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## Social and emotional factors as predictors of poor outcomes following cardiac surgery

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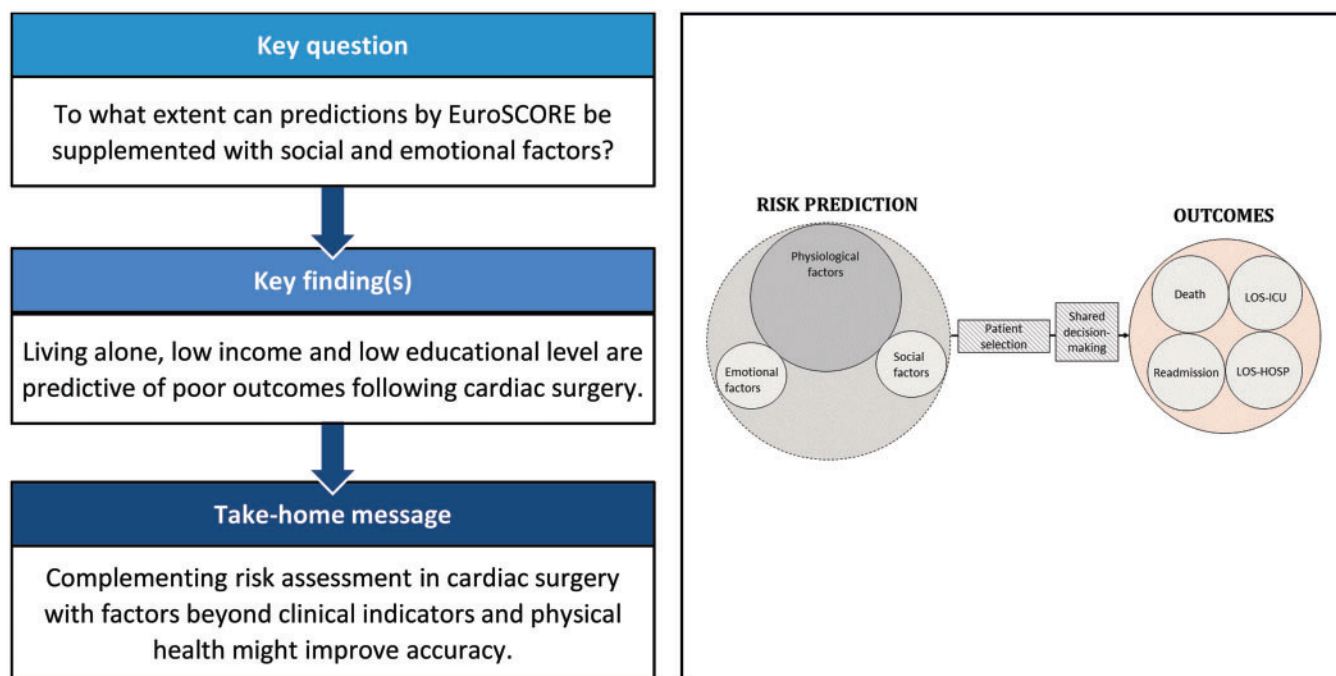
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### Abstract

**OBJECTIVES:** Existing risk prediction models in cardiac surgery stratify individuals based on their predicted risk, including only medical and physiological factors. However, the complex nature of risk assessment and the lack of parameters representing non-medical aspects of patients' lives point towards the need for a broader paradigm in cardiac surgery. Objectives were to evaluate the predictive value of emotional and social factors on 4 outcomes; death within 90 days, prolonged stay in intensive care ( $\geq 72$  h), prolonged hospital admission

( $\geq 10$  days) and readmission within 90 days following cardiac surgery, as a supplement to traditional risk assessment by European System for Cardiac Operative Risk Evaluation (EuroSCORE).

**METHODS:** The study included adults undergoing cardiac surgery in Denmark 2014–2017 including information on register-based socio-economic factors, and, in a nested subsample, self-reported symptoms of anxiety and depression. Logistic regression analyses were conducted, adjusted for EuroSCORE, of variables reflecting social and emotional factors.

**RESULTS:** Amongst 7874 included patients, lower educational level (odds ratio 1.33; 95% confidence interval 1.17–1.51) and living alone (1.25; 1.14–1.38) were associated with prolonged hospital admission after adjustment for EuroSCORE. Lower educational level was also associated with prolonged intensive care unit stay (1.27; 1.00–1.63). Having a high income was associated with decreased odds of prolonged hospital admission (0.78; 0.70–0.87). No associations or predictive value for symptoms of anxiety or depression were found on any outcomes.

**CONCLUSIONS:** Social disparity is predictive of poor outcomes following cardiac surgery. Symptoms of anxiety and depression are frequent especially amongst patients with a high-risk profile according to EuroSCORE.

**Subj collection:** 105, 123

**Keywords:** Risk assessment • Cardiac surgery • Risk factors

#### ABBREVIATIONS

AUC	Area under the curve
CABG	Coronary artery bypass grafting
CI	Confidence interval
EuroSCORE	European System for Cardiac Operative Risk Evaluation
HADS	Hospital Anxiety and Depression Scale
HR	Hazard ratio
ICU	Intensive care unit
LOS-HOSP	Length of hospital admission
LOS-ICU	Length of intensive care unit stay
OR	Odds ratio
SD	Standard deviations

## INTRODUCTION

Cardiac surgical procedures are being offered to older, more complex and high-risk patients than earlier. However, the likelihood of adverse outcomes for patients is highly dependent on their preoperative risk profiles. The patients differ regarding level of surgical difficulty and risk, whilst surgeons differ in their technical skills. Thus, stratification of risk is called for.

The existing risk prediction models stratify individuals based on their predicted risk and tailor treatment to categories of individuals in which the highest benefit is expected to be achieved [1]. Such risk stratification simply recounts the standard procedural risks and assume that individuals classified into the same risk category form a fairly homogeneous group. However, individuals with equal estimated mortality risk may have very different combinations of risk factors and should presumably not be managed the same way. The risk of poor outcomes in cardiac surgery is traditionally presumed to be attributed to biological processes, objectively quantified by risk evaluation, ignoring other relevant factors (e.g. emotional and social factors).

Several risk stratification models are available for estimating baseline risk for mortality following cardiac surgery. The European System for Cardiac Operative Risk Evaluation (EuroSCORE) is adopted primarily in Europe, first published in 1999 and updated in 2012, it differentiate low (<3), moderate (3–5) and high-risk (6+) groups [2], and include medical and physiological factors only and

lack parameters representing non-medical aspects of patients' lives. Previous studies agree that non-physiological, such as emotional [3, 4] and social [5, 6] factors are predictive of adverse outcomes following cardiac surgery.

The aim of the present study is to evaluate the predictive value of selected emotional and social factors for prolonged length of stay in the intensive care unit (ICU), prolonged length of hospital admission (LOS-HOSP), readmissions and death following cardiac surgery. The candidate predictors are tested as a supplement to EuroSCORE.

## MATERIALS AND METHODS

### Design and patients included

The protocol for this study has been previously published as it is part of a comprehensive research project aimed at supplementing prediction by EuroSCORE [7]. This study has a prospective design with follow-up until 90 days after cardiac surgery. Emotional and social factors were included through national administrative registers, clinical databases and a preoperative survey to investigate the predictive value of these parameters on prolonged stay in the ICU, prolonged hospitalization, readmissions and mortality within 90 days after cardiac surgery [7, 8]. The study population comprised patients aged 18 years or above undergoing cardiac surgery from November 2014 to November 2017 in Denmark. A nested subsample of patients participated in a preoperative survey. Patients planned for cardiac surgery at University hospital of Copenhagen, Rigshospitalet and Odense University Hospital were asked to fill out a questionnaire 1 day prior to surgery.

### Variables and data sources

**Predictors.** Information on socio-economic factors were obtained the year before inclusion for the total cohort from the Danish Education Register, the Danish Register on personal income and the Danish Civil Registration System. Socio-economic factors included information on educational level [basic school ( $\leq 10$  years), upper secondary or vocational education and higher education], income (median;  $\leq 50\%$ ,  $>50$ – $150\%$  and  $>150\%$ ) and cohabitation status [living alone (singles, divorced and widowed), being married or living with a partner]. Information on EuroSCORE was received

from 2 clinical databases covering the Eastern and Western part of Denmark, respectively. The databases generally have a high level of completeness of each procedure and for EuroSCORE completeness is >90% [9]. The total risk by EuroSCORE is calculated by adding scores from several medical and physiological risk factors. The score is defined to distinguish low (<3), moderate (3–5) and high risk (6+) [10].

Data on symptoms of anxiety and depression were obtained from a preoperative survey and only available for responders representing a nested subsample [7]. Eligible patients planned to undergo cardiac surgery consenting to participate were assessed for symptoms of anxiety and depression 1 day prior to surgery with the Hospital Anxiety and Depression Scale (HADS). HADS is a self-reported 14-item questionnaire that offers 2 subscales; depression (HADS-D) and anxiety (HADS-A). HADS has been found to be a valid and internally consistent measure [11]. For the current study mean Cronbach's alpha for HADS-D were 0.76 and 0.88 for HADS-A. Scores of 7 or less indicates non-cases, 8–10 suggest the possible presence of a mood disorder, whilst scores of 11 or more indicate the probable presence of a mood disorder.

**Outcomes.** Four outcomes were included in this study prolonged stay in the ICU ( $\geq 72$  h), prolonged hospital admission ( $\geq 10$  days), readmission or death within 90 days from the time of cardiac surgery. Each outcome was evaluated in separate models.

Information on hospital admission was obtained from the Danish National Patient Register, which has registered information on somatic conditions leading to hospitalization; information on length of ICU stay was received from clinical databases mentioned above.

## Death

Mortality is the most used outcome measure in cardiac surgery; thus, most existing prediction tools in cardiac surgery have been

developed to predict death. All-cause mortality until 90 days after cardiac surgery was included as an outcome and identified through the Danish Civil Registration System.

## Prolonged length of stay

The length of stay outcome was included as total number of days in the ICU (LOS-ICU), as well as total LOS-HOSP. Both LOS-ICU and LOS-HOSP were dichotomized to distinguish normal and prolonged length of stay. Previous studies have defined LOS-HOSP following cardiac surgery as the 75th percentile of the length of stay distribution, whilst others have defined it as hospitalization for 10 or more days [12, 13]. Since no consensus on the definition exists and based on our clinical framework, the definition of 10 days or more was adopted as prolonged LOS-HOSP for this study [7].

Prolonged length of stay in the ICU has in previous studies been defined as ranging from above 24 to 96 h or more [12, 14]. Based on the existing literature and clinical framework, prolonged LOS-ICU was for the present study defined as 72 h or more.

## Readmission

Recent studies have found high readmission rates amongst patients following cardiac surgery [15, 16], which makes it an important outcome with significant health and economic implications. For this study, readmission was included as a dichotomous outcome within 90 days following cardiac surgery.

## Statistical analysis

Baseline characteristics for time of hospitalization were described by percentages for categorical measures and means and standard deviations (SDs) for continuous measures, as well as median a range to express normality.

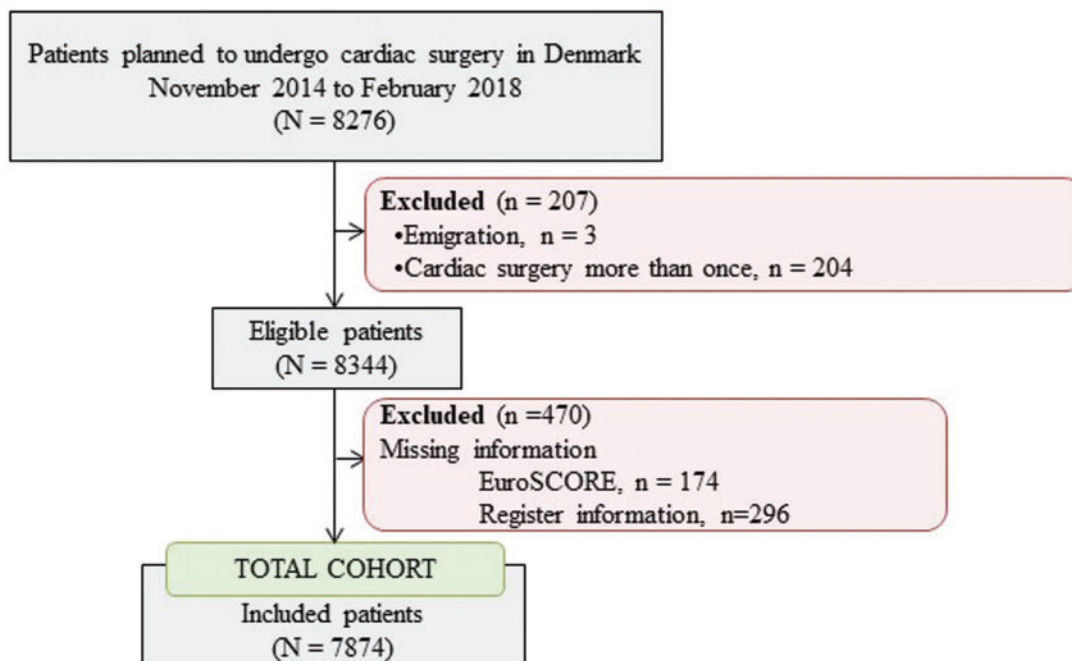


Figure 1: Flow chart, total population. EuroSCORE: European System for Cardiac Operative Risk Evaluation.

**Table 1:** Clinical and socio-demographic information for the total and nested cohort

	Total cohort	Nested cohort
Sex, N (%)		
Women	1937 (25)	208 (20)
Men	5937 (75)	848 (80)
Age (range 18–90)		
<49, N (%)	722 (9)	82 (8)
50–59, N (%)	1271 (16)	194 (18)
60–69, N (%)	2434 (31)	322 (31)
70–79, N (%)	2881 (37)	406 (38)
80+, N (%)	541 (7)	52 (5)
Median (25–75% percentiles)	68 (59–74)	68 (59–73)
Mean (SD)	66 (12)	65 (11)
IQR	15	14
Cohabitation status, N (%)		
Living with a partner	4895 (62)	681 (64)
Living alone	2979 (38)	375 (36)
Educational level, N (%)		
Basic school	2820 (36)	311 (29)
Upper secondary/vocational	3339 (42)	450 (43)
Higher education	1715 (22)	295 (28)
Equivalized disposable income (median 188,955 DKK), N (%)		206,284 DKK
<50% median	505 (6)	75 (7)
>50–150%	5594 (71)	737 (70)
>150%	1775 (23)	244 (23)
Surgical procedure, N (%)		
CABG, isolated	3701 (48)	690 (65)
Aortic valve, isolated	1233 (16)	86 (8)
Mitral valve, isolated	393 (5)	37 (4)
Aorta, isolated	315 (4)	23 (2)
Valve other, isolated	49 (0.4)	5 (1)
Other	280 (5)	47 (4)
Non-isolated procedures	1774 (23)	168 (16)
EuroSCORE, N (%)		
High	1422 (18)	107 (10)
Moderate	1904 (24)	264 (25)
Low	4548 (58)	685 (65)

CABG: coronary artery bypass grafting; DKK: Danish krone; EuroSCORE: European System for Cardiac Operative Risk Evaluation; IQR: interquartile range; SD: standard deviation.

Logistic regression analyses were conducted to explore the association between candidate predictor variables and outcomes. Logistic regression models were reported as odds ratio (OR), with 95% confidence intervals (CIs) for death, readmission, LOS-ICU and LOS-HOSP adjusting for either (i) age (10 years intervals) and sex or (ii) EuroSCORE. To explore whether a high HADS-A or HADS-D score was related to a high EuroSCORE  $\chi^2$  test was performed.

In the register-based data, the number of missing values was low for educational level [ $n = 270$  (3%)], cohabitation status [ $n = 58$  (1%)] and income [ $n = 13$  (<1%)]; however, to determine the best model based on variable selection, data were imputed, by assigning missing for educational level to basic education, missing for cohabitation status to non-cohabitant and missing for income to the median value. In the nested subsample, 7 (<1%) had missing values for 1 item for the subscale HADS-A. For HADS-D, the number of missing was 6 (<1%). Since so few values were missing, imputations were done by assigning missing to the category most frequently occurring.

**Table 2:** Distribution of patient-reported anxiety and depression according to classification by EuroSCORE

EuroSCORE	HADS-A			HADS-D		
	<8 N (%)	8–10 N (%)	≥11 N (%)	<8 N (%)	8–10 N (%)	≥11 N (%)
Low	447 (65)	114 (17)	124 (18)	576 (84)	70 (10)	39 (6)
Moderate	179 (68)	43 (16)	42 (16)	215 (81)	32 (12)	17 (7)
High	63 (59)	17 (16)	27 (25)	77 (72)	17 (16)	13 (12)

EuroSCORE: European System for Cardiac Operative Risk Evaluation; HADS-A: Hospital Anxiety and Depression Scale–anxiety; HADS-D: Hospital Anxiety and Depression Scale–depression.

Each of the predictor variables was excluded separately in a multiple regression model to determine its incremental value, by an automated backwards selection procedure with a set liberal significance level of 0.10, maintained EuroSCORE in the models. To determine discrimination and calibration the receiver operating characteristic curve including area under the curve (AUC) and Brier score were used. An AUC value of 0.5 indicates that the model discriminates no better than chance and a value of 1 indicates that the model discriminates perfectly. The Brier score quantifies the average prediction error with a range from 0 to 0.25; values close to 0 represent informative models, whilst values close to 0.25 represent non-informative models.

Analyses were conducted using SAS version 9.4.

## ETHICAL STATEMENT

According to Danish legislation, surveys should only be approved by the Danish Data Protection agency (j.no. 2012-58-0004). Patient consent was obtained from all participants of the preoperative survey. Use of register data was permitted by the Danish National Board of Health.

## RESULTS

### Demographic and outcome distribution

A total of 8276 patients were eligible for inclusion in this study. We had to exclude a total of 544 (7%); one-third of whom had had cardiac surgery more than once in the inclusion period, another third had missing information and the rest of the excluded patients for whom we did not have specific information on EuroSCORE. Due to a lack of implementation of the updated EuroSCORE II, at the beginning of the study risk calculations for a total of 597 (8%) patients are based on EuroSCORE I. A total of 7874 (93%) were included for analyses (Fig. 1, flow chart). A total of 1056 patients were included in the nested subsample.

Mean age of the total cohort was 66 (SD 12), with almost 70% being 60–79 years old. Male patients constituted 75% of the cohort and 4895 (62%) had a partner. Most patients had an income of 50–150% of the median. Isolated coronary artery bypass grafting (CABG) was performed on half the population, and almost a quarter had non-isolated procedures. Patients assigned to a high-risk EuroSCORE were 1422 (18%) (Table 1). Of the total population, 390 (5%) died within 90 days, 645 (8%) experienced prolonged ICU

**Table 3:** Associations between clinical and socio-demographic factors and outcomes

	LOS-HOSP <sup>a</sup>		LOS-ICU <sup>b</sup>		Readmissions		Death	
	N (%)	OR (95% CI)	N (%)	OR (95% CI)	N (%)	OR (95% CI)	N (%)	OR (95% CI)
	4474		645		2901 (37)		390	
<b>Educational level</b>								
Basic school	1658 (59)	1.21 (1.77–1.37)	256 (9)	1.26 (0.99–1.60)	1007 (36)	0.85 (0.75–0.96)	156 (6)	1.17 (0.87–1.57)
Upper secondary/vocational	1904 (57)	1.16 (1.03–1.31)	276 (8)	1.25 (0.99–1.59)	1222 (37)	0.89 (0.79–1.01)	162 (5)	1.12 (0.84–1.50)
Higher education	912 (53)	1.00 (reference)	113 (7)		672 (39)		72 (4)	
<b>EuroSCORE</b>								
Low		0.56 (0.50–0.63)		0.43 (0.33–0.54)		0.80 (0.72–0.90)		0.38 (0.28–0.53)
Moderate		1.00 (reference)						
High		1.73 (1.49–2.01)		4.92 (3.97–6.09)		1.06 (0.92–1.22)		4.94 (3.78–6.46)
<b>Equivalent disposable income</b>								
<50% median	305 (60)	1.09 (0.90–1.31)	39 (8)	0.80 (0.56–1.14)	188 (37)	1.03 (0.85–1.25)	31 (6)	1.10 (0.74–1.64)
>50–150% median	3253 (58)	1.00 (reference)	487 (9)		2041 (36)		295 (5)	
>150% median	916 (52)	0.83 (0.74–0.92)	119 (7)	0.88 (0.70–1.09)	672 (38)	1.09 (0.98–1.22)	64 (4)	0.78 (0.59–1.04)
<b>EuroSCORE</b>								
Low		0.57 (0.51–0.64)		0.43 (0.34–0.55)		0.80 (0.72–0.89)		0.39 (0.28–0.54)
Moderate		1.00 (reference)						
High		1.74 (1.50–2.02)		4.97 (4.01–6.15)		1.06 (0.92–1.22)		4.97 (3.80–6.50)
<b>Cohabitation status</b>								
Living with a partner	2700 (55)	1.00 (reference)	357 (7)		1846 (38)		222 (5)	
Living alone	1774 (60)	1.14 (1.04–1.25)	288 (10)	1.16 (0.98–1.38)	1055 (35)	0.89 (0.81–0.98)	168 (6)	1.05 (0.85–1.31)
<b>EuroSCORE</b>								
Low		0.56 (0.50–0.63)		0.43 (0.33–0.54)		0.80 (0.72–0.90)		0.38 (0.28–0.53)
Moderate		1.00 (reference)						
High		1.72 (1.48–2.00)		4.89 (3.95–6.05)		1.07 (0.93–1.23)		4.94 (3.78–6.46)

Analyses adjusted for EuroSCORE. Frequency and percentage of events for each outcome according to categories of the independent variables. Percentages calculated for event compared to no event for each category of the independent variable.

<sup>a</sup>≥10 days.

<sup>b</sup>≥72 h.

CI: confidence interval; EuroSCORE: European System for Cardiac Operative Risk Evaluation; LOS-HOSP: length of hospital admission; LOS-ICU: length of intensive care unit stay; OR: odds ratio.

stay, 4474 (57%) prolonged hospital admission and 2901 (37%) patients were readmitted to hospital within 90 days after cardiac surgery (Table 1 and Supplementary Material, Table S1).

**Nested cohort.** A total of 1083 patients completed the HADS questionnaire prior to cardiac surgery 2014–2017. Exclusion was done due to missing data for 27 (2%) patients, thus 1056 patients included for analyses. In the nested subsample, 80% were male, the median age was 68, more than one-third lived alone and 737 (70%) had an income between 50% and 150% of the median. Most patients had isolated CABG procedure, whilst 107 (10%) had a high-risk EuroSCORE (Table 1). In the subsample 24 (2%) died, 53 (5%) experienced prolonged LOS-ICU, 600 (57%) experienced prolonged LOS-HOSP, whilst 396 (38%) were readmitted to hospital within 90 days.

Regarding the HADS-A subscale, a total of 689 (65%) revealed no symptoms of anxiety. The remaining patients included 174 (16%) scoring 8–10 and 193 (18%) scored 11 or more. A total of 868 (82%) did not reveal any symptoms of depression. A total of 119 (11%) scored 8–10 and a total of 69 (7%) had a HADS-D score of 11 or more. Distribution of anxiety and depression was found to be highest in the EuroSCORE high-risk (6+) group. 25% of patients with a high risk by EuroSCORE scored 11 or above for anxiety compared to 18% for low risk and 16% for moderate risk (Table 2). Whilst 12% of the high-risk patients versus 6% (low-risk) and 7% (moderate-risk) scored 11 or above on the depression scale (Table 2). However, a  $\chi^2$  test revealed no significant

association between EuroSCORE and HADS-A (*P*-value, 0.26), whilst higher HADS-D scores were significantly associated with higher EuroSCORE (*P*-value, 0.02).

## Associations and predictive value

**Total cohort.** Through logistic regression analyses, we found that lower educational level and living alone were associated with death, LOS-ICU and LOS-HOSP. Regarding lower educational level, the association with LOS-HOSP (OR 1.21; 95% CI 1.17–1.37) remained when adjusting for EuroSCORE. However, regarding LOS-ICU, the association adjusted for sex and age, was not present when adjusting for EuroSCORE. Regarding living alone, the association with LOS-HOSP remained when adjusting for EuroSCORE, but was only present for LOS-ICU (OR 1.37; 95% CI 1.16–1.62) and death (OR 1.31; 95% CI 1.06–1.62) when adjusting for sex and age (Table 3 and Supplementary Material, Table S2). A high income made patients less likely to experience LOS-HOSP (OR 0.83; 95% CI 0.74–0.92) and LOS-ICU (OR 0.77; 95% CI 0.62–0.95), however, the association with LOS-ICU vanished when adjusting for EuroSCORE (Table 3 and Supplementary Material, Table S2). The outcomes of readmission did not show any statistically significant associations.

The multiple regression models revealed low educational level, lower income and living alone as predictors of prolonged LOS-HOSP. The discriminative value was acceptable based on AUC of 0.618; however, the Brier score of 0.234 indicates a poor

**Table 4:** Model fitting and variable selection by backwards elimination for all outcomes

	LOS-HOSP <sup>a</sup>			LOS-ICU <sup>b</sup>			Readmission			Death		
	Number in	$\chi^2$	P-value	Number in	$\chi^2$	P-value	Number in	$\chi^2$	P-value	Number in	$\chi^2$	P-value
Equalized disposable income		<b>12.09</b>	<b>0.002</b>	3	1.48	0.48	3	0.33	0.85	1	3.27	0.19
Educational level		<b>3.26</b>	<b>0.20</b>	2	3.69	0.16		<b>5.56</b>	<b>0.06</b>	3	0.16	0.92
Cohabitation status		<b>5.66</b>	<b>0.01</b>		<b>3.00</b>	<b>0.08</b>		<b>4.48</b>	<b>0.03</b>	2	0.14	0.71
EuroSCORE		<b>305.21</b>	<b>&lt;0.0001</b>		<b>591.84</b>	<b>&lt;0.0001</b>		<b>28.62</b>	<b>&lt;0.0001</b>		<b>392.19</b>	<b>&lt;0.0001</b>
Fit statistics	AUC	(95% CI)	Brier score	AUC	(95% CI)	Brier score	AUC	(95% CI)	Brier score	AUC	(95% CI)	Brier score
	0.6182	(0.60–0.63)	0.2344	0.7631	(0.74–0.78)	0.0675	0.5394	(0.52–0.55)	0.2316	0.7688	(0.75–0.79)	0.0437

<sup>a</sup>≥10 days.<sup>b</sup>≥72 h.

AUC: area under the curve; CI: confidence interval; EuroSCORE: European System for Cardiac Operative Risk Evaluation; LOS-HOSP: length of hospital admission; LOS-ICU: length of intensive care unit stay.

Bold: variables not eliminated

**Table 5:** Associations between patient-reported outcomes and outcomes of prolonged LOS-HOSP, prolonged LOS-ICU and readmissions and death within 90 days

	LOS-HOSP <sup>a</sup> OR (95%CI)	LOS-ICU <sup>b</sup> OR (95%CI)	Readmissions OR (95%CI)	Death OR (95%CI)
HADS anxiety				
<8	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
>8	0.96 (0.74–1.25)	0.81 (0.44–1.49)	1.15 (0.88–1.49)	1.01 (0.43–2.41)
HADS depression				
<8	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
>8	1.03 (0.74–1.43)	0.74 (0.35–1.59)	1.14 (0.83–1.58)	0.63 (0.20–1.92)

Adjusted for EuroSCORE.

<sup>a</sup>≥10 days.<sup>b</sup>≥72 h.

CI: confidence interval; EuroSCORE: European System for Cardiac Operative Risk Evaluation; HADS: Hospital Anxiety and Depression Scale; LOS-HOSP: length of hospital admission; LOS-ICU: length of intensive care unit stay; OR: odds ratio.

informative model (Table 4). Furthermore, living alone was found to be a predictor of LOS-ICU with an acceptable Brier score of 0.068 and AUC of 0.763 (Table 4). Both lower educational level and living alone predicted readmissions (Table 4). None of the candidate variables were predictive of death (Table 4 and Supplementary Material, Fig. S1).

**Nested cohort.** Logistic regression analyses in the nested cohort revealed no associations for either anxiety or depression irrespective of adjustment for sex and age or EuroSCORE on all outcomes (Table 5 and Supplementary Material, Table S3). The lack of associations was confirmed in the multiple regression models where either of the subscales showed any predicting value of any outcome (Table 6).

## DISCUSSION

In this cohort study including a total of 7874 patients undergoing cardiac surgery, we examined social and emotional factors for associations with poor outcomes and tested them as prognostic factors. The principal findings were that (i) patients with lower educational level and/or were living alone were more likely to

experience prolonged hospitalization following cardiac surgery, (ii) high income was protective of prolonged hospitalization, (iii) low educational level predicted both prolonged hospitalization and readmission following cardiac surgery, (iv) living alone had relatively high predictive values for prolonged hospitalization, prolonged ICU stay and readmission and (v) the presence of symptoms of anxiety and depression measured by HADS was pronounced in the included population, however, neither were associated with or in any way predictive of poor outcomes following cardiac surgery.

The results of the present study confirm our previous findings that living alone is predictive of poor outcomes following cardiac surgery [17]. Previous studies confirm the association and predictive value of living alone [18, 19]. Patients undergoing CABG surgery and living alone have been found to be more than 3 times more likely to be readmitted to hospital (OR 3.42; 95% CI 1.38–8.48) than those living with a partner [18]. Having a partner has been found to increase long-term survival significantly after CABG (OR 2.49; 95% CI 1.47–4.24) [19]. Socially isolated patients are generally more likely to have excessive alcohol intake and smoke [20], delay seeking treatment [21] and demonstrate non-compliance with medical regimens [22], which may be explained by a lack of emotional or practical support gained from living with another person [18].

**Table 6:** Model fitting and variable selection by backwards elimination for all outcomes

	LOS-HOSP <sup>a</sup>			LOS-ICU <sup>b</sup>			Readmission			Death		
	Number in	$\chi^2$	P-value	Number in	$\chi^2$	P-value	Number in	$\chi^2$	P-value	Number in	$\chi^2$	P-value
HADS-A (df = 1)	1	0.08	0.78	2	0.13	0.72	1	1.02	0.31	2	0.23	0.64
HADS-D (df = 1)	2	0.13	0.72	1	0.58	0.44		0.14	0.70	1	0.68	0.41
EuroSCORE (df = 2)		34.31	<0.0001		35.00	<0.0001		9.13	0.01		28.54	<0.0001
Fit statistics	AUC	95% CI	Brier score	AUC	95% CI	Brier score	AUC	95% CI	Brier score	AUC	95% CI	Brier score
	0.5897	0.56–0.62	0.2371	0.6848	0.61–0.76	0.0457	0.5387	0.51–0.57	0.2323	0.8391	0.77–0.91	0.0209

<sup>a</sup>Admission to hospital  $\geq 10$  days.

<sup>b</sup>Admission to intensive care unit  $> 72$  h.

AUC: area under the curve; CI: confidence interval; EuroSCORE: European System for Cardiac Operative Risk Evaluation; HADS-A: Hospital Anxiety and Depression Scale–anxiety; HADS-D: Hospital Anxiety and Depression Scale–depression; LOS-HOSP: length of hospital admission; LOS-ICU: length of intensive care unit stay.

The knowledge of prevalence and influence of emotional factors in cardiac surgery is lagging behind the evidence documented in other heart conditions. In cardiac surgery, the emphasis has been on preserving cognitive function rather than mental health *per se* [23]. Previous studies have established anxiety as a risk factor for patients undergoing cardiac surgery [24, 25] and to be independently predictive of postoperative mortality (OR 5.1; 95% CI 1.3–20.2) [24]. Preoperative anxiety has furthermore been established to predict hospital readmission with a three-fold increase in readmission risk [hazard ratio (HR) 3.14; 95% CI 1.66–5.94] [25]; and to increase the risk of poor postoperative outcomes, readmission, mortality and increased health care utilization [26].

The influence of depression on outcomes following cardiac surgery has been more ambiguous with some studies reporting no predictive value of depressive symptoms (HR 1.36; 95% CI 0.78–2.39) [27]. A positive association between preoperative depression and all-cause mortality was observed in a recent meta-analysis (pooled HR 1.46; 95% CI 1.23–1.73) [28]; whilst another study found symptoms of depression to be associated with higher death rates following CABG (HR 2.4; 95% CI 1.4–4.0) [29]. The lack of predictive value of depression is confirmed with this study finding no association between depression and outcomes.

As described above, associations between both HADS subscales and outcomes were insignificant; however, the wide CIs for the estimates may indicate that the sample size was too small which might have led to a type II error. Thus, any conclusion drawn from this data of no associations need to be replicated with a larger sample size.

## Strength and limitations

Several limitations exist for this study. First, symptoms of anxiety and depression were based on patient-reported data; use of antidepressants, anxiolytics or psychiatric services was not assessed to confirm the validity of the data. Second, as for most preoperative surveys, there is a challenge to include urgent patients, which might lead to the included population having a lower risk profile than the total cardiac population. Thus, the estimates might be slightly underestimated. However, both populations show rather similar distributions (Table 1); thus, no noticeable selection bias seems to be present. Third, it is conceivable that potential candidates of cardiac surgery are selected for non-surgical

interventions due to estimated high-risk profile leading to a high-risk case avoidance. Thus, the estimates of any study aiming to predict outcomes in cardiac surgery above and beyond an existing risk assessment might be underestimated since evaluation is not done on a total population of potential candidates of cardiac surgery. Finally, an automated stepwise approach was utilized, principally due to its objectivity and that it generally results in smaller, clinically applicable models, but stepwise methods have well-known limitations such as unstable variable selection and biased coefficient estimation [30]. Thus, it is conceivable that it may have reduced the predictive performance of the models. The overall model fit statistics indicate that the variance explained by our prediction models is at best modest. Perhaps some factors that are yet to be tested in cardiac surgery could explain additional variance. Despite the limitations of the study and the lack of significant associations between symptoms of anxiety and depression and outcomes, the models made informative predictions that calls for further research and external validation in a similar, but perhaps larger population.

Future directions include development of interventions targeting vulnerable patients planned for cardiac surgery, which according to the findings of this study includes patients living alone, with low income and/or low educational level. Such interventions should include navigation and targeted focus throughout the admission process. Furthermore, the predictive value of the social factors of this study need to be tested alongside EuroSCORE in an unselected population of candidates of cardiac surgery, perhaps even by incorporating the factors in a nomogram or online calculator to ensure usability and availability.

## CONCLUSION

We tested social and emotional factors for their predictive value as a supplement to EuroSCORE and reported different aspects of model performance that can be interpreted for further research applications. Based on the cohorts included, low educational level, a low income and living alone predicted prolonged hospitalization. Living alone, furthermore, predicted prolonged ICU stay and readmission following cardiac surgery. None of the tested variables predicted death within 90 days following cardiac surgery. Neither the presence of symptoms of anxiety nor depression were associated with or predicted any outcomes.

## SUPPLEMENTARY MATERIAL

Supplementary material is available at *ICVTS* online.

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## Author contributions

**Pernille Feveje Cromhout:** Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Visualization; Writing—original draft; Writing—review & editing. **Lau Caspar Thygesen:** Conceptualization; Data curation; Formal analysis; Investigation; Methodology; Supervision; Writing—review & editing. **Philip Moons:** Conceptualization; Investigation; Methodology; Supervision; Writing—review & editing. **Samer Nashef:** Conceptualization; Methodology; Writing—review & editing. **Sune Damgaard:** Data curation; Software; Writing—review & editing. **Selina Kikkenborg Berg:** Conceptualization; Funding acquisition; Investigation; Methodology; Project administration; Resources; Supervision; Writing—review & editing.

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