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Identifying potential predictors of the risk of surgical site infection following cardiac surgery: a scoping review

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SUMMARY

Objectives: This scoping review was undertaken to identify risk prediction models and pre-operative predictors of surgical site infection (SSI) in adult cardiac surgery. A particular focus was on the identification of novel predictors that could underpin the future development of a risk prediction model to identify individuals at high risk of SSI, and therefore guide a national SSI prevention strategy.

Methods: A scoping review to systematically identify and map out existing research evidence on pre-operative predictors of SSI was conducted in two stages. Stage 1 reviewed prediction modelling studies of SSI in cardiac surgery. Stage 2 identified primary studies and systematic reviews of novel cardiac SSI predictors.

Results: The search identified 7887 unique reports; 7154 were excluded at abstract screening and 733 were selected for full-text assessment. Twenty-nine studies (across 30 reports) were included in Stage 1 and reported the development (N=14), validation (N=13), or both development and validation (N=2) of 52 SSI risk prediction models including 67 different pre-operative predictors. The remaining 703 reports were re-assessed in Stage 2; 49 studies met the inclusion criteria, and 56 novel pre-operative predictors that have not been assessed previously in models were identified.

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Conclusions: This review identified 123 pre-operative predictors of the risk of SSI following cardiac surgery, 56 of which have not been included previously in the development of cardiac SSI risk prediction models. These candidate predictors will be a valuable resource in the future development of risk prediction scores, and may be relevant to prediction of the risk of SSI in other surgical specialities.

Introduction

Surgical site infections (SSIs) are the most common healthcare-associated infections in people undergoing cardiac surgery in the UK [1]. They are estimated to affect approximately 8.6% of patients undergoing coronary artery bypass graft (CABG) surgery and 2.2% of patients undergoing non-CABG surgery up to 30 days post-operatively [2]. SSIs are associated with a 10-fold increase in mortality, a six-fold increase in hospital readmission, prolonged hospitalisation [3], the need for further surgery, and extended outpatient care [4]. The direct costs of treating SSIs are estimated to exceed £15 million annually in the UK [5]. Targeted SSI prevention strategies may be as clinically effective as non-targeted interventions, more cost-effective, and reduce the drivers of antimicrobial resistance. To date, no randomised controlled trials testing such interventions exist.

Risk prediction modelling can be utilised to predict future outcomes following surgery. Pre-operative identification of patients with a high risk of SSI can guide the use of prevention and treatment strategies to reduce this risk, or prompt early intervention to prevent disease progression. These prediction models can consider a range of factors that are often patient related, such as age, comorbidities and the surgical intervention itself. Most models for cardiac surgery populations have been developed to predict mortality and general morbidity outcomes [6,7], rather than SSI specifically. Furthermore, there are limitations to how these models have been validated, with most only being validated in a specific geographic or surgical population. The performance of even those models with the greatest evidence base in predicting SSI in cardiac surgery is limited; the Australian Clinical Risk Index [8] and Brompton Harefield Infection Score [9] have area under the curve (AUC) values of approximately 0.7. Currently, the use of risk prediction models to guide SSI prevention strategies remains inconsistent [2].

This scoping review was undertaken to identify candidate pre-operative predictors of SSI in adults following cardiac surgery that have been considered during the development of existing risk prediction models, and novel predictors from primary studies that have not been included in any previous prediction models. These candidate predictors will be considered in the development of a future risk prediction model of SSI following cardiac surgery that will underpin the identification of high-risk patients. In combination with work to identify barriers and facilitators to SSI prevention and surveillance [10,11], a national SSI prevention strategy in adult cardiac surgery will be developed.

Methods

This scoping review was conducted to systematically identify and map out pre-operative predictors of SSI following cardiac surgery. The review was conducted in two stages, using the same search for both. Stage 1 identified prediction modelling studies of SSI in patients who underwent cardiac surgery, and Stage 2 identified primary studies and systematic reviews of novel predictors of SSI in these patients. This scoping review has been reported according to the PRISMA Extension for Scoping Reviews [12]. The original protocol was registered on the PROSPERO database [13]; protocol amendments are described in Appendix A (see online supplementary material).

Sources of evidence

Embase, MEDLINE and Web of Science were searched from 2000 to February 2022, June 2022 and July 2022, respectively. There have been substantial changes in the use of antimicrobials in clinical practice over the past few decades, so the searches were restricted to reports since 2000 for applicability. The database searches were carried out sequentially, allowing for each subsequent search to be recalibrated to optimise sensitivity and specificity. The search strategy combined terms for cardiac surgery and SSI together with a bespoke filter to identify candidate risk predictors or predictive models (Appendix B, see online supplementary material). The search also included a parallel search strand for known predictors of SSI or existing cardiac surgery risk scores. The search results were limited to studies in adults by applying a filter to remove non-human studies, and research in neonates, infants or children. Case reports, editorials and letters were excluded, and no language restrictions were applied. The reference lists of relevant guidelines, systematic reviews and included studies were also screened to identify any additional reports.

Stage 1. Identifying pre-operative predictors in risk prediction modelling studies

Study selection

Prediction modelling studies on risk of SSI in adults (age ≥18 years) undergoing clean operations in cardiac surgery which assessed at least one pre-operative predictor were eligible. A prediction modelling study was defined based on the PROBAST definition [14] as 'a study that aimed to develop, validate, or update a multi-variable prediction model to estimate the risk of the occurrence of SSI in adults following clean cardiac surgery'.

The population of interest included patients undergoing clean cardiac surgery. Clean surgery was defined using the Centers for Disease Control and Prevention classification of Class 1 wounds: uninfected, no inflammation present, and closed primarily. If wound drainage was required, a closed draining method was necessary [15]. Any cardiac surgeries via median sternotomy were eligible, but surgeries for infective

endocarditis, an infective source (abscess, wound, graft infection), and minimally invasive surgeries were excluded.

SSI was defined as any infection originating in cardiac surgical wounds or the organs or spaces opened or manipulated during the operative procedure [16]. Studies that reported this outcome as (but not limited to) any SSI, mediastinitis or deep sternal wound infection (DSWI) were included. Studies that reported SSI only as part of a composite outcome were excluded.

Search results were screened independently by two reviewers to identify any potentially eligible reports for either review stage. Studies considered relevant for Stage 1 were obtained for full-text review, and assessed for inclusion in Stage 1 independently by two reviewers. Disagreements were resolved through discussion or referral to a third reviewer.

Data extraction

Data were extracted into standardized forms developed in Excel (Microsoft Corp, Redmond, WA, USA). These forms were piloted on a small number of studies and adapted as necessary. Data were extracted on study characteristics, patient characteristics, type of surgery, SSI definition, and follow-up period. All patient-level predictors that could be measured prior to surgery were extracted and mapped. Predictors that could not be measured prior to surgery (e.g. duration of operation, length of ICU stay) or were related to surgical preparation (e.g. method of hair removal, bacterial decolonisation) were excluded as these may be influenced by facility-specific procedures.

The type of prediction modelling study, the modelling methods used, what eligible predictors were assessed and included in the final model, and the discriminative capability of the model (AUC) were also extracted. For studies that included multiple prediction models, data were extracted for all models that met the review eligibility criteria. Models with the same name included in multiple studies that were validated in a different surgical population, or used a different outcome definition, were classified as distinct models, and data were extracted separately for these.

Synthesis

The results were described and charted based on existing scoping frameworks and guidance [17,18]. The key study characteristics and prediction model characteristics were depicted using tables and charts. Simplifications were made to aid predictor mapping and understanding of their usage in

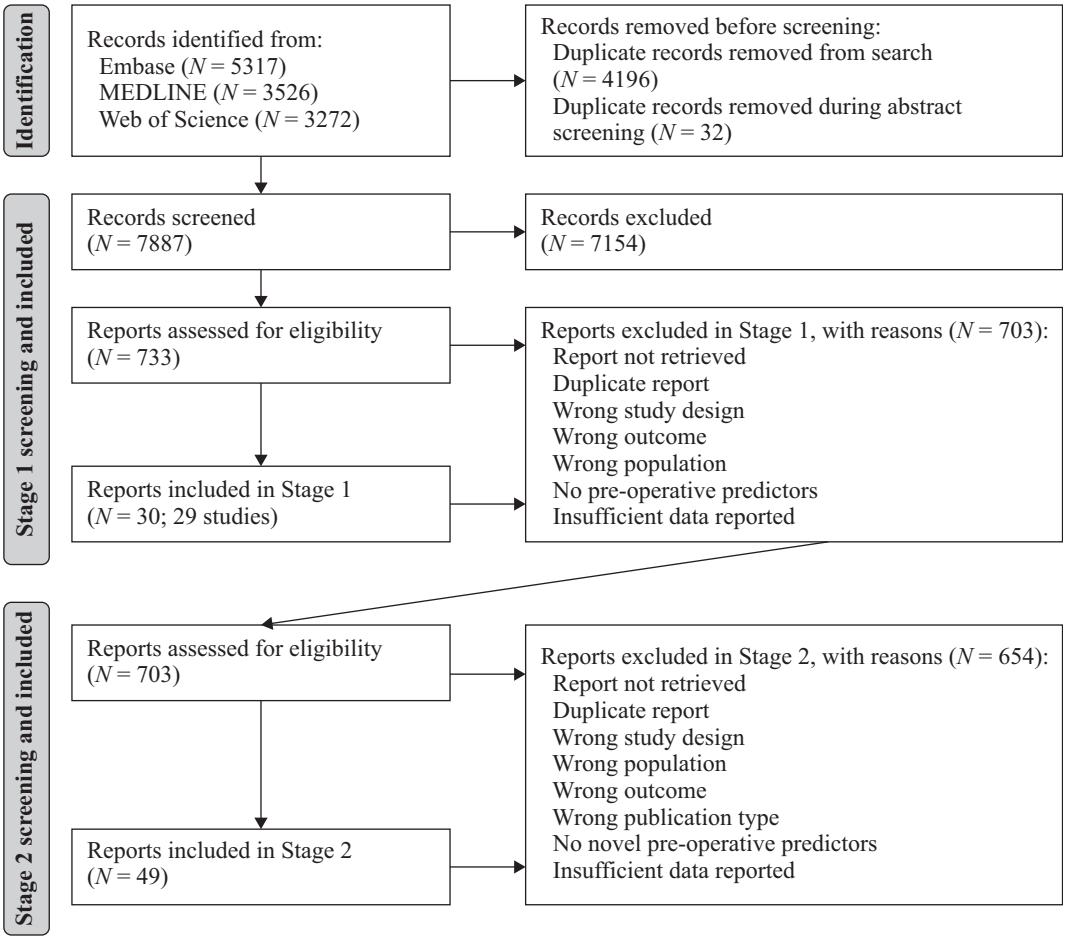

Figure 1. PRISMA flow diagram displaying the two-stage screening approach.

existing cardiac SSI risk prediction models. Predictors with similar or overlapping definitions were grouped together; for example, 'mitral insufficiency' and 'mitral stenosis' were grouped as 'mitral valve disease'. All extracted pre-operative predictors were presented in a table, along with the frequencies of assessment and inclusion across all included models. To understand how the broader clinical categories of predictors have been used in these existing models, individual predictors were organised into four categories: medication, biochemistry, demographics and comorbidity. The discriminative performance (AUC) of models across different studies has also been tabulated.

Stage 2. Identifying novel pre-operative predictors in primary studies

Study selection

Stage 2 was conducted after data extraction was completed for Stage 1. Primary studies of a cohort or case–control design and systematic reviews that evaluated the association between a 'novel' predictor and SSI in adults (age ≥18 years) undergoing clean cardiac surgery were included. Cohort studies measured one or more predictors in a cohort of patients undergoing cardiac surgery who were then followed-up to determine whether or not they developed SSI. Case–control studies selected patients with SSI following cardiac surgery and patients without SSI following cardiac surgery, comparing predictor frequencies between groups. Novel predictors were defined as any factor that could be measured pre-operatively that had not been evaluated in any of the prediction modelling studies included in Stage 1.

To identify relevant studies for Stage 2, two reviewers independently rescreened the full texts of all studies that were excluded from Stage 1. The two reviewers assessed and included studies that evaluated eligible predictors.

Data extraction

As with Stage 1, data were extracted into standardised, piloted forms developed in Excel. Data on study characteristics, patient characteristics, type of surgery outcome definition, and length of follow-up were extracted. 2x2 tables were constructed showing the number of participants with and without SSI, cross-classified against the number with and without the novel candidate predictor.

Synthesis

The key characteristics from the extracted studies were tabulated. The extracted novel predictors were listed in a table, along with *P*-values, to indicate evidence of an association with the risk of SSI following cardiac surgery.

Results

Search results

The searches identified 7887 unique records; 7154 studies were excluded during title and abstract screening, and 733 studies were selected for full-text assessment. Twenty-nine studies (detailed in 30 reports) were included in Stage 1. The remaining 703 studies were re-assessed for inclusion in Stage 2; 49 studies were included in Stage 2. Figure 1 summarizes the screening approach.

Stage 1. Pre-operative predictors included in risk prediction modelling studies

Study characteristics

Twenty-nine studies reported the development (*N*=14), validation (*N*=13), or development and validation (*N*=2) of 52 prediction models of the risk of SSI following cardiac surgery. Table I outlines the key study characteristics. Most studies were conducted in European or North American countries (72%). Almost all were cohort studies (93%) that assessed at least 1000 patients (86%). For studies that reported the duration of follow-up, most followed-up for 30 days after surgery (20%).

Model characteristics

Of the 52 SSI risk prediction models, 40 included pre-operative predictors alone, and 12 also included intra-operative predictors. Figure 2 describes the key characteristics of these models. Twenty-four models (46%) predicted the risk of SSI in patients who had undergone isolated CABG surgery, with other models commonly developed for isolated valve surgery (21%) and mixed cardiac surgery (14%).

There was considerable variation in the SSI definitions used (Figure 2b). Most models were for DSWI (44%) or any SSI (36%) outcomes. Logistic regression was most commonly used in model development (40%). Models developed more recently used a greater diversity of methods, including machine learning approaches (4% used extreme gradient boosting).

Table I
Characteristics of included prediction modelling studies

Characteristic	Category	Number of studies
Study type	Development	14
	Validation	13
	Development and validation	2
Study design	Cohort	27
	Nested case–control	1
	Case–control	1
Location	North America	12
	Europe	9
	Asia	3
	Australia and Oceania	3
	South America	1
	International	1
Follow-up time (days)	30	7
	>30	1
	60	1
	Until discharge	2
	Postoperative period	1
	NR	17
Sample size	100–999	8
	1000–9999	15
	10,000–99,999	3
	100,000–999,999	7

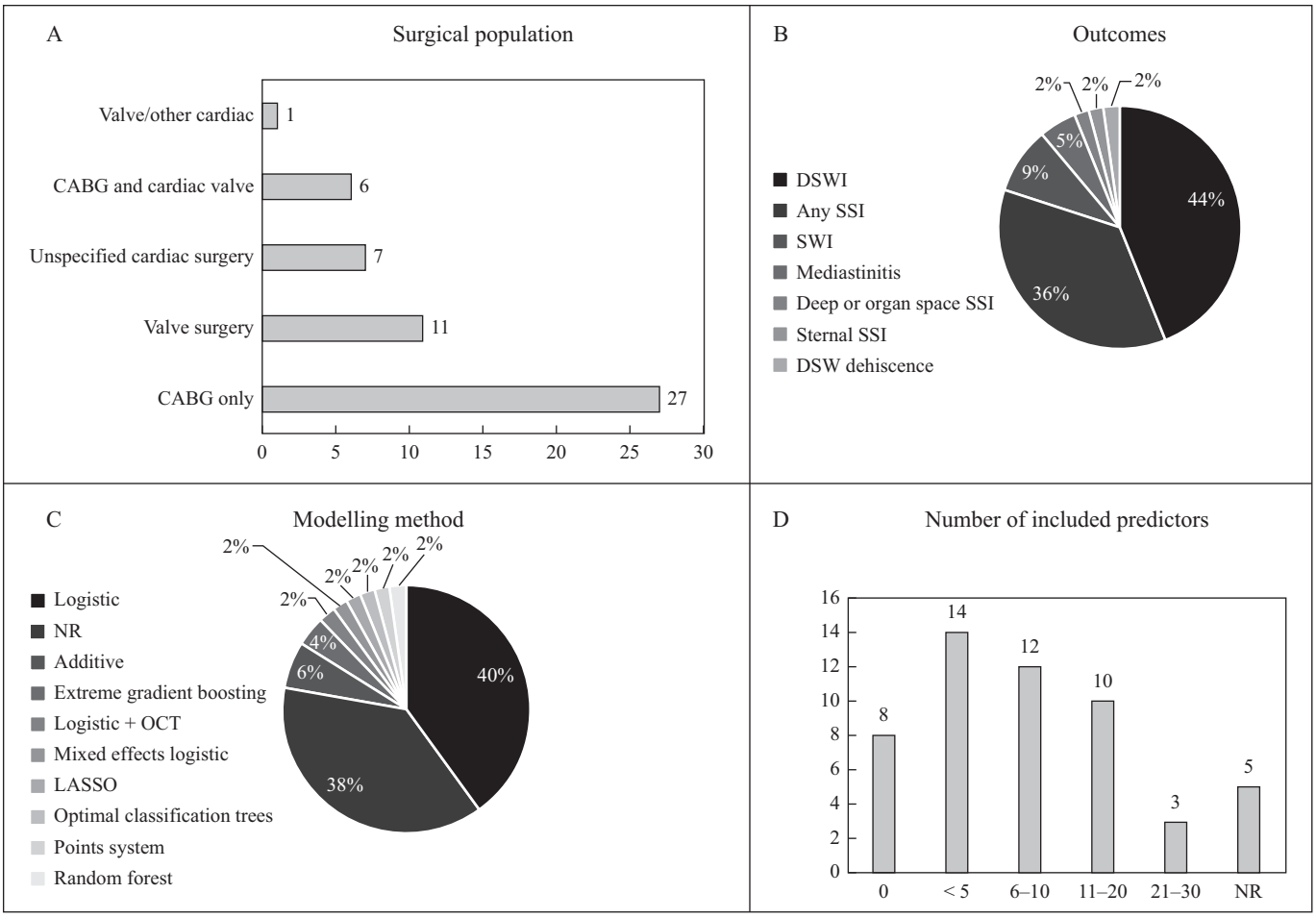

Figure 2. Overview of model characteristics. Figure panel includes surgical population (A), outcome of surgical site infection (SSI) (B), prediction modelling method used (C), and number of pre-operative factors included in the final model (D). NR, not recorded (if the characteristic could not be identified in the study report). CABG, coronary artery bypass graft; DSWI, deep sternal wound infection; SWI, sternal wound infection; OCT, optimal classification trees.

Approximately half of the final models included more than 10 pre-operative predictors, with the total number ranging from one to 26. Eight finalised models included intra-operative predictors only. It was not possible to identify the predictors included in the models (N=5) developed by Orfanoudaki *et al.* as these were not reported in the development study [19].

Pre-operative predictors

Table II summarises the pre-operative predictors considered for inclusion, and those selected for the final prediction models. The most common predictors included in the final models were comorbidities and demographic factors. These included body mass (69%), diabetes (50%), gender (38%), chronic obstructive pulmonary disease (38%), age (35%), peripheral vascular disease (33%), cardiogenic shock (29%), left ventricular ejection fraction (27%), surgical priority (27%), and number of diseased vessels (23%). The pre-operative predictors included in the finalised model are reported in Appendix C, Table III (see online supplementary material).

Most models were found to have low-to-moderate discriminative performance [AUC=0.5–0.7, Appendix C, Table IV (see online supplementary material)]. The STS model had the greatest reported performance (AUC=0.89) in a study validating a prediction model for the risk of DSWI in an Indian cardiac surgery population [20].

Stage 2. Novel Pre-operative predictors included in primary studies

Study characteristics

Table III summarises the characteristics of the studies included in Stage 2. Most studies were conducted in European or North American countries (65%). Thirty-four (69%) were cohort studies, 13 (27%) were case–control studies, and two were systematic reviews. Cardiac surgery (49%) and isolated CABG surgery (43%) were the most common study populations. Outcome definition varied and included DSWI, mediastinitis, all SSIs, sternal wound infection and wound infection. Follow-up ranged from 30 days to 3 years following surgery; the majority of studies followed-up for 30 days. Patient sample sizes ranged from 23 to 5.6 million, with studies most commonly assessing 100–1000 patients (49%).

Table II
Pre-operative predictors in existing models of risk of surgical site infection following cardiac surgery

Predictor	Included	Assessed
Biochemistry		
Creatinine	11	9
Haematocrit	1	6
Platelet count	1	6
White blood cell count	1	1
Haemoglobin	0	5
Albumin	0	1
Comorbidities		
Diabetes	26	5
Chronic obstructive pulmonary disease	20	7
Peripheral vascular disease	17	5
Cardiogenic shock	15	10
Surgical priority	14	14
Left ventricular ejection fraction	14	11
Number of diseased vessels	12	7
Renal impairment	10	13
Heart failure	10	9
Endocarditis	10	9
Previous cardiac surgery	9	15
Myocardial infarction	9	12
Angina	9	10
Cerebrovascular event	7	13
Hypertension	6	9
Pulmonary hypertension	6	7
Type of surgery	6	4
Neurological disorder	5	7
ASA score	4	5
Arrhythmia	3	8
Valvular disease (mitral)	2	9
Valvular disease (aortic)	1	10
Valvular disease (tricuspid)	1	9
Valvular disease (pulmonic)	1	5
Intubation	1	2
Left ventricular size	1	0
Pulmonary function	1	0
Malignancy	0	7
Chest infection	0	7
Thoracic radiotherapy	0	7
Hepatic disease	0	7
Syncope	0	7
Left ventricular dimension	0	5
Previous cardiac surgery (valve disease)	0	5
Colostomy	0	3
Coagulopathy	0	2
EuroSCORE II	0	2
Dependency	0	2
Weight loss	0	2
Obstructive sleep apnoea	0	2
Hypercholesterolaemia	0	1
Anaemia	0	1
Deep venous thrombosis	0	1
Demographics		
Body mass	36	5
Gender	20	10
Age	18	9
Surgical period	8	8
Ethnicity	6	6
Smoking	5	11
Alcohol consumption	1	6
Family history of heart disease	1	6
Socio-economic status	1	1
Recreational drug use	0	7
Pre-operative length of stay	0	5
Medications		
Immunosuppressants	5	10
ACE inhibitors	0	7
ADP receptor inhibitors	0	7
Glycoprotein IIb/IIIa inhibitors	0	7
Anticoagulants	0	5
Antiplatelets	0	5
Beta blockers	0	5

ASA, American Society of Anesthesiologists; ACE, angiotensin-converting enzyme; ADP, adenosine diphosphate.
Assessed, assessed but not included in model; included, assessed and included in model (not counted in 'assessed'). If two or more similar predictors were assessed or included in the same model, this was counted once.

Table III
Key characteristics of studies included in Stage 2

Characteristic	Category	Number of studies
Study design	Cohort	34
	Case–control	13
	Systematic review	2
Location	Europe	18
	North America	14
	Asia	9
	South America	4
	Australia/Oceania	2
	International	2
Surgical population	Cardiac	24
	CABG	21
	CABG and valve	1
	CABG and/or valve	2
	CABG or SAVR	1
Outcome	DSWI	14
	Mediastinitis	12
	SSI	12
	SWI	11
	Wound infection	3
Follow-up period	30 days	9
	>30 days	2
	90 days	4
	6 months	1
	1 year	1
	3 years	1
	NR	31
Sample size	<100	7
	100–999	24
	1000–9999	11
	10,000–99,999	3
	100,000–999,999	2
	≥1 million	2

CABG, coronary artery bypass graft; SAVR, surgical aortic valve replacement; DSWI, deep sternal wound infection; SSI, surgical site infection; SWI, sternal wound infection; NR, not reported.
Total outcome count is 52 as three studies examined two SSI outcomes separately.

Table IV
Novel pre-operative factors and their association with risk of surgical site infection (SSI) following cardiac surgery: supporting and contradictory studies

Predictor	Associated with risk of SSI	No association
	Biochemistry	
Bilirubin	–	Theodore, 2019 [41]
Blood urea	Bugra, 2021 [26]	–
Calcium	–	Bugra, 2021 [26]
Cholesterol	–	Bugra, 2021 [26]
CRP	Bugra, 2021 [26]; Cappabianca, 2006 [27]; Elenbaas, 2010 [28]	Tschudin–Sutter, 2013 [29]
ESR	Bugra, 2021 [26]; Togan, 2015 [42]	–
HDL	Bugra, 2021 [26]	–
LDL	–	Bugra, 2021 [26];
GFR	–	Theodore, 2019 [41]
Iron deficiency	–	Immohr, 2021 [43]
Oxidative stress	–	Suehiro, 2014 [44]
	Comorbidities	
Asymptomatic bacteriuria	–	Duarte, 2018 [45]
Calcified aorta	Filsoufi, 2009 [46]; Toumpoulis, 2005 [47]	–
Depression	Theodore, 2019 [41]	–
Frailty	Lemus-Barrios, 2020 [48]; Back, 2019 [49]	–
Gastrointestinal disease	–	Crape, 2021 [50]
Opiate addiction	Hosseinrezaei, 2012 [51]	–
HIV	–	Boccara, 2008 [34]; Dominici, 2020 [35]; Jimenez-Exposito, 2006 [36]; Robich, 2014 [37]
Hypothyroidism	–	Jaimes, 2017 [52]
Intramuscular adipose tissue content	Kiriya, 2020 [53]	–
Metabolic syndrome	Ozkan, 2017 [21]; Ozyazicioglu, 2010 [22]; Zapata, 2020 [23]	Ardeshiri, 2014 [24]; Pimenta, 2007 [25]
Pre-operative infection	–	Tadros, 2013 [54]; Zapata, 2020 [23]
Psoas total muscle index	–	Kiriya, 2020 [53]
Psychiatric history	–	Hassan, 2006 [55]
Rheumatoid arthritis	–	Hassan, 2006 [55]
Staphylococcus aureus colonization	Maillet, 2011 [56]; Munoz, 2008 [57]	–
MRSA colonization	Munoz, 2008 [57]	Cutrell, 2016 [58]; Dodds Ashley, 2004 [59]
UTI	–	Duarte, 2018 [45]
Vitamin B12	Bugra, 2021 [26]	–
Demographics		
Distressed Communities Index	Mehaffey, 2020 [60]	–
Hospital transfer	Al Salmi, 2019 [61]	–
Latitude	Abdelnoor, 2016 [62]	–
Payer status	–	Benedetto, 2021 [63]
Physical activity	Van Laar, 2017 (ages 66–75 years) [64]	Van Laar, 2017 (ages $\leq$ 65 and >75 years) [64]
	Medication	
Alpha blockers	Eton, 2016 [30]	–
Aspirin	–	Eton, 2016 [30]; Robinson, 2007 [65]
Bronchodilators	–	Eton, 2016 [30]
Calcium channel blockers	–	Eton, 2016 [30]
Clopidogrel	–	Eton, 2016 [30]
Diuretics	–	Eton, 2016 [30]
Heparin	–	Cayci, 2008 [66]
Heparin or nitrates	Nespor, 2015 [67]	–
Nitrates	–	Eton, 2016 [30]; Toumpoulis, 2005 [47]
NSAIDs	–	Eton, 2016 [30]
Proton pump inhibitors	–	Eton, 2016 [30]

(*continued on next page*)

Table IV (*continued*)

Predictor	Associated with risk of SSI	No association
SSRI/SNRIs	—	Tully, 2012 [68]
Statins	Kayani, 2013 [31]	Eton, 2016 [30]; Oddsson, 2012 (studied in mediastinitis and SWI separately) [32]; Young, 2010 [33]
Thrombolysis	—	Toumpoulis, 2005 [47]
Vasopressors	—	Eton, 2016 [30]
	Risk scores	
ACDS (continuous)	Batista, 2006 [69]	—
ACDS (ordinal, quintiles)	—	Batista, 2006 [69]
CHA_2DS_2-VASc score	Kalyoncuoglu, 2019 [70]	—
NHSN risk score (>1)	—	Cutrell, 2016 [58]
PACDS (continuous)	Batista, 2006 [69]	—
PACDS (ordinal, quintiles)	Batista, 2006 (Q3, Q5) [69]	Batista, 2006 (Q2, Q4) [69]
Prognostic nutritional index	Hayashi, 2020 [71]	Lee, 2020 [72]

ACDS, admission chronic disease score; CRP, C-reactive protein; GFR, glomerular filtration rate; HDL, high-density lipoprotein; HIV, human immunodeficiency virus; LDL, low-density lipoprotein; NHSN, National Healthcare Safety Network (USA); NSAID, non-steroidal anti-inflammatory drugs; PACDS, pre-admission chronic disease score; *S. aureus*, *Staphylococcus aureus*; MRSA, methicillin-resistant *Staphylococcus aureus*; ESR, erythrocyte sedimentation rate; SSRI, selective serotonin re-uptake inhibitors; SNRI, serotonin—norepinephrine re-uptake inhibitors; SWI, sternal wound infection; UTI, urinary tract infection.
Studies that found an association reported a *P*-value $\leq$0.05.

Novel pre-operative factors

Fifty-six pre-operative novel candidate predictors of the risk of SSI following cardiac surgery were identified (Table IV); most were comorbidities or related to medication use. The most commonly evaluated predictors in the included studies were metabolic syndrome [21—25], C-reactive protein (CRP) [26—29], use of statins [30—33], and human immunodeficiency virus (HIV) [34—37]. Findings on whether these predictors are associated with the risk of SSI were inconsistent, except for HIV where no association was found across all four studies (Table IV).

Discussion

This review identified 52 existing prediction models of the risk of SSI following cardiac surgery that considered pre-operative predictors. Forty models included pre-operative predictors alone. Overall, model performance was found to be poor to moderate. Sixty-seven pre-operative predictors were considered during the development of these models, with final models most often including comorbidities and demographic predictors such as body mass and diabetes. Fifty-six novel pre-operative factors that have not been considered previously in cardiac SSI risk model development were identified. This review also highlights significant heterogeneity in the surgical populations sampled, duration of follow-up, and definitions of predictors and SSI outcomes across studies.

Over 100 predictors have been identified, but their correlations and interactions need to be assessed in a comparable population to evaluate their predictive utility. Given that a risk model with such a large number of variables is not feasible, a more pragmatic approach would involve using a large-scale national dataset to create a hierarchy of risk, identifying the top 10—20 variables, and developing a standardised scoring system.

Blood biomarkers have been included in cardiac SSI risk model development, but are often excluded from final models. This review identified several blood biomarkers of inflammation and lipid regulation that may improve prediction of the risk of SSI that have not been considered in model development. PhenoAge utilizes blood biomarkers such as CRP to estimate biological age [38], and has the potential to outperform the use of traditional risk factors in predicting morbidity and mortality. In the UK, blood testing is recommended prior to elective cardiac surgery [39]; the use of blood biomarkers in identifying the risk of SSI should be explored further.

The increase in antimicrobial-resistant infections requires careful decisions around the strategies implemented to mitigate risk. Given the increasing accessibility and wider use of electronic health records in research, future cardiac SSI risk prediction models should utilise routine data to predict not only SSI, but also organism type. A recent study in the *Journal of Hospital Infection* found that women are primarily susceptible to Gram-negative SSIs following cardiac surgery, whereas men are primarily susceptible to Gram-positive infections [40]. This has directly influenced antibiotic prophylaxis regimens within the study hospitals. Risk stratification tools would facilitate personalised SSI prevention strategies, potentially making them more cost-effective and reducing the burden of antimicrobial resistance.

As this was a scoping review, the aim was to identify risk prediction models and pre-operative predictors of SSI in adult cardiac surgery. The intention was not to provide a synthesis of the utility or accuracy of identified predictors. Risk of bias was not assessed, consistent with scoping review methodology [17,18]. Instead, this review focused on mapping the extent to which each predictor has been studied or considered in model development. Another limitation is the focus on cardiac surgery populations, potentially excluding predictors of the risk of SSI in other surgical populations that could be applicable to cardiac surgery. Furthermore, only patient-level predictors were included, as these are essential for individual risk

assessment. While pre-operative care practices, such as antimicrobial prophylaxis, affect patient risk, they are generally standardised across patients within a single setting, and are less suitable for individual risk stratification. The main strength of this review was the breadth of studies included, which facilitated the identification of pre-operative factors that have not been considered previously in risk modelling studies.

In conclusion, this review identified 123 pre-operative factors that could predict SSI following cardiac surgery, 56 of which have not been considered in existing risk prediction models. This list of candidate predictors will be valuable in the future development of risk prediction scores, and may also be relevant to other surgical specialities.

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Conflict of interest statement
None declared.

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Ethical approval
Not required. This scoping review synthesizes publicly available information and does not involve patient data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2024.12.002.

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