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Predictive models of surgical site infections after coronary surgery: insights from a validation study on 7090 consecutive patients

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SUMMARY

Background: The role of specific scoring systems in predicting risk of surgical site infections (SSIs) after coronary artery bypass grafting (CABG) has not been established.
Aim: To validate the most relevant predictive systems for SSIs after CABG.
Methods: Five predictive systems (eight models) for SSIs after CABG were evaluated retrospectively in 7090 consecutive patients undergoing isolated (73.9%) or combined (26.1%) CABG. For each model, accuracy of prediction, calibration, and predictive power were assessed with area under receiver–operating characteristic curve (aROC), the Hosmer–Lemeshow test, and the Goodman–Kruskal γ-coefficient, respectively. Six predictive scoring systems for 30-day in-hospital mortality after cardiac operations were evaluated as to prediction of SSIs. The models were compared one-to-one using the Hanley–McNeil method.
Findings: There were 724 (10.2%) SSIs. Whereas all models showed satisfactory calibration ($P = 0.176$–0.656), accuracy of prediction was low (aROC: 0.609–0.650). Predictive power was moderate (γ: 0.315–0.386) for every model but one (γ: 0.272). When compared one-to-one, the Northern New England Cardiovascular Disease Study Group mediastinitis score had a higher discriminatory power both in overall series (aROC: 0.634) and combined CABG patients (aROC: 0.648); in isolated CABG patients, both models of the Fowler score showed a higher discriminatory power (aROC: 0.651 and 0.660). Accuracy of prediction for SSIs was low (aROC: 0.564–0.636) even for six scoring systems devised to predict mortality after cardiac surgery.
Conclusion: In this validation study, current predictive models for SSIs after CABG showed low accuracy of prediction despite satisfactory calibration and moderate predictive power.

Introduction

Despite advances in infection control practices and wound dressings, surgical site infections (SSIs) remain a major

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complication of every surgical discipline, accounting for increased rates of morbidity, mortality, and new surgical procedures, as well as for longer postoperative hospital stays, higher costs and poor health-related quality of life [1,2]. Their incidence in Europe ranges from 0.7% in prosthetic surgery of knee up to 9.7% in colon surgery, whereas incidence of sternal and leg-wound infections after coronary artery bypass grafting (CABG) reaches 8.4% and 7.0%, respectively [1–7]. The rate of SSIs can be reduced by adopting prevention practices that include modification of risk factors and adequate surgical techniques together with vigilance during the postoperative course [1,2].

In cardiac surgery, scoring systems have been devised over the years to predict the risk of death, as well as of other postoperative complications [3,8–14]. Certainly, every study from which each score has been derived contributed to increase knowledge on the specific complication it referred to, most of these models being based on preoperative characteristics of patients and the surgical techniques used. However, as pertains to scores predicting SSIs, there are generally some concerns about their real validity in clinical practice despite no considerable differences regarding their design [3,14–18].

In the present study, five of the most relevant scoring systems that have been created specifically to predict the risk of SSIs after CABG were validated retrospectively in a large series of patients undergoing isolated or combined coronary surgery in a single Italian institution [14–18]. In addition, six scoring systems, which are being widely used to predict 30-day in-hospital mortality after cardiac operations, were evaluated regarding prediction of SSIs [8–13].

Methods

Between January 1st, 1999 and September 28th, 2018, a total of 7098 consecutive patients underwent CABG at the Division of Cardiac Surgery of the University Hospital of Trieste, Italy. Their baseline characteristics, operative data, and other relevant variables pertaining to in-hospital course were prospectively recorded in a computerized data registry. Eight (0.1%) patients having sternal separation without infection were ruled out *a priori* from the present study, which takes into consideration only the infectious complications of the surgical site. The remaining 7090 patients who underwent isolated ($N = 5243$, 73.9%) or combined ($N = 1847$, 26.1%) CABG were the validation sample for five scoring systems specifically created to predict the risk of SSIs after CABG: (i) the Northern New England Cardiovascular Disease Study Group (NNECDSG) mediastinitis score; (ii) the Alfred Hospital (AH) risk index (two models, A and B); (iii) the Fowler score (two models, preoperative only and combined); (iv) the Friedman score (two models, preoperative only and combined); and (v) the Brompton Harefield Infection Score (BHIS) (Supplementary Table S1) [14–18].

Six scoring systems devised specifically to predict 30-day in-hospital mortality after cardiac surgery were also evaluated: (i) the Ontario Province Risk (OPR) score; (ii) the Higgins score; (iii) the additive European System for Cardiac Operative Risk Evaluation (EuroSCORE); (iv) the logistic EuroSCORE; (v) EuroSCORE II; and (vi) the Age, Creatinine, Ejection Fraction (ACEF) score [8–13].

Throughout the study period, both in-hospital and post-discharge surveillance of the surgical wounds was performed for every patient by an expert cardiac surgeon. All patients having surgical site complication at any time following hospital discharge were referred to a specifically dedicated surgical outpatient clinic. Details pertaining to the patients and their disease were recorded in a computerized data registry. Further details concerning perioperative management of patients regarding their surgical wounds are summarized in Supplementary Table S2.

Definitions

Unless otherwise stated, definitions of preoperative clinical variables were those employed for EuroSCORE II [11]. Atherosclerosis of the ascending aorta was demonstrated using the epiaortic ultrasonography scan, which was performed intraoperatively in every patient [19]. The Centers for Disease Control and Prevention classification of the SSIs was adopted [20]. Regarding sternal wound infections (SWIs), superficial infection involves only skin or subcutaneous tissues, deep infection involves deep soft tissues (fascial and muscle layers) with or without the sternal bone, and organ/space infection involves the mediastinum (mediastinitis). Usually, deep infection and mediastinitis are considered to be deep SWIs.

Approval to conduct the study was acquired from the hospital ethics committee based on retrospective data retrieval; the need for patients to provide individual written consent was waived.

Statistical methods

Data were expressed as number of patients and percentage. Accuracy of prediction (discriminatory power) of each predictive scoring system was assessed with the receiver–operating characteristic (ROC) curve analysis and the calculation of the area under the ROC curve (aROC), with 95% confidence interval (CI). According to arbitrary guidelines, accuracy of prediction was defined as low (aROC: 0.5–0.7), moderate (aROC: 0.7–0.9), or high (aROC: 0.9–1). The scores were compared one-to-one in the overall series and in subsets of patients (isolated and combined CABG, single (SITA) and bilateral internal thoracic artery (BITA) grafting, as well as off-pump and

Table I
Validation sample ($N = 7090$): sites of surgical wound infections[a]

Site	No.	%
Any	724	0.102
Sternotomy	604	0.085
Superficial	304	0.043
Deep	272	0.038
Mediastinum	28	0.004
Groin	57/714[b]	0.080
Leg wound	99/5389[c]	0.018
Other[d]	8	0.001
Sepsis (SSI-related)	39	0.006

SSI, surgical site infection.
[a] Eight (0.1%) patients having sternal separation without infection were excluded *a priori* from this analysis.
[b] No. of patients undergoing femoral cannulation for cardiopulmonary bypass or intra-aortic balloon pump insertion.
[c] No. of patients undergoing saphenous vein harvesting.
[d] Radial artery harvesting site and chest drain site.

Table II
Validation sample ($N = 7090$): performance of eight predictive models for all SSIs/SWIs after CABG[a]

Outcome/predictive model	Overall model fit			Calibration			Discriminatory power		Predictive power	
	χ^2	df	*P*	χ^2	df	*P*	aROC	95% CI	γ	*P*
All SSIs										
Preoperative models										
NNECDSG mediastinitis score [14]	166.660	8	0.000	4.835	6	0.565	0.634	0.623–0.645	0.315	0.000
AH risk index A [15]	135.473	3	0.000	1.006	2	0.605	0.613	0.601–0.624	0.367	0.000
Fowler score (preoperative only) [16]	236.963	12	0.000	10.810	8	0.213	0.628	0.617–0.640	0.272	0.000
Friedman score (preoperative only) [17]	112.125	3	0.000	3.472	2	0.176	0.609	0.597–0.620	0.355	0.000
BHIS [18]	138.259	7	0.000	3.287	5	0.656	0.617	0.605–0.628	0.322	0.000
Combined models										
AH risk index B [15]	171.264	4	0.000	4.158	4	0.385	0.633	0.622–0.645	0.381	0.000
Fowler score (combined) [16]	269.785	12	0.000	9.615	8	0.293	0.650	0.639–0.662	0.318	0.000
Friedman score (combined) [17]	161.394	4	0.000	5.847	5	0.321	0.635	0.623–0.646	0.386	0.000
SWIs										
Preoperative models										
NNECDSG mediastinitis score [14]	160.395	8	0.000	3.415	6	0.755	0.641	0.629–0.652	0.330	0.000
AH risk index A [15]	119.984	3	0.000	1.754	2	0.416	0.617	0.606–0.628	0.380	0.000
Fowler score (preoperative only) [16]	210.209	12	0.000	5.779	8	0.672	0.620	0.608–0.631	0.253	0.000
Friedman score (preoperative only) [17]	106.739	3	0.000	2.768	2	0.251	0.616	0.605–0.627	0.374	0.000
BHIS [18]	124.408	7	0.000	5.332	5	0.377	0.618	0.606–0.629	0.322	0.000
Combined models										
AH risk index B [15]	148.464	4	0.000	3.870	4	0.424	0.635	0.624–0.646	0.386	0.000
Fowler score (combined) [16]	221.829	12	0.000	4.127	8	0.845	0.638	0.626–0.649	0.291	0.000
Friedman score (combined) [17]	127.999	4	0.000	5.752	5	0.331	0.630	0.619–0.641	0.371	0.000

SSIs, surgical site infections; SWIs, sternal wound infections; CABG, coronary artery bypass grafting; df, degrees of freedom; aROC, area under the receiver–operating characteristic curve; CI, confidence interval; NNECDSG, Northern New England Cardiovascular Disease Study Group; AH, Alfred Hospital; BHIS, Brompton and Harefield infection score.
[a] Eight (0.1%) patients having sternal separation without infection were excluded *a priori* from this analysis.

on-pump CABG) using the method of Hanley and McNeil ($P < 0.05$ was considered for statistical significance). Overall model fit was assessed for each score; $P < 0.05$ was regarded as evidence that at least one of the independent variables contributed to the prediction of the outcome. Goodness-of-fit (calibration) was assessed with the Hosmer–Lemeshow test: a large χ^2 value ($P < 0.05$) indicated poor fit; small χ^2 values (with *P*-value closer to 1) indicated a good logistic regression model fit. Expected risks of all SSIs and of SWIs according to each score were compared with the corresponding actual rates. Finally, predictive power of the scores was assessed using the Goodman–Kruskal γ correlation coefficient. According to Haley, the predictive power was defined as low (γ: <0.3), moderate (γ: 0.3–0.5), or high (γ: >0.5). Data analyses were performed using the SPSS software package for Windows, version 22 (SPSS, Inc., Chicago, IL, USA).

Results

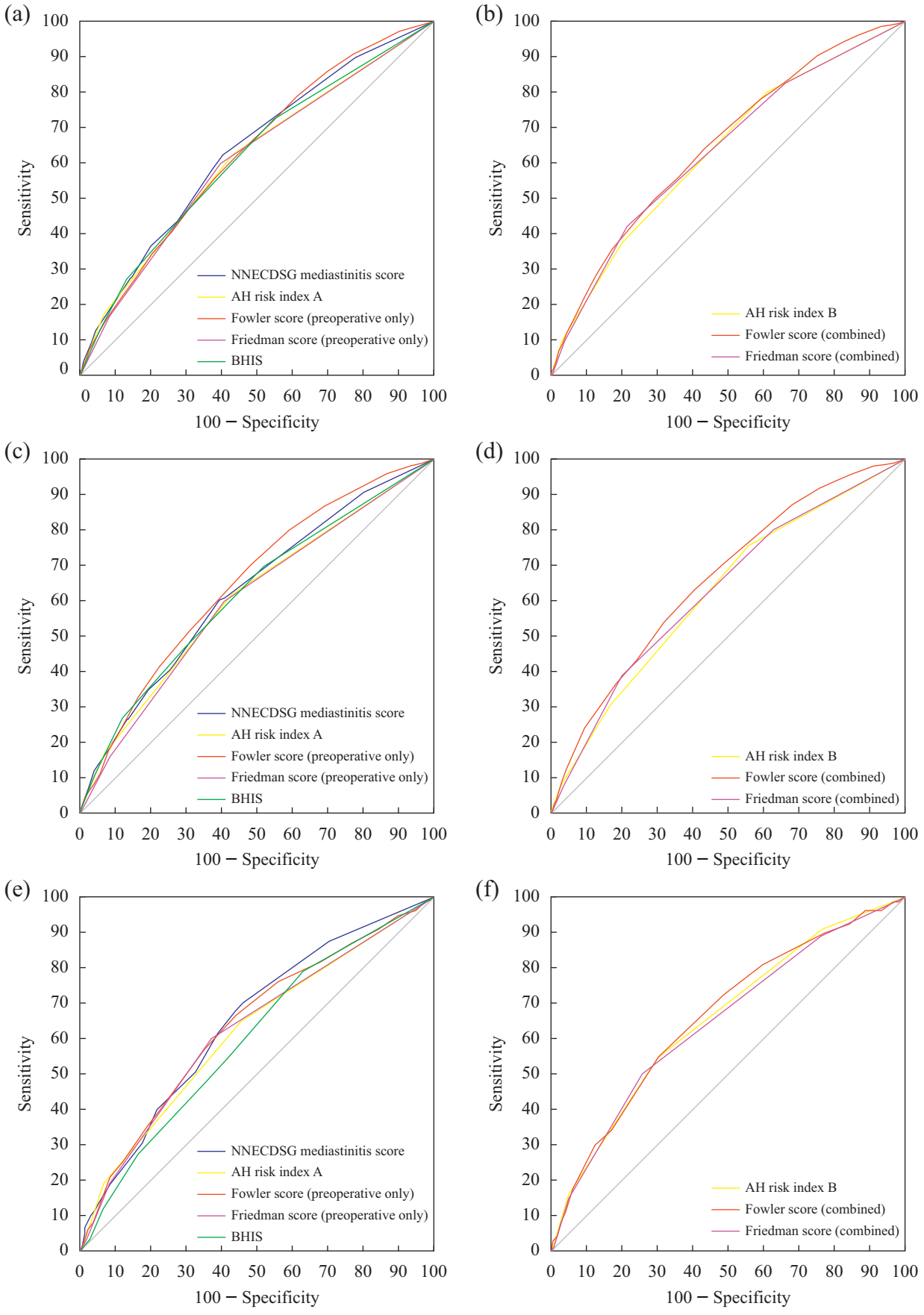
The validation sample

Half of patients were aged ≥70 years (mean: 68.2 ± 9.1) and 21% were females. Body mass index was >30, >35 and >40 kg/m^2 in 19.6%, 2.9%, and 0.3% of patients, respectively. Diabetes, chronic obstructive pulmonary disease (COPD), severe renal impairment (estimated glomerular filtration rate ≤50 mL/min) and extracardiac arteriopathy were co-morbidities in 30.2%, 8.8%, 17.2%, and 27.5% of cases, respectively. Congestive heart failure, myocardial infarction within 90 days before surgery, left ventricular ejection fraction <40%, and cardiogenic shock were present, preoperatively, in 35.3%, 20.3%, 12.3%, and 0.9% of patients, respectively. There was an urgent or emergent surgical priority in about 60% of cases. SITA or BITA grafting, as well as off-pump technique, were adopted in 44.6%, 43.8%, and 4.4% of subjects,

Table III
Actual rate of all SSIs (and SWIs) compared with the (mean) expected risk according to five predictive systems (eight models) for SSIs after CABG

Variable	%
Actual rate of SSIs	10.2
Actual rate of SWIs	8.5
NNECDSG mediastinitis score	0.9
AH risk index A	9.7
Fowler score (preoperative only)	3.1
Friedman score (preoperative only)	2.7
BHIS	4.3
AH risk index B	11.0
Fowler score (combined)	3.3
Friedman score (combined)	3.5

AH, Alfred Hospital; BHIS, Brompton and Harefield infection score; CABG, coronary artery bypass grafting; NNECDSG, Northern New England Cardiovascular Disease Study Group; SSIs, surgical site infections; SWIs, sternal wound infections.


(a)
Sensitivity
100 − Specificity
NNECDSG mediastinitis score
AH risk index A
Fowler score (preoperative only)
Friedman score (preoperative only)
BHIS
(b)
Sensitivity
100 − Specificity
AH risk index B
Fowler score (combined)
Friedman score (combined)
(c)
Sensitivity
100 − Specificity
NNECDSG mediastinitis score
AH risk index A
Fowler score (preoperative only)
Friedman score (preoperative only)
BHIS
(d)
Sensitivity
100 − Specificity
AH risk index B
Fowler score (combined)
Friedman score (combined)
(e)
Sensitivity
100 − Specificity
NNECDSG mediastinitis score
AH risk index A
Fowler score (preoperative only)
Friedman score (preoperative only)
BHIS
(f)
Sensitivity
100 − Specificity
AH risk index B
Fowler score (combined)
Friedman score (combined)

respectively. Cardiopulmonary bypass time was >100 min and length of surgery >300 min in 52% and 35% of cases, respectively. Overall, an intra-aortic balloon pump (IABP) was implanted in 7.5% of patients and packed red blood cells were transfused in 43.9% of patients.

There were 271 (3.8%) in-hospital deaths post surgery (mean EuroSCORE II: 6.1%). A total of 724 (10.2%) SSIs and 604 (8.5%) SWIs occurred. Patients with SSI had a higher mortality rate than did patients without such infection (5.2% vs 3.7%; $P = 0.044$) and were more likely to have a concomitant infection other than SSI (16.6% vs 9.1%; $P < 0.0001$), as well as a postoperative hospital stay >16 days (23.9% vs 6.1%; $P < 0.0001$) (Table I; Supplementary Tables S3–S5).

Predictive models' performance in the validation sample

Regarding the five scoring systems (eight models) specifically created to predict SSIs/SWIs after CABG that were considered in this study, there was evidence for every score that most of the independent variables contributed to the prediction of the outcome ($P < 0.0001$). All predictive models showed a satisfactory calibration ($P = 0.176–0.845$), whereas accuracy of prediction was low (aROC: 0.609–0.650). Predictive power was moderate (γ: 0.315–0.386) for every score, except for the preoperative-only model of Fowler score both for SSIs (γ: 0.272) and SWIs (γ: 0.253), and for the combined model of Fowler score for SWIs (γ: 0.291) (Tables II and III).

The one-to-one comparison of the models showed that: (i) in the overall series as well as in combined CABG patients, NNECDSG mediastinitis score had a higher discriminatory power both for all SSIs (aROC: 0.634 and 0.648; Figure 1A, B, E and F) and SWIs (aROC: 0.641 and 0.657; Figure 2A, B, E, and F); (ii) in isolated CABG patients, both models of Fowler score had a higher discriminatory power both for all SSIs (aROC: 0.651 and 0.660; Figure 1C and D) and SWIs (aROC: 0.651 and 0.654; Figure 2C and D); (iii) in isolated CABG patients receiving BITA grafts, the preoperative-only model of Fowler score had a higher discriminatory power for SWIs (aROC: 0.661; Figure 3A); (iv) in isolated CABG patients undergoing on-pump surgery, the preoperative-only model of Fowler score had a higher discriminatory power for SWIs (aROC: 0.653; Figure 4C); (v) in isolated CABG patients receiving SITA grafts or undergoing off-pump surgery, the considered models had similar discriminatory powers for SWIs (Figure 2C, D and 3A, B) (Tables IV and V; Figures 1–4).

In the overall series, accuracy of prediction was low both for all SSIs (aROC: 0.564–0.636) and SWIs (aROC: 0.553–0.624) even for the scoring systems devised to predict 30-day in-hospital mortality after cardiac surgery that were considered in the present study. However, (i) EuroSCORE II (aROC: 0.636) showed a higher discriminatory power than all other predictive models ($P \leq 0.0051$) except for Higgins score (aROC: 0.616; $P = 0.066$); (ii) ACEF score (aROC: 0.564) showed a lower discriminatory power than all other models ($P \leq 0.0095$; Table VI; Supplementary Figures 1A and B).

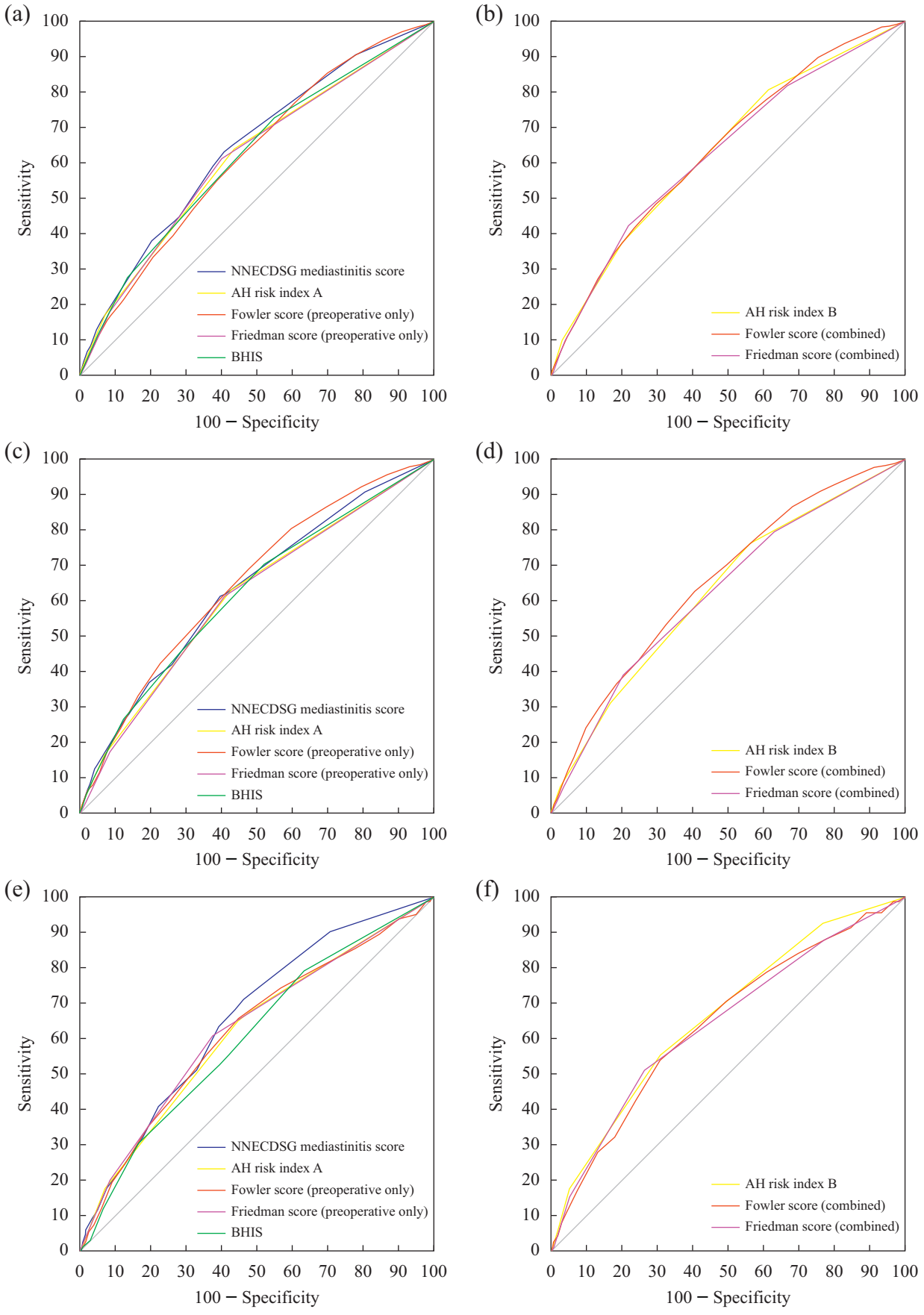
Discussion

The National Nosocomial Infections Surveillance (NNIS) System's risk index, which stratifies patients according their American Society of Anesthesiologists score, wound type, and the duration of surgery, has been widely used to determine the risk of SSIs across a broad range of surgical operations [3]. Regarding CABG, however, the NNIS System's risk index has been criticized for not being able to reflect accurately the patient's severity of illness and the perioperative factors that might influence the risk of infection [21]. Consequently, new risk factor analyses have been performed over the years and new models based on these studies have been created to predict specifically SSIs after CABG [14–18].

According to the present study, which is a comparative analysis of the most relevant predictive models for SSIs after CABG, as well as a validation study performed on a large series of patients undergoing isolated or combined CABG at a single Italian institution, all the models include both diabetes and obesity among the variables; whereas other predictors of SSIs would include female sex, COPD, renal impairment, extracardiac arteriopathy, left ventricular dysfunction (or its surrogates or measures such as congestive heart failure, low left-ventricular ejection fraction, myocardial infarction, cardiogenic shock, and use of IABP), urgent or emergency priority, prolonged surgery, and need of blood transfusion [14–18]. The mechanisms underlying the susceptibility to infectious diseases in people with diabetes are not completely understood, but the evidence suggests that hyperglycaemia results in the formation of advanced glycation end-products, which can affect host cell function by impairing humoral response, complement activation, chemotaxis, adhesion and phagocytosis as well as intracellular and extracellular killing. Thus, diabetic patients are at increased risk of SSIs, and such a risk seems to be highest in patients undergoing cardiac surgery [22,23]. Because of its association with insulin resistance, endothelial dysfunction, and systemic pro-inflammatory and thrombotic states, obesity is a well-recognized risk factor for SSIs after CABG. It increases the risk of all types of SSI through augmented postoperative mechanical loads, facilitated bacterial contamination, and failure to adjust antibiotic doses to body mass, an error that leads to inappropriately low tissue antibiotic concentrations. Finally, the bradytrophic properties of fatty tissue contribute to poor wound healing [24,25].

The most relevant finding of the study was that current predictive models for all SSIs after CABG showed low accuracy of prediction (aROC <0.7) despite satisfactory calibration and moderate predictive power. Besides, this poor performance regarding discriminatory power for SSIs (and SWIs) after CABG was common even to six scoring systems devised to predict 30-day in-hospital mortality after cardiac surgery [8–13]. Although this finding of low performance was confirmed for every predictive model, the models did not show the same performance when they were compared one-to-one: (i) NNECDSG mediastinitis score had a higher discriminatory power both for all SSIs and SWIs in the overall series and in combined

Figure 1. ROC curves comparison for all SSIs of eight predictive systems (five preoperative-only (A, C, E) and three combined models (B, D, F)) for SSIs after CABG: overall series (A, B), isolated (C, D) and combined CABG (E, F). AH, Alfred Hospital; BHIS, Brompton and Harefield infection score; CABG, coronary artery bypass grafting; NNECDSG, Northern New England Cardiovascular Disease Study Group; ROC, receiver–operating characteristic; SSIs, surgical site infections.


(a)
Sensitivity
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(b)
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AH risk index B
Fowler score (combined)
Friedman score (combined)
(c)
Sensitivity
100 − Specificity
NNECDSG mediastinitis score
AH risk index A
Fowler score (preoperative only)
Friedman score (preoperative only)
BHIS
(d)
Sensitivity
100 − Specificity
AH risk index B
Fowler score (combined)
Friedman score (combined)
(e)
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NNECDSG mediastinitis score
AH risk index A
Fowler score (preoperative only)
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AH risk index B
Fowler score (combined)
Friedman score (combined)

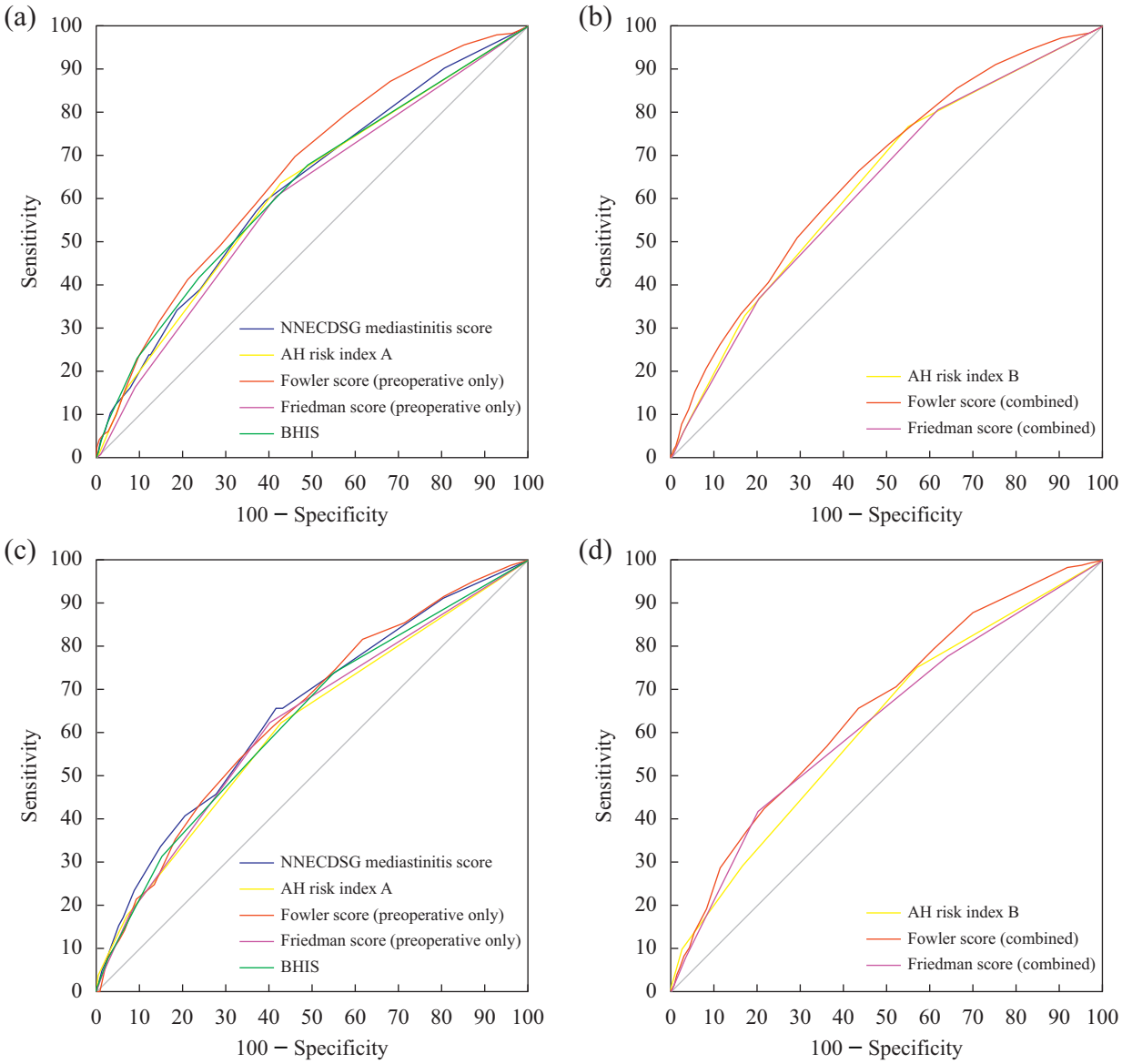

Figure 3. ROC curves comparison for SWIs of eight predictive systems (five preoperative-only (A, C) and three combined models (B, D)) for SSIs after CABG: isolated, bilateral (A, B) and single ITA grafting (C, D). AH, Alfred Hospital; BHIS, Brompton and Harefield infection score; CABG, coronary artery bypass grafting; ITA, internal thoracic artery; NNECDSG, Northern New England Cardiovascular Disease Study Group; ROC, receiver–operating characteristic; SSIs, surgical site infections; SWIs, sternal wound infections.

CABG patients; (ii) both models of Fowler score had a higher discriminatory power both for all SSIs and SWIs in isolated CABG patients; (iii) in isolated CABG patients receiving BITA grafts or undergoing on-pump surgery, the preoperative-only model of Fowler score had a higher discriminatory power for SWIs; (iv) EuroSCORE II showed a higher discriminatory power for SSIs than all other scores except for Higgins score [11,12,14,16].

It is important to notice that the two predictive models that showed better performance, the NNECDSG mediastinitis score and the Fowler score, were provided with a higher number of variables than three other systems (8 and 12 vs 4, 5 and 6), and that renal impairment, COPD, and left ventricular dysfunction (or its surrogates or measures) were common to both models [14,16]. Renal failure (primarily when on chronic dialysis) and a history of COPD are well-recognized risk factors for all SSIs post CABG, especially for SWIs following BITA grafting [26,27]. Besides, left ventricular dysfunction could enhance the risk of SSIs because of impaired tissue perfusion and the need for

Figure 2. ROC curves comparison for SWIs of eight predictive systems (five preoperative-only (A, C, E) and three combined models (B, D, F)) for SSIs after CABG: overall series (A, B), isolated (C, D) and combined CABG (E, F). AH, Alfred Hospital; BHIS, Brompton and Harefield infection score; CABG, coronary artery bypass grafting; NNECDSG, Northern New England Cardiovascular Disease Study Group; ROC, receiver–operating characteristic; SSIs, surgical site infections; SWIs, sternal wound infections.

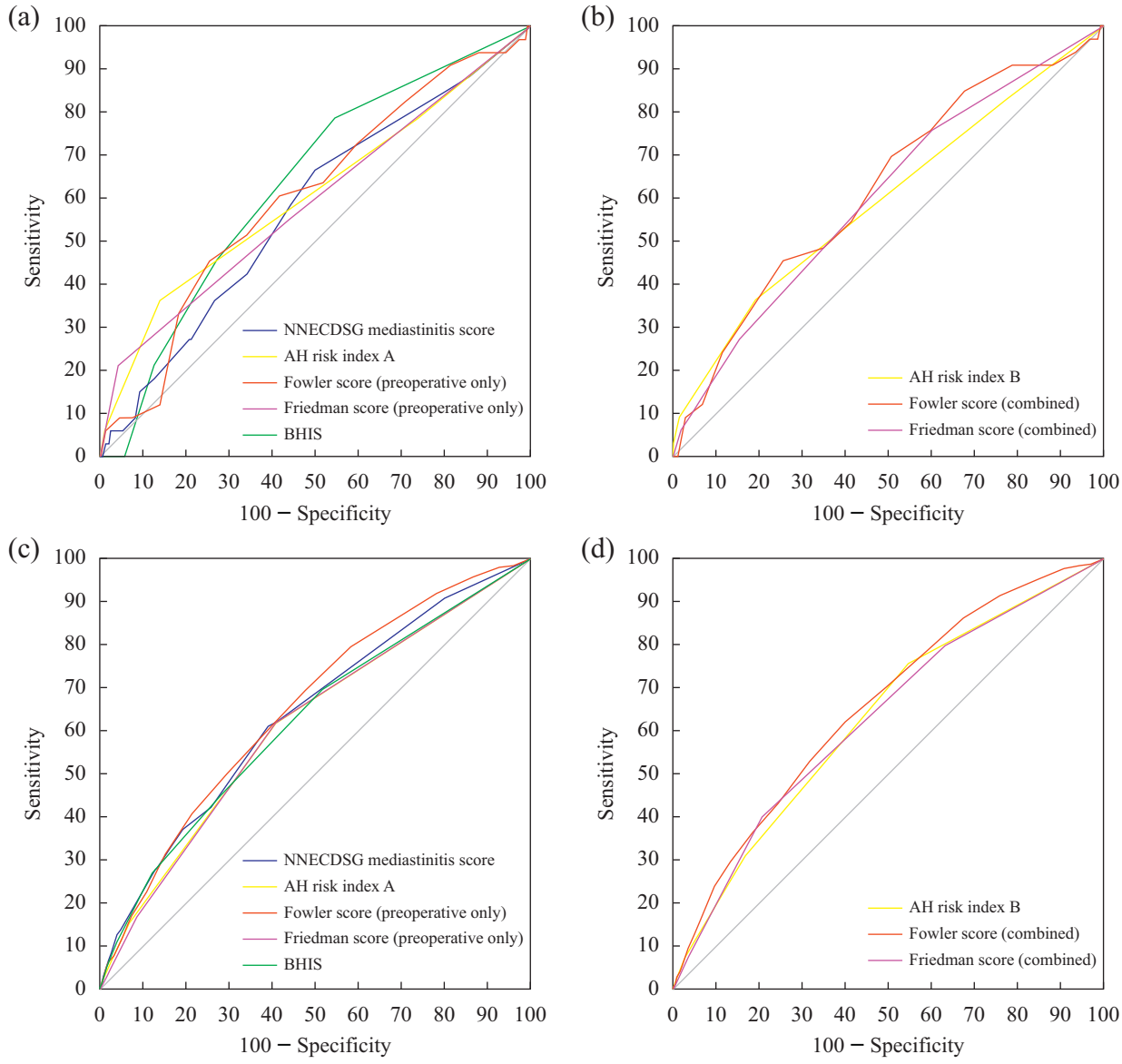

Figure 4. ROC curves comparison for SWIs of eight predictive systems (five preoperative-only (A, C) and three combined models (B, D)) for SSIs after CABG: off-pump (A, B) and on-pump isolated CABG (C, D). AH, Alfred Hospital; BHIS, Brompton and Harefield infection score; CABG, coronary artery bypass grafting; NNECDSG, Northern New England Cardiovascular Disease Study Group; ROC, receiver–operating characteristic; SSIs, surgical site infections; SWIs, sternal wound infections.

inotropes and vasoconstrictors in the immediate postoperative period [28]. In CABG patients, COPD is associated with an increased risk of many complications in addition to chest infections, including pneumothorax, pulmonary edema, atrial fibrillation, longer intensive care unit and hospital stay, and in-hospital mortality, especially for patients aged ≥75 years, requiring steroids, and undergoing on-pump surgery. Preoperative and postoperative respiratory complications increase risk of prolonged mechanical ventilation that, together with left ventricular dysfunction, are predictors of postoperative acute kidney injury requiring renal replacement therapy even in patients without preoperative renal dysfunction [27,29–31].

This study has several limitations. First, the validation sample was derived from a single centre where BITA grafting is being performed on a routine basis and almost invariably during cardiopulmonary bypass, being the off-pump technique reserved to presence of a diseased ascending aorta [26,32]. This fact is just an example of different patient management between the validation sample and the original series from which the predictive model has been derived that could explain the reduced performance of the model, though the extended BITA use may widely explain the higher rate of SSIs (10.2%), primarily SWIs (8.5%), of the validation sample. Second, the validation sample of this study encompasses patients who were operated on during two decades. How many changes on clinical practice and used surgical techniques could have occurred during such a long period? Once again, as an example, the rate of BITA use for isolated CABG has changed from about 60% up to

Table IV
Validation sample ($N = 7090$): performance comparison of eight predictive models for all SSIs after CABG[a]

Predictive model	Overall	Isolated CABG	Combined CABG
Preoperative models			
NNECDSG mediastinitis score [14]	+	±	+
AH risk index A [15]	±	−	±
Fowler score (preoperative only) [16]	±	+	±
Friedman score (preoperative only) [17]	−	−	±
BHIS [18]	±	−	−
Combined models			
AH risk index B [15]	±	−	±
Fowler score (combined) [16]	±	+	±
Friedman score (combined) [17]	±	−	±

SSIs, surgical site infections; CABG, coronary artery bypass grafting; NNECDSG, Northern New England Cardiovascular Disease Study Group; BHIS, Brompton and Harefield infection score; AH, Alfred Hospital.
[a] Eight (0.1%) patients having sternal separation without infection were excluded *a priori* from this analysis.

Table VI
Validation sample ($N = 7090$): discriminatory power for SSIs/SWIs of six predictive models for 30-day in-hospital mortality after cardiac operation[a]

Predictive model	SSIs		SWIs	
	aROC	95% CI	aROC	95% CI
OPR score [8]	0.595	0.581–0.608	0.580	0.567–0.594
Additive EuroSCORE [9]	0.611	0.598–0.624	0.598	0.585–0.612
Logistic EuroSCORE [10]	0.615	0.601–0.628	0.603	0.589–0.616
EuroSCORE II [11]	0.636	0.622–0.649	0.624	0.611–0.638
Higgins score [12]	0.616	0.603–0.629	0.604	0.590–0.617
ACEF score [13]	0.564	0.550–0.578	0.553	0.539–0.567

SSIs, surgical site infections; SWIs, sternal wound infections; aROC, area under the receiver–operating characteristic curve; CI, confidence interval; OPR, Ontario Province Risk; EuroSCORE, European System for Cardiac Operative Risk Evaluation; ACEF, Age, Creatinine, Ejection Fraction.
[a] Eight (0.1%) patients having sternal separation without infection were excluded *a priori* from this analysis.

100% in the last few years [26,32]. Third, the limited number of events (SSIs: 724; SWIs: 604) could have depotentiated the adopted statistical methods. Fourth, the role of potentially strong predictors of outcome post surgery, such as preoperative levels of glycated haemoglobin, could not be evaluated completely because of their too recent introduction in the present authors' clinical practice [18,23]. Fifth, all SSIs, including those deriving from femoral cannulation and chest drain, were considered in the study. This event may not have occurred in the other assessments in this study. Finally, because acceptability, feasibility, and impact of the models in clinical practice were not examined, the present results should be considered in no way conclusive and should be verified on a prospective and multi-centre basis.

In conclusion, based on the results of this validation study performed on >7000 patients at a single Italian centre, the most relevant current predictive models for SSIs after CABG showed low accuracy of prediction despite satisfactory calibration and moderate predictive power. Accuracy of prediction for SSIs was low even for the scoring systems devised to predict 30-day in-hospital mortality after cardiac surgery. New predictive systems having a sufficient number of variables, and incorporating renal failure, COPD, and left ventricular dysfunction in addition to diabetes and obesity could be more effective in preventing SSIs after CABG.

Table V
Validation sample ($N = 7090$): performance comparison of eight predictive models for all SWIs after CABG[a]

Predictive model	Overall series	Isolated CABG	Combined CABG	Isolated CABG, BITA	Isolated CABG, SITA	Isolated CABG, off-pump	Isolated CABG, on-pump
Preoperative models							
NNECDSG mediastinitis score [14]	+	±	+	−	±	±	±
AH risk index A [15]	±	−	±	−	±	±	−
Fowler score (preoperative only) [16]	±	+	±	+	±	±	+
Friedman score (preoperative only) [17]	−	−	±	−	±	±	−
BHIS [18]	±	−	−	±	±	±	−
Combined models							
AH risk index B [15]	±	±	±	±	±	±	±
Fowler score (combined) [16]	±	+	±	±	±	±	±
Friedman score (combined) [17]	±	−	±	±	±	±	±

SWIs, sternal wound infections; CABG, coronary artery bypass grafting; BITA, bilateral internal thoracic artery; SITA, single internal thoracic artery; NNECDSG, Northern New England Cardiovascular Disease Study Group; AH, Alfred Hospital; BHIS, Brompton and Harefield infection score.
[a] Eight (0.1%) patients having sternal separation without infection were excluded *a priori* from this analysis.

Conflict of interest statement
None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2019.01.009.

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