Comparison of four contemporary risk models at predicting mortality after aortic valve replacement

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Objective: Risk stratification for aortic valve replacement (AVR) is desirable given the increased demand for intervention and the introduction of transcatheter aortic valve implantation. We compared the prognostic utility of the European System for Cardiac Operative Risk Evaluation (EuroSCORE), EuroSCORE II, Society of Thoracic Surgeons (STS) score, and an Australasian model (Aus-AVR score) for AVR.

Methods: We retrospectively calculated the 4 risk scores for patients undergoing isolated AVR at Auckland City Hospital from 2005 to 2012 and assessed their discrimination and calibration for short- and long-term mortality.

Results: A total of 620 patients were followed up for 3.8 ± 2.4 years, with an operative mortality of 2.9% ($n = 18$). The mean EuroSCORE, EuroSCORE II, STS score, and Aus-AVR score was $8.7\% \pm 8.3\%$, $3.8\% \pm 4.7\%$, $2.8\% \pm 2.7\%$, and $3.2\% \pm 4.8\%$, respectively. The corresponding C-statistics for operative mortality were 0.752 (95% confidence interval [CI], 0.652-0.852), 0.711 (95% CI, 0.607-0.815), 0.716 (95% CI, 0.593-0.837), and 0.684 (95% CI, 0.557-0.811). The corresponding Hosmer-Lemeshow test *P* and chi-square values for calibration were .007 and 21.1, .125 and 12.6, .753 and 5.0, and .468 and 7.7. The corresponding Brier scores were 0.0348, 0.0278, 0.0276, and 0.0294. Independent predictors of operative mortality included critical preoperative state, atrial fibrillation, extracardiac arteriopathy, and mitral stenosis. The log-rank test *P* values were all $<.001$ for mortality during follow-up for all 4 scores, stratified by quintile.

Conclusions: All 4 risk scores discriminated operative mortality after isolated AVR. The EuroSCORE had poor calibration, overestimating operative mortality, although the other 3 scores fitted well with contemporary outcomes. The STS score was the best calibrated in the highest quintile of operative risk. (*J Thorac Cardiovasc Surg* 2015;149:443-8)

See related commentary on pages 449-50.

Surgical aortic valve replacement (AVR) has been the recommended treatment of severe symptomatic aortic valve disease.¹⁻³ The introduction of transcatheter aortic valve implantation (TAVI) has made accurate risk stratification even more important in selecting the optimal treatment modality for high-risk patients with aortic stenosis.^{1,4} The European System for Cardiac Operative Risk Evaluation (EuroSCORE), published in 1999, and the Society of Thoracic Surgeons (STS) score, published in 2008, have been the 2 most widely used risk models for cardiac surgery.^{5,6} Despite this, recent studies have shown that the

original EuroSCORE overestimated operative mortality for valve surgery⁷ and performed less well than the STS score.⁸⁻¹⁰ The revised EuroSCORE II was published in 2012 to better fit contemporary outcomes.¹¹ Other risk models specific to AVR have been developed, including one based on an Australasian population (Aus-AVR score).¹² We compared the prognostic utility of the EuroSCORE, EuroSCORE II, STS score, and Aus-AVR score for detecting mortality in a contemporary isolated AVR cohort.

METHODS

All patients undergoing isolated AVR without concomitant valve or coronary surgery from January 2005 to December 2012 at Auckland City Hospital were included. The clinical characteristics and outcomes were extracted from a prospectively collected database. The EuroSCORE II definitions were used for the preoperative characteristics. Angina and dyspnea were graded using the Canadian Cardiovascular Society classification and the New York Heart Association functional classification, respectively. Valvular stenosis or regurgitation was considered present only if at least moderate in severity. The estimated glomerular filtration rate was calculated using the Modification of Diet and Renal Disease equation and the last serum creatinine measurement preoperatively.

The EuroSCORE,⁵ EuroSCORE II,¹¹ STS score,⁶ and Aus-AVR score¹² were calculated for all patients retrospectively after separate data collection of the parameters for each score for which the definitions might differ. No significant changes were found in the operative techniques or perioperative care during the study period. The mortality data were checked against

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Abbreviations and Acronyms

Aus-AVR score	= risk model specific to AVR based on an Australasian population
AVR	= aortic valve replacement
EuroSCORE	= European System for Cardiac Operative Risk Evaluation
STS	= Society of Thoracic Surgeons
TAVI	= transcatheter aortic valve implantation

New Zealand's national registry up to June 30, 2013. Both operative mortality (in-hospital or within 30 days) and mortality during follow-up were prespecified outcomes for the analyses.

The Mann-Whitney *U* test and Fisher exact test was used for univariate analyses for continuous (presented as the mean $\pm$ standard deviation) and categorical variables (presented as the percentages and frequencies), respectively. Kaplan-Meier curves and the log-rank (Mantel-Cox) test were used for univariate survival analyses for mortality during follow-up. The variables with $P < .10$ in the univariate analyses and age, gender, and ethnicity were incorporated into the multivariate analyses, using logistic regression to identify the predictors of operative mortality. Receiver operating characteristics analysis was used to calculate the C-statistic and 95% confidence intervals (CIs) for operative mortality. The C-statistics were compared for significant differences using the Hanley and McNeil test. The Fisher exact test was used to compare the observed and predicted operative mortality for each score and, together with the Hosmer-Lemeshow test and Brier score, to assess calibration. All tests were 2-tailed. The Statistical Package for Social Sciences, version 17.0 (SPSS, Inc, Chicago, Ill), and Prism, version 5 (GraphPad Software, San Diego, Calif), were used for the statistical analyses. The regional ethics committee approved the present study.

RESULTS

During the 8-year study period, 620 patients had undergone isolated AVR at Auckland City Hospital. The baseline characteristics are listed in Table 1. The mean age was 64.8 ± 15.5 years, and 34.5% ($n = 214$) were women. The mean EuroSCORE, EuroSCORE II, STS score, and Aus-AVR score was $8.7\% \pm 8.3\%$, $3.8\% \pm 4.7\%$, $2.8\% \pm 2.7\%$, $3.2\% \pm 4.8\%$, respectively. Mechanical valves were implanted in 30.6% ($n = 190$) and bioprosthetic valves in 69.4% ($n = 430$).

The operative mortality was 2.9% (18 of 620 patients). Multivariate analyses revealed a critical preoperative state, atrial fibrillation, extracardiac arteriopathy, and mitral stenosis to independently predict operative mortality (Table 2).

The results of the discrimination and calibration analyses for operative mortality are listed in Table 3. The C-statistic for operative mortality using EuroSCORE, EuroSCORE II, STS score, and Aus-AVR score was 0.752 (95% CI, 0.652-0.852), 0.711 (95% CI, 0.607-0.815), 0.716 (95% CI, 0.593-0.837), and 0.684 (95% CI, 0.557-0.811), respectively. No statistically significant difference was found among these C-statistics (Hanley and McNeill $P = .485$ -.967).

In terms of calibration, the EuroSCORE had the only *P* values that were statistically significant using the Fisher exact test and Hosmer-Lemeshow test ($P < .001$ and $P < .007$, respectively). The *P* values for EuroSCORE II, the STS score, and the Aus-AVR score using the Fisher exact test and Hosmer-Lemeshow test were not ($P = .433$ and $P = .125$, $P = 1.000$ and $P = .753$, and $P = .869$ and $P = .468$, respectively). The EuroSCORE also had the highest Brier score (0.0348). The Brier score was 0.0278, 0.0276, and 0.0294 for EuroSCORE II, the STS score, and the Aus-AVR score, respectively. Calibration plots by quintiles of scores for operative mortality are illustrated in Figure 1. The EuroSCORE overestimated operative mortality in all quintiles, with increasing discrepancy in the higher quintiles. EuroSCORE II and the Aus-AVR score also overestimated operative mortality in the highest quintile to a moderate degree; however, the STS score had good calibration in all quintiles.

The mean follow-up period was 3.8 ± 2.4 years, and the 1-, 3-, and 5-year survival rate for the cohort was 94.2%, 89.1%, and 82.6%, respectively. Kaplan-Meier survival curves by quintile for all 4 scores are shown in Figure 2. The log-rank test results were $P < .001$ for all scores.

DISCUSSION

The present study had several important findings regarding risk model utility for isolated AVR. The discrimination of operative mortality was similar for all scores. The 3 newer scores were better calibrated to contemporary outcomes by not overestimating operative mortality as does the original EuroSCORE. In the highest quintile, the STS score was the most accurate. We also found that the accuracy of the Aus-AVR score was comparable to that of EuroSCORE II and the STS score.

The original EuroSCORE has been reported in recent studies to overestimate operative mortality in cardiac surgery, including isolated AVR.⁷ This has been attributed to changing patient demographics and risk factor profiles and improving perioperative care in anesthesia, surgery, and intensive care.¹³ This encouraged revision and development of newer risk models, including those evaluated in our study.^{6,11,12} Before the publication of EuroSCORE II, studies had identified the STS score to have improved calibration compared with the EuroSCORE.⁸⁻¹⁰ More recent studies have shown that EuroSCORE II provides more accurate estimates of operative mortality than can the EuroSCORE in cardiac surgery cohorts, with 13.3% to 18.9% of cases being isolated AVR.¹³⁻¹⁵ One study comparing the EuroSCORE, EuroSCORE II, and the STS score for isolated AVR reported similar findings.¹⁶ Our observation that the EuroSCORE overestimated operative mortality and that the newer scores generally fitted better with contemporary isolated AVR outcomes was consistent with the findings from other studies.

TABLE 1. Baseline characteristics—demographics, presentation, and medical history

Characteristic	Value
Demographic	
Age (y)	64.8 ± 15.5
Female gender	34.5% (214)
Ethnicity	
New Zealand European	70.8% (439)
Maori or Pacific	21.1% (131)
Other	8.1% (50)
Body mass index (kg/m ²)	29.6 ± 11.5
Body surface area (m ²)	1.92 ± 0.26
Presentation	
NYHA class	
1	21.9% (136)
2	37.3% (231)
3	27.9% (173)
4	12.9% (80)
Unstable angina, class 4	2.7% (17)
Syncope	6.1% (38)
Critical preoperative state	3.1% (19)
Operation status	
Urgent	50.6% (314)
Emergency	0.3% (2)
Medical history	
Previous cardiac surgery	22.6% (140)
Valve surgery	14.7% (91)
Coronary artery bypass grafting	8.4% (52)
Other cardiac operation	1.8% (11)
Congestive heart failure	20.3% (126)
Myocardial infarction	8.7% (54)
Recent myocardial infarction within 90 d	2.9% (18)
Atrial fibrillation	19.2% (119)
Diabetes	17.3% (107)
Hypertension	49.0% (304)
Hypercholesterolemia	54.0% (335)
Current smoker	10.8% (67)
Smoking history	54.4% (337)
Active infective endocarditis	10.8% (65)
Cerebrovascular accident	6.1% (38)
Extracardiac arteriopathy	6.0% (37)
Chronic pulmonary disease	19.0% (118)
Dialysis	2.4% (15)
Poor mobility	0.2% (1)
Investigation results	
Ejection fraction	
Normal (>50%)	65.0% (403)
Mild or moderate impairment (30%-50%)	29.8% (185)
Severe impairment (<30%)	5.2% (32)
Aortic stenosis	
Severe	74.0% (459)
Moderate	1.3% (8)
Aortic regurgitation	
Severe	23.5% (146)
Moderate	12.4% (77)

(Continued)

TABLE 1. Continued

Characteristic	Value
Mitral stenosis	
Severe	0.0% (0)
Moderate	0.5% (3)
Mitral regurgitation	
Severe	0.5% (3)
Moderate	7.6% (47)
Tricuspid regurgitation	
Severe	0.5% (3)
Moderate	4.2% (26)
Pulmonary hypertension	
Moderate (31-55 mm Hg)	15.6% (97)
Severe (>55 mm Hg)	2.7% (15)
Left main artery stenosis ≥50%	2.7% (17)
Main coronary vessel stenosis ≥50%	
0	82.9% (514)
1	8.2% (51)
2	2.4% (15)
3	6.5% (40)
Creatinine clearance (mL/min)	83 ± 40
Operative mortality	2.9% (18)

Data presented as mean ± standard deviation or % (n). NYHA, New York Heart Association.

Despite improvements in calibration, we did not find the newer scores to have improved discrimination for isolated AVR. In fact, the EuroSCORE had the highest C-statistic of 0.752 for operative mortality. Other studies have also found statistically similar C-statistics between the EuroSCORE and EuroSCORE II¹³⁻¹⁷ and between the EuroSCORE and the STS score.^{9,10,16} However, just as in our study, the statistical power might have influenced these outcomes. Additional studies are required to assess whether the inclusion of other potentially important parameters not traditionally incorporated into risk scores could help in this regard, such as the assessment of frailty, porcelain aorta, liver disease, and right ventricular dysfunction.¹⁸

The accuracy of risk scores to predict mortality in high-risk patients is of great importance. This is the group of patients for whom alternative modalities such

TABLE 2. Multivariate analysis of operative mortality (predictors with *P* < .10 included)

Outcome predictor	OR	95% CI	<i>P</i> value
Critical preoperative state	7.72	1.49-39.9	.015
Atrial fibrillation	3.38	1.18-9.69	.023
Extracardiac arteriopathy	4.11	1.04-16.1	.043
Chronic pulmonary disease	2.85	0.955-8.53	.060
Mitral stenosis	6.13	1.39-27.0	.015

OR, Odds ratio; CI, confidence interval.

TABLE 3. Discrimination and calibration analyses

Outcomes	EuroSCORE	EuroSCORE II	STS score	Aus-AVR score
Predicted operative mortality (%)	8.7 ± 8.3	3.8 ± 4.7	2.8 ± 2.7	3.2 ± 4.8
Discrimination for operative mortality				
C-statistic (95% CI)	0.752 (0.652-0.852)	0.711 (0.607-0.815)	0.715 (0.593-0.837)	0.684 (0.557-0.811)
Hanley and McNeill <i>P</i> value				
	.671 (ESII)	.967 (STS)	.754 (Aus-AVR)	
	.701 (STS)	.785 (Aus-AVR)		
	.485 (Aus-AVR)			
Calibration for operative mortality (2.9%)				
Observed/predicted ratio	0.33	0.77	1.05	0.90
Fisher's exact test <i>P</i> value	<.001	.433	1.000	.869
Brier score	0.0348	0.0278	0.0276	0.0294
Hosmer-Lemeshow test <i>P</i> value (chi-square)	.007 (21.1)	.125 (12.6)	.753 (5.0)	.468 (7.7)

EuroSCORE, European System for Cardiac Operative Risk Evaluation; *STS*, Society of Thoracic Surgeons; *Aus-AVR*, risk model specific to aortic valve replacement based on an Australasian population; *CI*, confidence interval; *ESII*, EuroSCORE II.

as medical treatment or TAVI will be considered, given that TAVI is currently recommended for high-risk operable or inoperable patients, a group difficult to define.¹ Our study has shown that in the highest quintile of predicted risk, the EuroSCORE immensely overestimated operative mortality. EuroSCORE II and the Aus-AVR score also moderately, although nonsignificantly, overestimated operative mortality. The STS score was the most accurate. We would therefore recommend the STS score for risk stratification of patients referred for TAVI. Other studies have generally found the EuroSCORE to

significantly overestimate mortality for high-risk patients for AVR.^{8-10,13-16} Mixed results have been reported for EuroSCORE II to overestimate^{13,17} and underestimate¹⁵ the risks, and also for the STS score to overestimate⁹ and underestimate^{8,10,16} operative mortality in high-risk patients, although always to lesser degrees than the overestimation with the EuroSCORE.

In the Australasian population with a different ethnic distribution from the rest of the world, the EuroSCORE has also been shown to overestimate mortality.¹⁹ This stimulated the development of regional risk models for

FIGURE 1. Calibration of operative mortality observed and predicted quintiles of each risk model: A, European System for Cardiac Operative Risk Evaluation (*EuroSCORE*); B, EuroSCORE II; C, Society of Thoracic Surgeons (*STS*) score; and D, a risk model specific to aortic valve replacement based on an Australasian population (*Aus-AVR*) score. The expected line (red) is the mean score for that quintile, and the observed line (blue) is the proportion of patients with operative mortality in that quintile.

FIGURE 2. Survival curves by quintile for each risk model: A, European System for Cardiac Operative Risk Evaluation (*EuroSCORE*); B, *EuroSCORE II*; C, Society of Thoracic Surgeons score (*STS*); and D, a risk model specific to aortic valve replacement based on an Australasian population (*Aus-AVR*) score.

isolated coronary artery bypass grafting²⁰ and isolated AVR (the *Aus-AVR* score).¹² Our study results have externally validated the latter score, showing that it has good discrimination and calibration for operative mortality comparable to that of the *EuroSCORE II* and *STS* score. Although the population from which each score was derived had a different ethnic breakdown, only the *STS* score included ethnicity as one of the determinants in predicting mortality.

A number of studies have found the *EuroSCORE*,²¹⁻²³ *EuroSCORE II*,²⁴ and the *STS* score²⁵ to predict mortality during follow-up for cardiac surgery cohorts, although these were mostly composed of those undergoing coronary artery bypass grafting. Our Kaplan-Meier curves showed similar trends that these risk scores can stratify long-term mortality, with the lowest and highest risk quintiles having the best and worst survival over time. Given our limited numbers, however, our study was underpowered for additional statistical analyses to prove the scores' predictive power.

Study Limitations

The present study was a single-center observational study that focused on isolated AVR. The retrospective calculation of risk scores from the clinical records could have introduced minor biases to the values obtained. The unique ethnic breakdown of our New Zealand population might restrict the generalizability of the study results; however, because the *Aus-AVR* score was not superior

to the other scores, the influence of ethnicity was likely to be limited. The moderate sample size and number of mortality events contributed to important limitations and influenced the outcomes of the present study in several ways. First, the absolute C-statistics in our study were generally lower than those reported in validation studies of the risk scores with larger samples. Second, although differences were present in the c-statistics and calibration parameters among the scores, these did not reach statistical significance and thus could not determine which performed best in different aspects if inherently small differences were present among them. Finally, analyses of how well the scores performed in different subgroups could not be performed. Thus, larger studies and meta-analyses are required to confirm our findings. Additionally, the follow-up period was somewhat restricted given that ours was a contemporary cohort.

CONCLUSIONS

We found all 4 risk scores to discriminate operative mortality, with no statistically significant differences among them, although this finding was influenced by the limited sample size. The *EuroSCORE* significantly overestimated operative risk, but the other 3 more recent scores had reasonable calibration with contemporary isolated AVR. In the highest quintile of risk, which is important when considering other treatment modalities such as TAVI, the *STS* score appeared to have the best calibration, although the other scores overestimated the risk.

References

1. Joint Task Force on the Management of Valvular Heart Disease of the European Society of Cardiology (ESC); European Association for Cardio-Thoracic Surgery (EACTS), Vahanian A, Alfieri O, Andreotti F, Antunes MJ, Barón-Esquivias G, Baumgartner H, et al. Guidelines on the management of valvular heart disease (version 2012). *Eur Heart J*. 2012;33:2451-96.
2. Varadarajan P, Kapoor N, Bansal RC, Pai RG. Survival in elderly patients with severe aortic stenosis is dramatically improved by aortic valve replacement: results from a cohort of 277 patients aged > or =80 years. *Eur J Cardiothorac Surg*. 2006;30:722-7.
3. Nkomo VT, Gardin JM, Skelton TN, Gottdiener JS, Scott CG, Enriquez-Sarano M. Burden of valvular heart diseases: a population-based study. *Lancet*. 2006;368:1005-11.
4. Smith CR, Leon MB, Mack MJ, Miller DC, Moses JW, Svensson LG, et al. PARTNER Trial Investigators. Transcatheter versus surgical aortic-valve replacement in high-risk patients. *N Engl J Med*. 2011;364:2187-98.
5. Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R. European system for cardiac operative risk evaluation (EuroSCORE). *Eur J Cardiothorac Surg*. 1999;16:9-13.
6. O'Brien SM, Shahian DM, Filardo G, Ferraris VA, Haan CK, Rich JB, et al. Society of Thoracic Surgeons Quality Measurement Task Force. The Society of Thoracic Surgeons 2008 cardiac surgery risk models: part 2—isolated valve surgery. *Ann Thorac Surg*. 2009;88(1 Suppl):S23-42.
7. Parolari A, Pesce LL, Trezzi M, Cavallotti L, Kassem S, Loardi C, et al. EuroSCORE performance in valve surgery: a meta-analysis. *Ann Thorac Surg*. 2010;89:787-93.
8. Dewey TM, Brown D, Ryan WH, Herbert MA, Prince SL, Mack MJ. Reliability of risk algorithms in predicting early and late operative outcomes in high-risk patients undergoing aortic valve replacement. *J Thorac Cardiovasc Surg*. 2008;135:180-7.
9. Wendt D, Osswald BR, Kayser K, Thielmann M, Tossios P, Massoudy P, et al. Society of Thoracic Surgeons score is superior to the EuroSCORE determining mortality in high risk patients undergoing isolated aortic valve replacement. *Ann Thorac Surg*. 2009;88:468-74.
10. Basraon J, Chandrashekar YS, John R, Agnihotri A, Kelly R, Ward H, et al. Comparison of risk scores to estimate perioperative mortality in aortic valve replacement surgery. *Ann Thorac Surg*. 2011;92:535-40.
11. Nashef SA, Roques F, Sharples LD, Nilsson J, Smith C, Goldstone AR, et al. EuroSCORE II. *Eur J Cardiothorac Surg*. 2012;41:734-44.
12. Ariyaratne TV, Billah B, Yap CH, Dinh D, Smith JA, Shardey GC, et al. An Australian risk prediction model for determining early mortality following aortic valve replacement. *Eur J Cardiothorac Surg*. 2011;39:815-21.
13. Barili F, Pacini D, Capo A, Rasovic O, Grossi C, Alamanni F, et al. Does EuroSCORE II perform better than its original versions? A multicentre validation study. *Eur Heart J*. 2013;34:22-9.
14. Chalmers J, Pullan M, Fabri B, McShane J, Shaw M, Mediratta N, et al. Validation of EuroSCORE II in a modern cohort of patients undergoing cardiac surgery. *Eur J Cardiothorac Surg*. 2013;43:688-94.
15. Di Dedda U, Pelissero G, Agnelli B, De Vincentiis C, Castelvécchio S, Ranucci M. Accuracy, calibration and clinical performance of the new EuroSCORE II risk stratification system. *Eur J Cardiothorac Surg*. 2013;43:27-32.
16. Barili F, Pacini D, Capo A, Ardemagni E, Pellicciari G, Zanobini M, et al. Reliability of new scores in predicting perioperative mortality after isolated aortic valve surgery: a comparison with the society of thoracic surgeons score and logistic EuroSCORE. *Ann Thorac Surg*. 2013;95:1539-44.
17. Grant SW, Hickey GL, Dimarakis I, Trivedi U, Bryan A, Treasure T, et al. How does EuroSCORE II perform in UK cardiac surgery: an analysis of 23 740 patients from the Society for Cardiothoracic Surgery in Great Britain and Ireland National Database. *Heart*. 2012;98:1568-72.
18. Kappetein AP, Head SJ, Gèneux P, Piazza N, van Mieghem NM, Blackstone EH, et al. Updated standardized endpoint definitions for transcatheter aortic valve implantation: the Valve Academic Research Consortium-2 consensus document. *J Am Coll Cardiol*. 2012;60:1438-54.
19. Yap CH, Reid C, Yip M, Rowland MA, Mohajeri M, Skillington PD, et al. Validation of the EuroSCORE model in Australia. *Eur J Cardiothorac Surg*. 2006;29:441-6.
20. Reid C, Billah B, Dinh D, Smith J, Skillington P, Yip M, et al. An Australian risk prediction model for 30-day mortality after isolated coronary artery bypass: the AusSCORE. *J Thorac Cardiovasc Surg*. 2009;138:904-10.
21. De Maria R, Mazzoni M, Parolini M, Gregori D, Bortone F, Arena V, et al. Predictive value of EuroSCORE on long term outcome in cardiac surgery patients: a single institution study. *Heart*. 2005;91:779-84.
22. Biancari F, Kangasniemi OP, Luukkonen J, Vuorisalo S, Satta J, Pokela R, et al. EuroSCORE predicts immediate and late outcome after coronary artery bypass surgery. *Ann Thorac Surg*. 2006;82:57-61.
23. O'Boyle F, Mediratta N, Fabri B, Pullan M, Chalmers J, McShane J, et al. Long-term survival after coronary artery bypass surgery stratified by EuroSCORE. *Eur J Cardiothorac Surg*. 2012;42:101-6.
24. Biancari F, Vasques F, Mikkola R, Martin M, Lahtinen J, Heikkinen J. Validation of EuroSCORE II in patients undergoing coronary artery bypass surgery. *Ann Thorac Surg*. 2012;93:1930-5.
25. Puskas JD, Kilgo PD, Thourani VH, Lattouf OM, Chen E, Vega JD, et al. The Society of Thoracic Surgeons 30-day predicted risk of mortality score also predicts long-term survival. *Ann Thorac Surg*. 2012;93:26-33.