariate analysis revealed that the EuroSCORE was the strongest predictor of all-cause death (hazard ratio[HR]: 1.17; $P<0.001$), CV death (HR: 1.16; $P<0.001$), and MACCE (HR: 1.09; $P=0.01$). The ACEF score and logistic CSS were predictive factors for TVR (HR: 0.25, $P=0.03$; HR: 0.85, $P=0.01$).

The EuroSCORE scoring system most accurately predicts all-cause death, CV death, and MACCE over 5 years, whereas low ACEF score and logistic CSS are independently associated with TVR over the 5-year period following CABG in patients with LMCAD undergoing CABG.

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**Abbreviations**: ACEF = Age, creatinine, and ejection fraction, ACEI = Angiotensin-converting enzyme inhibitors, ARB = Angiotensin receptor blockers, CABG = Coronary artery bypass graft, CKD = Chronic kidney disease, CSS = Clinical SYNTAX score, CV = Cardiovascular, DES = Drug-eluting stents, eGFR = estimated glomerular filtration rate, EuroSCORE = European system for cardiac operative risk evaluation, HR = Hazard ratios, LIMA = Left internal mammary artery, LM-3VD = LM triple-vessel disease, LMCAD = Left main coronary artery disease, logistic CSS = Logistic Clinical SYNTAX score, LVEF = Left ventricular ejection fraction, MACCE = Major adverse cardio-cerebral events, MI = Myocardial infarction, PCI = Percutaneous coronary intervention, RIMA = Right internal mammary artery, ROC = Receiver operating characteristic, SYNTAX = Synergy between PCI with TAXUS and Cardiac Surgery, TVR = Target vessel revascularization.

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## INTRODUCTION

Left main coronary artery disease (LMCAD) is associated with angiographic high risk for major adverse cardiovascular (CV) events.[1,2] Established guidelines recommend revascularization with a coronary artery bypass graft (CABG) as the treatment of choice for patients with LMCAD,[3,4] although percutaneous coronary intervention (PCI) with drug-eluting stents (DESs) has demonstrated comparable results to CABG.[5–8] Several risk scoring systems based on angiographic, clinical, or both parameters have been developed to evaluate outcomes in patients with LMCAD undergoing CABG. The Synergy between PCI with TAXUS and Cardiac Surgery (SYNTAX) score includes factors of coronary angiographic complexity rather than clinical factors,[9] whereas the European system for cardiac operative risk evaluation (EuroSCORE)[10] and the Parsonnet score[11] include only clinical parameters that have shown good predictive power for postoperative mortality and morbidity following CABG and adult cardiac surgery.[12–16] Meanwhile, the age, creatinine, and ejection fraction (ACEF) score, comprising age, left ventricular ejection fraction (LVEF), and serum creatinine,[17] shows a fairly reasonable correlation with outcome prediction. The clinical SYNTAX score (CSS) is calculated by multiplying the SYNTAX score with the modified ACEF score.[18] However, each of these scoring systems has significant limitations. The SYNTAX score completely ignores the impact of comorbidities. The

ACEF, modified ACEF, and CSS do not calculate available data specific for an LMCAD patient undergoing CABG. Furthermore, the SYNTAX, Clinical SYNTAX, EuroSCORE, AECF, modified ACEF, logistic Clinical SYNTAX score (logistic CSS),[19] and Parsonnet scoring systems were developed in Western countries and have not been adequately validated in Asian populations. There is little evidence available to support long-term outcome predictions using the above scoring systems for Asian patients. This study aims to use different scores to investigate their predictive ability with regard to long-term outcomes in patients undergoing CABG.

# METHODS

## Patient Population

The preoperative coronary angiogram and medical records of 305 patients with LMCAD who underwent CABG at our institute between October 2000 and June 2011 were reviewed retrospectively. The study protocol was approved by the Institutional Review Committee on Human Research at our institution.

## Method of Collecting Different Scores

The diagnostic preoperative coronary angiograms obtained before CABG were reviewed by an experienced investigator who was not allowed to participate in data collection for clinical outcome and procedure. LMCAD was defined as a stenosis of >50%. Patients diagnosed with LMCAD on coronary angiography were asked to immediately consult a CV surgeon to evaluate the requirement of CABG if the coronary artery lesions were not amenable to treatment with PCI. The study only enrolled LMCAD patients who underwent CABG following consultations with interventional cardiologists and CV surgeons. Patients with documented cirrhosis and a known diagnosis of malignancy before CABG were excluded from the study. For coronary artery stenotic lesions >50% and measuring >1.5 mm, the SYNTAX score was calculated by 2 experienced operators in accordance with the SYNTAX score algorithm.[9] Additive EuroSCORE and Parsonnet scores were calculated based on the original methodology.[10,11] The ACEF score was calculated by the formula: age (years)/ejection fraction of left ventricle + 1 (if the serum creatinine was >2 mg/dL before CABG).[17] The modified ACEF score[18] was calculated by the formula: age (years)/ejection fraction of left ventricle (%) + 1 point for each 10-mL/min reductions when the estimated glomerular filtration rate (eGFR) was <60 mL/min/1.73 $m^2$.[20] CSS was calculated with the formula: CSS = SYNTAX score × modified ACEF score.[18] Logistic CSS was calculated using the formula developed by Farooq et al.[19]

## Clinical Outcomes

All patients underwent regular follow-up as outpatients with their CV surgeon or cardiologist after discharge. Initially, patients returned for outpatient visits every month for the first 3 to 6 months depending on the stability of the patients' clinical condition after optimizing medication in accordance with the clinical practice protocol prevailing at our institute. Patients who did not return to the outpatient clinics for follow-up were followed by chart review that included examination of further admission records and all outpatient clinic records at our institute. Finally, patients who could not be followed by the above-mentioned methods received a telephonic follow-up, with confirmation by the patients or their families of morbidity or mortality. Each case was followed up until the first episode of the predefined outcome end points or until the end of the specified follow-up period. All cases that did not meet predefined outcomes or death during follow-up were excluded from the analysis.

The study end-points were all-cause death and major adverse cardiocerebral events (MACCE), including CV death, myocardial infarction (MI), stroke, and target vessel revascularization (TVR).[21] All-cause death was defined as mortality from any cause; cardiac and non-cardiac CV deaths were defined as death resulting from sudden cardiac death, death due to acute MI, heart failure, stroke, and ventricular arrhythmia. MI was defined as the appearance of new abnormal Q waves or cardiac enzyme levels 5 times the upper limit of normal that were associated with the presence of ischemic symptoms or new electrocardiographic changes. Stroke was further classified as transient ischemic attacks, ischemic stroke, or intracranial hemorrhage. TVR was defined as any repeat revascularization by PCI or repeat CABG.

## Statistical Analysis

Continuous variables are expressed as mean ± standard deviation, and categorical variables as numbers and percentages. The Kaplan–Meier method was used to display cumulative incidence for various end-points. The predictive validities of outcomes in different scoring systems were qualified as receiver-operating characteristic (ROC; c-statistics) curves and comparisons of c-statistics, which were used to quantify the capacity of the estimated risk score for differentiating among subjects with different event times.[22] The ROC (c-statistics) curve and comparisons of c-statistics were conducted using the Medcalc statistical software (version 14.8.1, Mariakerke, Belgium). From the ROC curve analysis, the best cutoff value for each score was identified at the point where the sum of sensitivity and specificity was the highest. Based on the best cutoff value in different CV outcomes, the Kaplan–Meier survival curve displayed a 5-year event-free survival curve for different CV outcomes. Univariate and multivariate models were used to estimate HR in the Cox proportional hazards model to assess the associations of outcomes with different score systems in the follow-up period. To determine which covariates should be included in the adjusted multivariable models, a full model with all potential confounders, including history of diabetes, hypertension, dyslipidemia, smoking, old MI, atrial fibrillation, stroke, chronic kidney disease (CKD), end-stage renal disease, LVEF, and medications at discharge (ie, antiplatelet agents, β-blockers, angiotensin-converting enzyme inhibitors (ACEIs), angiotensin receptor blockers [ARB], statins, and nitrates), was developed. Composite factors of the selected scoring systems were excluded. Covariates were removed from the model using backward elimination with a threshold $P$ value >0.05. Covariates with $P$ value <0.05 in each scoring system were entered into the multivariate analysis to verify whether each scoring system was an independent predictor of CV outcomes as indicated. Except for the *c*-statistic, all other statistics were evaluated by using the software package SPSS version 17.0 (SPSS Inc, Chicago, IL).

# RESULTS

Three hundred five patients with LMCAD underwent CABG at our institute between October 2000 and June 2011 (Table 1). This patient cohort was male-dominant (men: 234, 76.5%), with a mean age of 66.0 ± 9.1 years. Of these, 162 (52.9%) patients had diabetes mellitus, 231 (75.5%) had

**TABLE 1.** Basic Characteristics

| Characteristic | n = 305 (%) |
|---|---|
| Demographics | |
| Male | 234 (76.5%) |
| Age, years | 66.04 ± 9.16 |
| Diabetes | 162 (52.9%) |
| Hypertension | 231 (75.5%) |
| Dyslipidemia | 156 (51%) |
| Smoker | 91 (31.7%) |
| Old myocardial infarction | 71 (23.2%) |
| Peripheral artery disease | 37 (12.1%) |
| Atrial fibrillation | 33 (10.8%) |
| History of stroke | 48 (15.7%) |
| COPD | 40 (13.1%) |
| LVEF% | 56.4 ± 18.6% |
| BMI, kg/m$^2$ | 25.8 ± 4.0 |
| Serum Cr, mg/dL | 1.9 ± 2.3 |
| CKD (eGFR $\leqq$ 60 mL/min/1.73m$^2$) | 135 (43.3%) |
| End-stage renal disease | 23 (7.5%) |
| Vessel involvement | |
| LM only | 3 (1%) |
| LM-1 vessel disease | 11 (3.6%) |
| LM-2 vessel disease | 43 (14.3%) |
| LM-3 vessel disease | 248 (81%) |
| Risk assessment | |
| SYNTAX score | 35.2 ± 9.5 |
| EuroSCORE | 5.5 ± 3.9 |
| ACEF score | 1.5 ± 0.8 |
| Modified ACEF score | 2.5 ± 2.0 |
| CSS | 92.2 ± 81.5 |
| Parsonnet score | 12.0 ± 9.0 |
| Logistic CSS | 11.0 ± 4.8 |
| Medication at discharge | |
| Antiplatelet | 259 (84.6%) |
| B-blocker | 113 (36.9%) |
| ACEI/ARB | 90 (29.4%) |
| Statin | 56 (18.3%) |
| Nitrate | 222 (72.5%) |

ACEF = age, creatinine, and ejection fraction, ACEI/ARB = angiotensin conversion enzyme/angiotensin receptor blocker, BMI = body mass index, CKD = chronic kidney disease, COPD = chronic obstructive pulmonary disease, CSS = clinical syntax score, eGFR = estimated glomerular filtration rate, EuroSCORE = European system for cardiac operative risk evaluation, LVEF = left ventricular ejection fraction, SYNTAX = The Synergy between PCI with TAXUS and Cardiac Surgery.

hypertension, and 156 (51%) had dyslipidemia. Seventy-one (23.2%) patients had a history of MI. The mean LVEF was 56.4% ± 18.6%, and the mean serum creatinine level was 1.9 ± 2.3 mg/dL; 135 (43.3%) patients had CKD (eGFR ≤60 mL/min/1.73 m$^2$). On a review of the surgical procedure, we observed that 245 (80%) patients received a LM triple-vessel disease (LIMA) graft; there were no instances reported for the use of the right internal mammary artery (RIMA). Two hundred forty-eight (81%) patients had LM triple-vessel disease (LM-3VD). In the study population, the mean SYNTAX score was 35.2 ± 9.5, the mean additive EuroSCORE was 5.5 ± 3.9, the mean ACEF score was 1.5 ± 0.8, the mean modified ACEF score was 2.5 ± 2.0, the mean CSS was 92.2 ± 81.5, the mean logistic CSS was 11.0 ± 4.8, and the mean Parsonnet score was

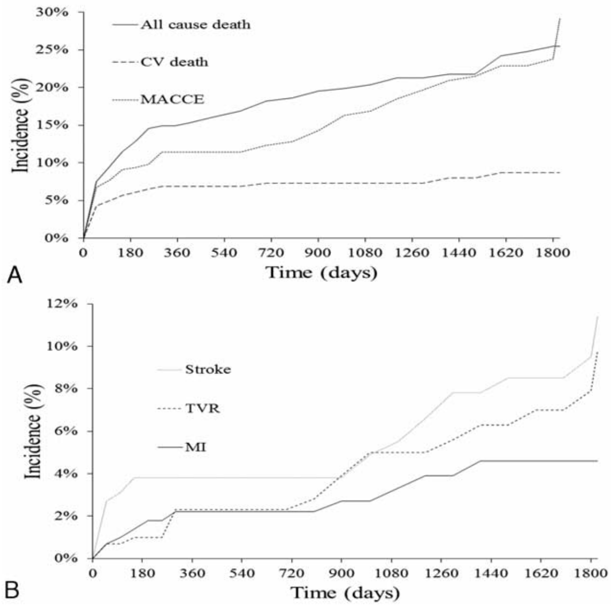


**FIGURE 1.** Cumulative incidence of outcomes. (A) Cumulative incidences of all-cause death, CV death, and MACCE; (B) cumulative incidences of stroke, TVR, and MI. CV = cardiovascular, MACCE = major adverse cardiocerebral event, MI = myocardial infarction, TVR = target vessel revascularization.

12.0 ± 9.0. From Table 1, these data indicate that our patient cohort was high mortality.

To examine the outcome of patients with LMCAD undergoing CABG, short- and long-term outcomes were analyzed and are shown in Figure 1 and Table 2. The mean follow-up period was 1084 days (median 1237 days; 25%–75% quartile range: 344–1825 days). The 5-year cumulative incidence showed 67 (25.5%) all-cause deaths and 59 (29.2%) MACCEs, including 23 (8.7%) CV deaths, 10 (4.6%) MIs, 21 (11.4%) strokes, and 17 (9.8%) TVRs (2 [0.7%] repeat CABGs and 15 (9.1%) PCIs). Among the 67 patients with all-cause death, 23 patients had CV death, 7 patients died of cancer diagnosed after undergoing CABG 1 year later, and 1 patient died of fulminant hepatitis after undergoing CABG 2 years later.

**TABLE 2.** Cumulative Incidences of Cardiovascular Outcomes in 6 Months, 1 year, 3 Years, and 5 Years

| Outcome | 6 Months | 1 Year | 3 Years | 5 Years |
|---|---|---|---|---|
| Numbers at risk | 259 | 228 | 167 | 98 |
| All-cause death | 39 (12.9%) | 45 (14.9%) | 60 (21.3%) | 67 (25.5%) |
| MACCE | 28 (9.4%) | 33 (11.4%) | 47 (18.5%) | 59 (29.2%) |
| CV death | 18 (6.1%) | 20 (6.9%) | 21 (7.3%) | 23 (8.7%) |
| MI | 5 (1.8%) | 6 (2.2%) | 9 (3.9%) | 10 (4.6%) |
| Stroke | 11 (3.8%) | 11 (3.8%) | 16 (6.6%) | 21 (11.4%) |
| TVR | 3 (1.0%) | 6 (2.3%) | 11 (5.0%) | 17 (9.8%) |
| Re-CABG | 2 (0.7%) | 2 (0.7%) | 2 (0.7%) | 2 (0.7%) |
| PCI | 1 (0.4%) | 4 (1.6%) | 9 (4.3%) | 15 (9.1%) |

CV death = cardiovascular death, MACCE = major cardiocerebral events, MI = myocardial infarction, PCI = percutaneous coronary intervention, Re-CABG = repeat coronary artery bypass grafting, TVR = target vessel revascularization.

**TABLE 3.** Discriminatory Ability of Different Score Systems in the Prediction of 5-year Outcomes

| | All-cause Death | | MACCE | | CV Death | | MI | | Stroke | | TVR (PCI + Repeat-CABG) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AUC* | P† | AUC* | P† | AUC* | P† | AUC* | P† | AUC* | P† | AUC* | P† |
| SYNTAX | 0.54 (0.48–0.59) | 0.35‡ | 0.50 (0.44–0.56) | 0.87‡ | 0.52 (0.46–0.57) | 0.74‡ | 0.61 (0.56–0.67) | 0.25‡ | 0.53 (0.47–0.58) | 0.58‡ | 0.50 (0.44–0.56) | 0.94‡ |
| EuroSCORE | 0.75 (0.70–0.80) | <0.01 | 0.54 (0.49–0.60) | 0.45 | 0.66 (0.60–0.71) | 0.08 | 0.66 (0.60–0.71) | 0.68 | 0.51 (0.45–0.57) | 0.81 | 0.65 (0.59–0.70) | 0.11 |
| ACEF | 0.76 (0.71–0.81) | <0.01 | 0.53 (0.47–0.58) | 0.69 | 0.65 (0.60–0.71) | 0.09 | 0.56 (0.50–0.62) | 0.66 | 0.6 (0.54–0.66) | 0.35 | 0.73 (0.67–0.78) | <0.01 |
| Modified ACEF | 0.73 (0.67–0.78) | <0.01 | 0.52 (0.46–0.58) | 0.77 | 0.64 (0.58–0.69) | 0.13 | 0.59 (0.54–0.65) | 0.86 | 0.59 (0.53–0.65) | 0.41 | 0.73 (0.68–0.78) | <0.01 |
| Clinical SYNTAX | 0.72 (0.66–0.77) | <0.01 | 0.52 (0.46–0.57) | 0.73 | 0.63 (0.57–0.68) | 0.11 | 0.51 (0.45–0.57) | 0.25 | 0.58 (0.52–0.63) | 0.49 | 0.7 (0.65–0.75) | <0.01 |
| Parsonnet | 0.68 (0.63–0.73) | <0.01 | 0.53 (0.48–0.59) | 0.6 | 0.66 (0.60–0.71) | 0.09 | 0.58 (0.52–0.63) | 0.75 | 0.51 (0.45–0.56) | 0.78 | 0.65 (0.60–0.71) | 0.11 |
| Logistic CSS | 0.76 (0.69–0.82) | <0.01 | 0.52 (0.44–0.60) | 0.70 | 0.62 (0.50–0.75) | 0.11 | 0.56 (0.41–0.71) | 0.59 | 0.53 (0.40–0.66) | 0.96 | 0.69 (0.60–0.79) | <0.01 |

ACEF = age, creatinine, and ejection fraction, AUC = area under curve, CABG = coronary artery bypass grafting, CSS = clinical syntax score, CV = cardiovascular, EuroSCORE = European system for cardiac operative risk evaluation, MACCE = major cardiocerebral events, MI = myocardial infarction, PCI = percutaneous coronary intervention, SYNTAX = The Synergy between PCI with TAXUS and Cardiac Surgery, TVR = target vessel revascularization.
* c-statistics (95% CI).
† Comparing with SYNTAX score.
‡ Comparing with AUC = 0.5.

To compare the discriminative ability of different scoring systems with regard to long-term outcomes, an ROC analysis of the SYNTAX, EuroSCORE, ACEF, modified ACEF, Clinical SYNTAX, logistic CSS, and Parsonnet scores in the prediction of 5-year outcomes was done (results summarized in Table 3). With regard to all-cause death, the EuroSCORE, ACEF, modified ACEF, Clinical SYNTAX, logistic CSS, and Parsonnet scores showed better discriminative ability compared with the SYNTAX score ($P < 0.01$). For TVR, the ACEF, modified ACEF, Clinical SYNTAX, and logistic CSS scores showed better discriminative ability than the SYNTAX score ($P < 0.01$). With regard to CV death, MI, stroke, and MACCE, there was no significant difference (on area under the curve [AUC]) between the SYNTAX score and the EuroSCORE, ACEF, modified ACEF, Clinical SYNTAX, and Parsonnet scores. In our study, the SYNTAX score showed the least discriminative ability in all outcomes (all $P > 0.05$) in patients of LMCAD who underwent CABG.

Comparing the AUC of the above scoring systems in all outcomes, the EuroSCORE showed the best discriminative ability for all-cause death (AUC = 0.75, 95% confidence interval [CI] = 0.70–0.80, $P < 0.01$), CV death (AUC = 0.66, 95% CI = 0.60–0.71, $P = 0.08$), MI (AUC = 0.66, 95% CI = 0.60–0.71, $P = 0.68$), and MACCE (AUC = 0.54, 95% CI = 0.49–0.60, $P = 0.45$). The modified ACEF score displayed a better discriminative ability for TVR (AUC = 0.73, 95% CI = 0.68–0.78, $P < 0.01$) and the ACEF score showed better discriminative ability for stroke (AUC = 0.60, 95% CI = 0.54–0.66, $P = 0.35$).

To obtain cutoff values, we did an ROC analysis. Based on the results of ROC curve (Figure 2), a EuroSCORE = 6 was identified as the best cutoff value for all-cause death (sensitivity: 65.67%; specificity: 71.43%), CV death (sensitivity: 69.57%; specificity: 65.96%), MI (sensitivity: 70%; specificity: 64.41%), and MACCE (sensitivity: 47.46% specificity: 65.85%). A modified ACEF score of 1.0 was the best cutoff value for TVR (sensitivity: 64.71% specificity: 71.87%) and an ACEF score of 1.0 was the best indicator for stroke (sensitivity: 61.9% specificity: 67.61%).

Based on the above cutoff values of different scoring systems for different outcomes, an EuroSCORE $\geq 6$ was a significantly good indicator of poor prognosis for all-cause death ($P < 0.01$), CV death ($P < 0.01$), MI ($P = 0.01$), and MACCE ($P < 0.01$), as shown in Figure 3. A modified ACEF score $\leq 1.0$ was indicative of a lower incidence of TVR ($P = 0.02$), whereas an ACEF score $\leq 1.0$ was indicative of a higher incidence of stroke ($P = 0.06$). Our study showed the individual scoring systems had good discriminative ability for different long-term outcomes.

To verify whether the scores from the different systems were independent risk factors of outcome, a multivariate analysis was conducted and the results are summarized in Figure 4. The EuroSCORE was a significant independent risk factor for all-cause death (HR = 1.17, 95% CI = 1.08–1.25, $P < 0.001$), CV death (HR = 1.16, 95% CI = 1.05–1.28, $P < 0.001$), and MACCE (HR = 1.09, 95% CI = 1.02–1.17, $P = 0.01$). The Parsonnet score was a significant independent risk factor for CV death (HR = 1.07, 95% CI = 1.02–1.11, $P < 0.001$) and MACCE (HR = 1.04, 95% CI = 1.01–1.07, $P = 0.01$). The ACEF score (HR = 0.25, 95% CI = 0.07–0.89, $P = 0.03$) and logistic CSS (HR = 0.85, 95% CI = 0.75–0.96, $P = 0.01$) were significant independent factors predictive for TVR. The SYNTAX, EuroSCORE, ACEF, Modified ACEF, CSS, logistic CSS, and Parsonnet scores did not show significance in predicting MI and stroke outcomes.

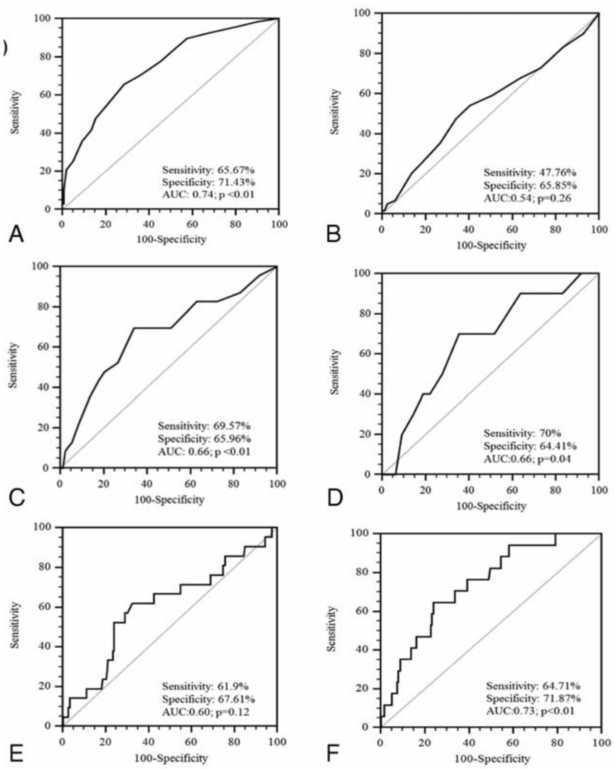


**FIGURE 2.** ROC analysis for different scoring systems for CV outcomes. (A) EuroSCORE for all-cause death, (B) EuroSCORE for MACCE, (C) EuroSCORE for CV death, (D) EuroSCORE for MI, (E) ACEF score for stroke, and (F) modified ACEF score for TVR. ACEF = age, creatinine, and ejection fraction, CV = cardiovascular, MACCE = major adverse cardiocerebral event, MI = myocardial infarction, ROC = receiver-operating characteristic, TVR = target vessel revascularization.

## DISCUSSION

The results of our study demonstrated that risk scoring systems for patients of LMCAD undergoing CABG that comprise clinical parameters have better predictive ability than the SYNTAX score with regard to long-term outcome. Our study revealed that the EuroSCORE is still the most reliable predictive scoring system for CABG, and concurs with previous studies reporting this finding.[12–14] Importantly, the EuroSCORE shows a powerful predictive ability for all-cause death, CV death, MI, and MACCE at 5 years after CABG. All scoring systems showed a statistically non-significant predictive capability for stroke. The modified ACEF score showed a negative correlation for TVR. When comorbidity and discharge medications were adjusted, the EuroSCORE and Parsonnet score were still found to be independent risk factors for CV death and MACCE. The EuroSCORE was an independent risk factor for all-cause death, and the ACEF score and logistic CSS were predictive factors for TVR.

The SYNTAX score was found to be significantly different from other scoring systems. This could be because the scoring system only takes into consideration coronary angiogram instead of clinical comorbidities, which have been proven to predict outcomes for patients of LMCAD undergoing CABG or PCI.[23] Özcan et al[24] reported that a SYNTAX score has good discriminative ability to predict short-term and long-term incidence of MACCE with an accuracy level of 36.5. However, their study group had a population with lesser disease severity (SYNTAX score: mean $24 \pm 9$) than the cohort in our study. Some studies have also shown that a SYNTAX score does not significantly affect long-term outcomes of coronary bypass surgery[23,25,26] and have suggested that clinical and angiographic information be taken into consideration to predict outcomes.[27] However, with advances in coronary interventions, the SYNTAX score has become the most commonly used tool for deciding between PCI or CABG for the LMCAD patients. Our study demonstrates that the SYNTAX score not only failed to discriminate between different long-term outcomes (including all-cause death, MACCE, CV death, MI, stroke, and TVR), but also fails when used for predictive factors.

The CSS shows acceptable predictive ability for 5-year MACCE and mortality for patients with complex CAD undergoing PCI, but it has no verified results specific to CABG.[18] The CSS has better discriminatory ability than the SYNTAX score in predicting short- and long-term outcomes for patients with complex CAD undergoing PCI.[28,29] Similarly, our study demonstrates that the CSS has better predictive ability than the SYNTAX score in predicting 5-year all-cause death and TVR and is even better than the EuroSCORE at predicting 5-year TVR (*c*-statistic of EuroSCORE vs CSS: 0.7 vs 0.65) and stroke (*c*-statistic of EuroSCORE versus CSS: 0.58 vs 0.51).

In addition, a logistic CSS was developed to validate the predictive ability for long-term outcomes,[19] and showed better discriminative ability than the SYNTAX score alone to predict 3-year mortality for CAD after PCI.[30] Our study results also showed that the logistic CSS has a superior ability to predict 5-year all-cause mortality and TVR compared with the SYNTAX score. However, because of the limitation of our small sample

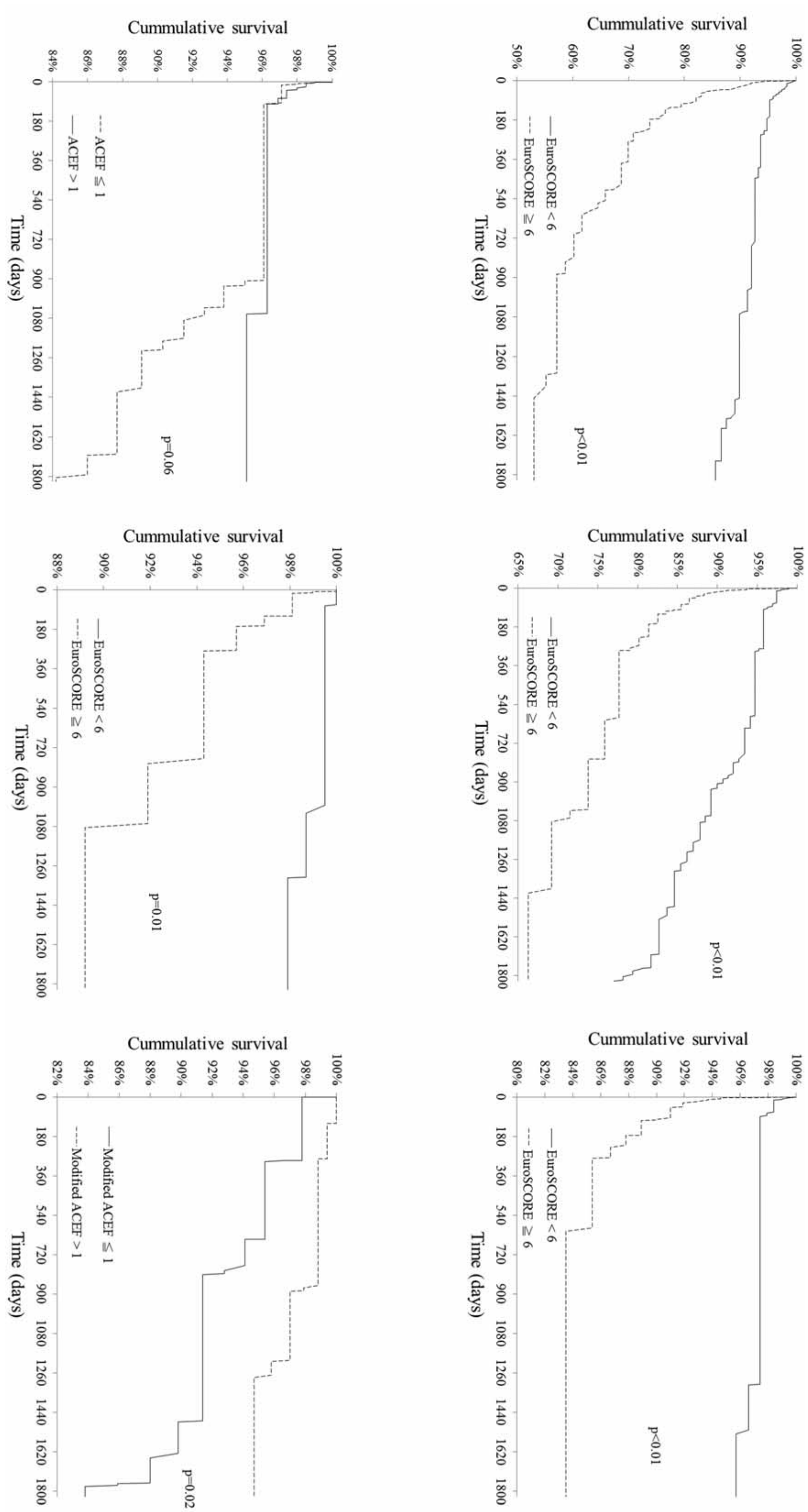


**FIGURE 3.** Event-free survival over 5 years stratified by the cutoff value of the most reliable scoring system. (A) EuroSCORE for all-cause death, (B) EuroSCORE for MACCE, (C) EuroSCORE for CV death, (D) EuroSCORE for MI, (E) ACEF score for stroke, and (F) modified ACEF score for TVR. ACEF = age, creatinine, and ejection fraction, CV = cardiovascular, MACCE = major adverse cardiocerebral event, MI = myocardial infarction, TVR = target vessel revascularization.

 

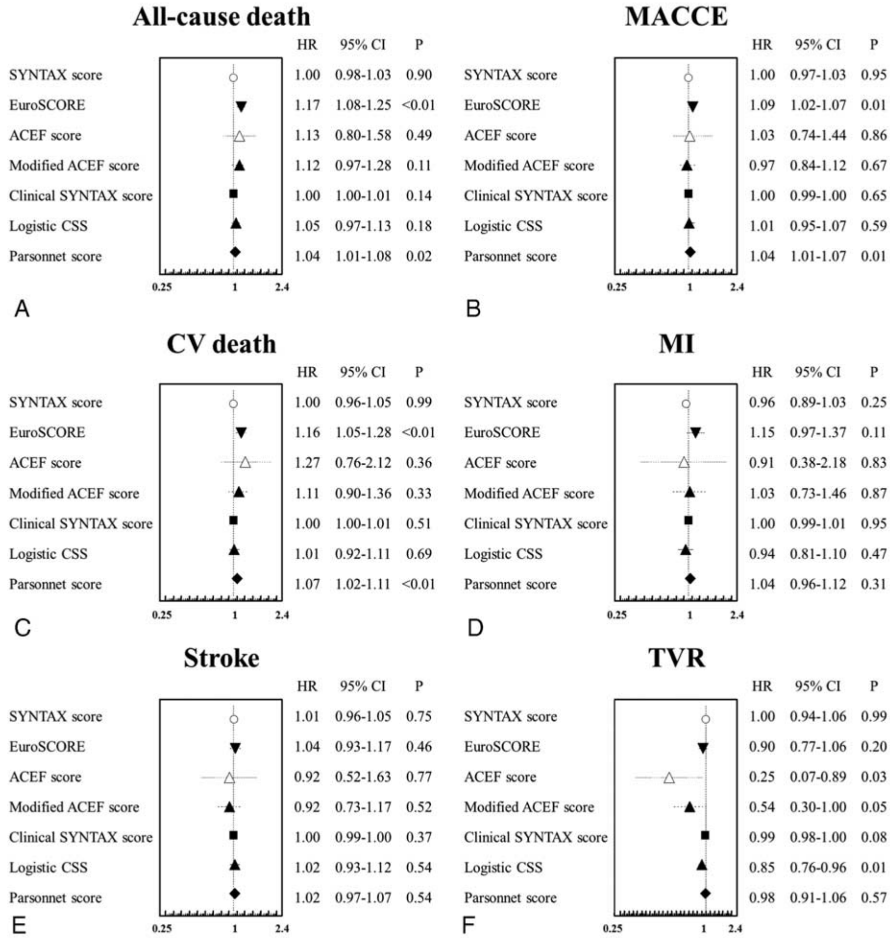


**FIGURE 4.** Adjusted hazard ratio of various scoring systems for different CV outcomes in 5 years. (A) All-cause death, (B) MACCE, (C) CV death, (D) MI, (E) stroke, and (F) TVR. CV = cardiovascular, MACCE = major adverse cardiocerebral event, MI = myocardial infarction, TVR = target vessel revascularization.

size (305 cases), further studies are needed to ascertain whether the logistic CSS has predictive ability specific to CABG patients.

We agree that risk scoring systems facilitate risk stratification, especially in high-risk LMCAD patients with much comorbidity undergoing CABG. However, not only the coronary arterial anatomy but also clinical characteristics should be taken into consideration for strategic therapeutic decision-making. Our study revealed that the EuroSCORE, which includes more clinical and procedural risk factors, had a better discriminative ability for all-cause death, CV death, and MACCE for long-term outcomes than either CSS or logistic CSS. Thus, for high-risk patients, the EuroSCORE is a satisfactory tool to predict long-term outcomes compared with CSS or logistic CSS.

There is much evidence in support of the ACEF score for predicting outcomes in patients undergoing PCI and elective cardiac operations[17,31,32]; however, there is lesser evidence of ACEF scores being used to predict outcomes in patients undergoing CABG. The LEADERS trial[32] in patients undergoing PCI reveals insignificant results for the predictive ability of the ACEF score with regard to TVR. Our study results indicate that an ACEF score can be treated as a predictive factor for TVR in patients undergoing CABG. The modified ACEF score was created by Garg et al[18] for developing a CSS, but it is rarely discussed in outcome studies of patients undergoing CABG. Kovacic et al[33] indicated that low scores of the ACEF and the modified ACEF scores show a negative association for TVR in patients undergoing PCI. In comparison, our results demonstrate similar results in predicting long-term TVR incidence in patients undergoing CABG (HR: 0.25, 95% CI: 0.07–0.89, $P = 0.03$). However, the modified ACEF score did not show significance for long-term TVR incidence in our patient cohort (HR: 0.54, 95% CI: 0.30–1.00, $P = 0.05$). This might explain why patients with higher serum creatinine levels would be less suitable for PCI and, thus, a lower incidence of TVR was noted. Therefore, patients suffering from recurrent chest pain with lower creatinine levels post-CABG are more likely to undergo a repeat PCI.

## Clinical Impact

Our study demonstrates that the EuroSCORE is a valid long-term outcome predictor for all-cause death, CV death, and MACCE. A EuroSCORE $\geq 6$ has excellent discriminative ability to predict all-cause death, CV death, MACCE, and MI incidence. Kappetein et al[7] reported that MACCE rates were not significantly different between CABG and PCI for the LMCAD subgroup. This may be explained by the fact that the outcomes of the LMCAD patients may be predominantly affected by complex coronary anatomy and the associated comorbidity. Therefore, for high-risk patients with LMCAD having both a high EuroSCORE and high SYNTAX score, either CABG or PCI is acceptable as therapeutic interventions. However, for patients with a high-risk EuroSCORE $\geq$6 but low SYNTAX score, PCI may be a better strategy than CABG. Recently, the SYNTAX score II, which combines the SYNTAX score and clinical characteristics, has been reported to have good discriminating ability to predict long-term mortality for complex CAD and unprotected LMCAD revascularization.[34,35] Our study also supports the findings of the influence of patient comorbidities affecting long-term outcome for complex CAD instead of coronary anatomy alone.

In fact, there are many risk factors that determine morbidity and mortality and may have potentially influenced our study results. First, not all of our patients underwent CABG alone. In our study, 25 (8%) patients underwent CABG together with valve surgery, which would have increased the complexity of cardiac surgery. Second, there were more patients with CKD ($n = 135$, 43.3%) or end-stage renal disease ($n = 23$, 7.5%) in our patient cohort. Third, the discharge medication was not well optimized, especially with regard to lesser use of statins ($n = 56$, 18.3%). Finally, because of the greater complexity of coronary anatomy in our patient cohort (LM-3VD, $n = 248$, 81%), our results are not applicable in conditions with less complex coronary anatomy.

## Study Limitation

There are some limitations to this study. First, our study had a small study sample, which is attributable to restrictions imposed by the study design of a retrospective study at a single center. However, the current literature does not supply much evidence for CABG with the above-mentioned risk scoring systems. Our study aimed to fill the requirement of an evaluation of predictive scoring systems of CV risk after CABG and shares these preliminary results with the academic community to inspire future research. Second, the discharge medication played an important role for long-term outcome; however, as this was a retrospective study, it was difficult to optimize medications as would have been possible in a prospective study. Third, the SYNTAX score used in this study was the site SYNTAX score calculated by operators instead of the corelab SYNTAX score.[36,37] Finally, during the long study period from 2000 to 2011, surgical techniques and improvements in devices would have advanced, although the surgeons and team members of the CABG teams at our institute did not change significantly. However, with the popularity and technical advances of PCI in LMCAD, the complexity of LMCAD patients undergoing CABG has increased and may have neutralized the improvements in surgical techniques and devices.

# CONCLUSIONS

In high-risk patients with LMCAD undergoing CABG, scoring systems with clinical parameters demonstrate better discriminative ability and sensitivity for long-term outcomes than the SYNTAX score. The EuroSCORE is the most accurate predictive scoring system for 5-year CV outcomes at present. A high EuroSCORE is the most accurate independent predictor of all-cause death, CV death, and MACCE over 5 years, whereas low ACEF score and logistic CSS are independently associated with TVR over the 5-year period following CABG.


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