Time to expand risk evaluation systems for cardiac surgery? Looking beyond physiological parameters

Pernille Fevejle Cromhout[1], Philip Moons[2,3], Lau Caspar Thygesen[4], Samer Nashef[5], Sune Damgaard[6], Selina Kikkenborg Berg[4,7,8].

Discussion paper

Affiliations

[1] Department of Thoracic Anaesthesiology, Rigshospitalet, Copenhagen University Hospital, Blegdamsvej 9, 2100 Copenhagen, Denmark

[2] Department of Public Health and Primary Care, KU Leuven - University of Leuven, Kapucijnenvoer 35 Box7001, 3000 Leuven, Belgium

[3] Institute of Health and Care Sciences, University of Gothenburg, Arvid Wallgrens backe, house 1, PO Box 457, 40530 Gothenburg, Sweden

[4] National Institute of Public Health, University of Southern Denmark, Studiestræde 6, 1455 Copenhagen, Denmark

[5] Surgical Department, Papworth Hospital, Cambridge, United Kingdom

[6] Department of Cardio-thoracic Surgery, Rigshospitalet, Copenhagen University Hospital, Blegdamsvej 9, 2100 Copenhagen, Denmark

[7] Department of Cardiology, Rigshospitalet, Copenhagen University Hospital, Blegdamsvej 9, 2100 Copenhagen, Denmark

8 Department of Public Health, University of Copenhagen, Øster Farimagsgade 5, 1014 Copenhagen, Denmark

Word count

Abstract: 96 (Max 200)

Text: 2617 (excluding title page, abstract, reference list and tables)

Abstract

Risk assessment in cardiac surgery traditionally consists of medical and physiological parameters. However, non-physiological factors have also been found to be predictive of poor outcomes following cardiac surgery. Therefore, the isolated focus on physiological parameters is questionable. This paper describes the emotional, behavioural, social and functional factors that have been established to play a role in outcomes following cardiac surgery. This forms a basis for future research, testing the value of these factors above and beyond the physiological parameters. By including such non-physiological factors, the accuracy of the existing risk scoring systems could potentially be improved.

Keywords

Risk assessment; Cardiac surgery; Risk factors

Background

Cardiac surgery is common in the modern western world. The number of individuals undergoing cardiac surgery has grown over the past decades as a consequence of an increasingly aging population. With surgical advancement, more complex and high-risk patients than before are being offered surgical procedures. Irrespective of its prevalence, cardiac surgery is still considered to be a high risk procedure. Thirty-day mortality rates after cardiac surgery range from 1-3%, increasing to 5-6% at one year (1–5). Readmission rates are about 15% at 30 days after discharge (6–8), but varies greatly after 30 days from 19 to 56% (8,9). Since patients differ in their level of surgical complexity and risk, and because surgeons differ in their technical performance skills, efforts to reduce poor outcomes such as mortality and readmission have been implemented. This frequently includes risk assessment of patients. In some countries report-card programs are implemented, publicly comparing hospital and surgeon performance. One of the original aims for the development of cardiac risk models was risk adjustment, allowing fair comparison of treatment outcomes among different institutions or surgeons. Subsequently, risk models were also applied in clinical decision making, advising individual patients of their operative risk (10,11).

Several risk scoring systems exist. The Society of Thoracic Surgeons (STS) risk score and the European System for Cardiac Operative Risk Evaluation (EuroSCORE) are two widely used risk assessment models that ascertain a patient's magnitude of risk for complications such as mortality after cardiac surgery. The STS risk score was first established in 1989 to assess mortality after cardiac surgery in adults. This risk stratification model has been widely used in North America and comprises over 40 clinical parameters. In addition to mortality, an updated version of the STS score provides risk prediction of major post-operative morbidities. The STS risk score is limited to risk prediction for surgical cases of isolated coronary artery bypass grafting (CABG), valve surgery, and combined procedures (12).

EuroSCORE was developed between 1995 and 1999. As cardiac surgery advanced over time, the original model was found to overestimate the risk of mortality for certain subgroups and was therefore updated in 2012 to EuroSCORE II. This latter risk scoring system comprises 18 clinical parameters (supplementary Table 1) and is applicable to all major cardiac surgical procedures (except transplants). EuroSCORE II is the preferred risk score model used in most of Europe (13,14).

Both the STS risk score and EuroSCORE II only include medical and physiological factors. Furthermore, a meta-analysis showed that the existing scoring systems have a summary area under the receiver operating curve of 0.76 (95% confidence interval (CI) 0.73-0.79) for the STS score and 0.77 (0.75-0.79) for EuroSCORE II for predicting in-hospital mortality (15). This shows that there is still room for improvement in order to make the risk assessment models more predictive and discriminatory. Indeed, there is mounting evidence that non-physiological factors, such as emotional (16–18), behavioural (19–21), social (22–29) and functional (30,31) factors are also predictive of poor outcomes following cardiac surgery. With the present paper, we want to raise awareness about the partiality of the existing risk evaluation in cardiac surgery, as well as, discuss selected non-physiological variables that have been shown to predict poor outcomes after cardiac surgery. Such non-physiological variables potentially could add accuracy and meaning to the existing scoring models if they are included above and beyond the traditional physiological parameters.

Methods

We applied the methodology of a state-of-the-art review (32). State-of-the-art reviews aim to offer new perspectives on an issue or highlight an area in need of further research. They address more current matters in contrast to other methods of literature reviews. In this respect, state-of-the-art

reviews are of considerable value for those seeking to identify potential opportunities for contemporary research (32) According to the SALSA (Search; AppraisaL; Synthesis; Analysis) framework, the typical methodology of a state-of-the-art review is a comprehensive search of the current literature; no formal quality assessment; narrative reporting sometimes with tabular accompaniment; and providing the current state of knowledge and priorities for future investigation and research (32). Literature searches for each factor included were performed in the PubMed database always consisting of 'cardiac surgery' combined with relevant terms for each factor as MeSH term and as free-text. Reviews and new literature were preferred. For the initial, general search strategy, please see Supplementary Table 2.

Emotional factors

In patients undergoing cardiac surgery the knowledge of prevalence and influence of emotional factors is lagging behind the evidence documented in other heart conditions. Indeed, the paucity of research in this group of patients regarding the influence of emotional factors on outcomes is striking. In cardiac surgery the emphasis has been on preserving cognitive function rather than mental health *per se* (33).

Depression

There is a high prevalence of depression among patients awaiting cardiac surgery with 20-40% of patients meeting criteria for major depressive disorder (16). Connerney and colleagues found that depression experienced after CABG was an independent risk factor of adverse outcomes, including mortality [risk ratio, 2.3; 95% CI, 1.17–4.56] (34). In a meta-analysis from 2016, a positive association between preoperative depression and all-cause mortality was observed in patients undergoing cardiac surgery [pooled hazard ratio (HR), 1.46; 95% CI, 1.23–1.73] (35). Depressive symptoms have furthermore been found to be associated with having an emergency admission

following CABG [OR, 1.088; 95% CI, 1.010–1.171] (36), a higher risk of major adverse cardiac and cerebrovascular event including death among cardiac surgery patients [HR, 1.12; 95% CI, 1.07-1.12] (37), and a lack of improvement in physical function six months after cardiac surgery (38).

Anxiety

The prevalence of preoperative anxiety has been found to be as much as 32%, increasing up to 45% following cardiac surgery (39). Preoperative anxiety is an independent predictor of hospital readmission and carries a three-fold increase in readmission risk [HR, 3.14; 95% CI, 1.66–5.94] after cardiac surgery (39). Some patients appear to suffer from severe anxiety for extended periods of time after surgery, which is often associated with substantial depression (40). A recent review identified that preoperative anxiety increased the risk of poor postoperative outcomes after CABG including atrial fibrillation, acute myocardial infarction, increased risk of readmission, morbidity and mortality, and increased health care utilisation (41).

Health-related Quality of Life

With declining mortality and major morbidity rates after cardiac surgery over the past decades, investigating self-perceived health status and quality of life (QoL) is a key aspect to evaluate the success of surgery, since it quantifies the impact on functional status and the emotional and mental well-being, as well as, social functioning of patients. Measurements of self-perceived health status and QoL can be used to evaluate the broad impact of a disease on a patient and extend the assessment process beyond traditional clinical parameters and tracking the multidimensional impact of surgery over time (42). Rumsfeld and colleagues found health-related quality of life to be an independent risk factor for mortality following CABG surgery [OR 1.39; 95% CI, 1.11-1.77] (43)

Social factors

Socioeconomic position (SEP) is usually measured by determining education, income, occupation, or a composite measure thereof. These have been found to influence disease incidence, treatment and health outcomes. Those with lower income, lower education or working in lower status occupations experience increased mortality and morbidity (22,25,26,28,44,45).

Living alone has been linked with poor health outcomes in earlier studies. There seem to be a number of reasons for this. Patients who are socially isolated are more likely to smoke and drink alcohol heavily (46,47), delay in seeking treatment (48) and demonstrate non-compliance with medical regimens (49). Others have found this simply to be due to lack of emotional or practical support gained through living with another person (50).

Educational level

Low educational level has been found related to a higher risk profile and poorer treatment in patients with myocardial infarction (23,24,51). Mortality risk has been found to be considerably higher for less educated (<12 years) patients [HR, 2.64; 95% CI, 1.92–3.63] than for more educated (≥12 years) patients [1.53; 95% CI, 1.02–2.29] (52).

Income/poverty

An inverse relation between income and mortality at one year after invasive cardiac procedures, including CABG, has been documented. In a cohort of 51,591 patients, each $10,000 increase in the median income was associated with a 10 percent reduction in the risk of death [HR, 0.90; 95% CI, 0.86-0.94] (29). Furthermore, waiting time for heart surgery has been found to be significantly influenced by economic status (P = 0.037) (53). This confirms the findings by Pell et al. that the mean waiting time for cardiac surgery increased across deprivation categories, with the most deprived patients waiting the longest [mean difference, 24 days; 95% CI, 15 to 32] (54).

Cohabitation

Generally, morbidity and mortality outcomes are better among cohabitating persons. Married status has been found to be independently associated with improved outcome in patients undergoing elective or urgent coronary revascularisation [HR, 0.7; 95% CI, 0.6-0.9] (55) and women living alone have been found to have a significantly increased all-cause mortality rate after acute myocardial infarction [HR, 6.24; 95% CI, 2.68-14.51] compared to women living with someone (56). The improving value of cohabitation has been confirmed in patients undergoing CABG surgery, with patients living alone being over three times more likely to be readmitted to hospital [OR, 3.42; 95% CI, 1.38–8.48] than those living with others (50).

Functional factors

The physiological factors included in EuroSCORE comprise a range of comorbidities. However, functional status as an independent predictor is not included in the score. Improved functional status and return to pre-morbid lifestyle is a major goal for most patients undergoing cardiac surgery.

Physical functioning

Afilalo et al. demonstrate that disability, specifically the presence of 3 or more impairments are incrementally predictive for mortality or major morbidity following cardiac surgery (OR, 2.66; 95% CI, 1.18–5.96 and 2.17; 95% CI, 0.93–5.04) (57). These authors argue that impairments are additive to existing risk scores and that inclusion of them in the risk assessment improves the discrimination (57). Furthermore, functional decline in patients undergoing cardiac surgery has been found to be associated with complications like pressure ulcers (58), delirium (59), and depression (60).

Frailty

Patients being referred for cardiac surgery are increasingly older. Rather than chronological age, frailty has been found to be associated with an almost three-fold increase of post-operative mortality

and severe morbidity following cardiac surgery [OR, 2.98; 95% CI, 1.35–6.56] in a group of older patients (30). In a systematic review from 2014, frailty has been found to have a strong positive relationship with poor postoperative outcomes such as major adverse cardiac and cerebrovascular events [OR, 4.89; 95% confidence interval, 1.64-14.60] (31).

Afilalo et al. found that when adding scores of frailty and disability to the STS risk score discrimination improved by yielding an area under the curve of 0.73, compared with 0.68 for the STS alone in a cohort of elderly patients undergoing cardiac surgery (57).

Cognition

Up to one-third of elective cardiac surgical patients enter surgery with some degree of pre-existing cognitive impairment. Preoperative cognitive impairment has been identified in patients presenting for coronary artery surgery (33%-37%), which may predispose to postoperative delirium and accelerate clinical deterioration (61). Furthermore, low preoperative cognitive functioning has been found to be associated with a more negative pattern of biological response to surgery, indicative of poorer physical recovery after cardiac surgery (62)

Behavioural factors

Several longitudinal and cross-sectional studies demonstrate that health-risk behaviours such as smoking, alcohol consumption, a sedentary lifestyle, and obesity are associated with a variety of health-risks and mortality (63).

Alcohol

Evidence concerning alcohol consumption has been ambiguous since alcohol consumption is associated with both harmful and beneficial health effects. Heavy drinking has been found to be significantly associated with an increased mortality rate among patients undergoing CABG [HR, 2.44; 95% CI, 1.47–4.04] (64).

Smoking

Smoking is a well-known risk factor for complications after surgery (65,66). Being a current smoker has been found to predict increased operative mortality after cardiac surgery among patients over the age of 70 years [14.8 vs. 2.1%, P 0.0001] (67). Pagano and colleagues found that there was a 29% additional risk of death after cardiac surgery among patients smoking [HR 1.29; 95% CI 1.191-1.407] and 25% for ex-smokers compared to patients who had never smoked (68). Furthermore, there is evidence that preoperative smoking cessation may reduce postoperative morbidity (69,70).

Obesity

The relation between body mass index (BMI) and survival after cardiac surgery has previously been found to be non-linear, with a U-shaped relationship in which the minimum risk occurs near a BMI of 30 kg/m2 and lower and higher BMIs are associated with higher risk (71). Severe obesity with BMI $\geq$ 40 has been found to be associated with increased risk of early complications and extended length of stay and it was established as an independent predictor of adverse outcomes following CABG surgery (19,72). An increased BMI has furthermore been found to be associated with a higher likelihood of readmission to hospital within 30 days of discharge following cardiac surgery [9.3 vs. 13.4%, P 0.025] (73).

Discussion

Cardiac surgery remains an established procedure for several heart conditions and as a consequence of an increasingly older population, cardiac surgery is being performed on more complex and high-risk populations than before. Adequate risk assessment to guide the clinical decision-making is therefore of rising importance.

Several of the above mentioned factors rely on patient-reported measures. Traditionally, clinical health factors, such as blood pressure control, has been proclaimed as valid measures of cardiovascular health (74). Although important, these measures alone are insufficient according to the World's Health Organization's definition of health "*... a state of complete physical, mental and social well-being.*" (75). Associations between self-reported health and morbidity and mortality has been confirmed in previous studies, where patient reported measures has been found to predict prolonged hospital stay, labour market affiliation, morbidity and mortality in cardiac patients (76–79).

For the application of patient-reported outcomes in risk assessment, it is of paramount importance to choose measures that provide valid and reliable responses. On the other hand, feasibility and practicality of collection, scoring, and interpretation of patient health status data have to be taken into consideration. Comprehensive testing, using extensive research instruments, is not an option when used in risk assessment schemes. Such questionnaires are typically too lengthy to be used in clinical practice. Indeed, in risk evaluation, each factor ought to be assessed in the shortest possible way, to warrant that the overall risk assessment is doable in day-to-day clinical practice. Short-form versions are likely most suitable. Furthermore, computer adaptive testing may be a promising approach, since the answer to a certain question determines what questions are subsequently asked. Such adaptive testing procedures can substantially reduce the questionnaire burden in respondents.

As described in this paper, several emotional, social, functional, and behavioural factors impact on mortality, readmission and complications following cardiac surgery. However, there is still some uncertainty about the true predictive value of these factors. Furthermore, it is not known what their added value would be above and beyond the physiological factors. Therefore, future research in this matter is imperative.

In Denmark, a comprehensive research project is ongoing in which we are developing a risk stratification model as a supplement to EuroSCORE. Emotional, social, functional and behavioural factors will be included through national administrative registers, clinical databases and surveys to predict mortality, readmissions and complications in patients within three months after cardiac surgery.

In conclusion, conventional risk assessment focuses on medical and physiological factors, but do not contain other relevant risk factors associated with increased risk of poor outcomes following cardiac surgery. Evidence has been established that also non-physiological factors are predictive of poor outcomes following cardiac surgery and need to be considered for inclusion in current risk evaluation models.

Declaration of Conflicting Interests

The authors declare that there is no conflict of interest.

References

1. STS The Society of Thoracic Surgeons. Adult Cardiac Surgery Database Executive Summary 10 Years. 2017.
2. von Kappelgaard LM, Davidsen M, Gislason G. Danish Heart Register - Yearly numbers 2016. 2016.
3. Bridgewater B, Keogh B, Kinsman R, Walton P. Sixth National Adult Cardiac Surgical Database Report. 2008.
4. Hansen LS, Hjortdal VE, Andreasen JJ, Mortensen PE, Jakobsen C-J. 30-day mortality after coronary artery bypass grafting and valve surgery has greatly improved over the last decade, but the 1-year mortality remains constant. Ann Card Anaesth. 2015 Jan;18(2):138–42.
5. Siregar S, Groenwold RHH, de Mol BAJM, Speekenbrink RGH, Versteegh MIM, Brandon Bravo Bruinsma GJ, et al. Evaluation of cardiac surgery mortality rates: 30-day mortality or longer follow-up? Eur J Cardiothorac Surg. 2013 Nov;44(5):875–83.
6. Hannan EL, Racz MJ, Walford G, Ryan TJ, Isom OW, Bennett E, et al. Predictors of readmission for complications of coronary artery bypass graft surgery. JAMA. 2003 Aug 13;290(6):773–80.
7. Stewart RD, Campos CT, Jennings B, Lollis SS, Levitsky S, Lahey SJ. Predictors of 30-Day Hospital Readmission After Coronary Artery Bypass. Ann Thorac Surg. 2000;70:169–74.
8. Iribarne A, Chang H, Alexander JH, Gillinov AM, Moquete E, Puskas JD, et al. Readmissions after cardiac surgery: Experience of the national institutes of health/canadian institutes of health research cardiothoracic surgical trials network. Ann Thorac Surg. 2014;
9. Sibilitz KL, Berg SK, Thygesen LC, Hansen TB, Køber L, Hassager C, et al. High readmission rate after heart valve surgery: A nationwide cohort study. Int J Cardiol. 2015 Apr 11;189:96–104.

10. Prins C, de Villiers Jonker I, Botes L, Smit FE. Cardiac surgery risk-stratification models. Cardiovasc J Afr. 2012 Apr;23(3):160–4.

11. Epstein AJ. Do cardiac surgery report cards reduce mortality? Assessing the evidence. Med care Res Rev. 2006;63(4):403–26.

12. Granton J, Cheng D. Risk stratification models for cardiac surgery. Semin Cardiothorac Vasc Anesth. 2008;12(3):167–74.

13. Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R. European system for cardiac operative risk evaluation (EuroSCORE). Eur J Cardiothorac Surg. 1999 Jul;16(1):9–13.

14. Nashef SAM, Roques F, Sharples LD, Nilsson J, Smith C, Goldstone AR, et al. Euroscore II. Eur J Cardio-thoracic Surg. 2012;41(4):734–45.

15. Sullivan PG, Wallach JD, Ioannidis JP. Meta-Analysis Comparing Established Risk Prediction Models (EuroSCORE II, STS Score, and ACEF Score) for Perioperative Mortality During Cardiac Surgery. Am J Cardiol. 2016;118:1574–82.

16. Celano CM, Huffman JC. Depression and cardiac disease: a review. Cardiol Rev. 2011 Jan;19(3):130–42.

17. Mallik S, Krumholz HM, Lin ZQ, Kasl S V, Mattera JA, Roumains SA, et al. Patients with depressive symptoms have lower health status benefits after coronary artery bypass surgery. Circulation. 2005 Jan 25;111(3):271–7.

18. Stenman M, Holzmann MJ, Sartipy U. Relation of major depression to survival after coronary artery bypass grafting. Am J Cardiol. 2014 Sep 1;114(5):698–703.

19. Terada T, Johnson JA, Norris C, Padwal R, Qiu W, Sharma AM, et al. Severe obesity is associated with increased risk of early complications and extended length of stay following coronary artery bypass grafting surgery. J Am Heart Assoc. 2016;5(6):9–11.

20. Ji Q, Zhao H, Mei Y, Shi Y, Ma R, Ding W. Impact of smoking on early clinical outcomes in patients undergoing coronary artery bypass grafting surgery. J Cardiothorac Surg. 2015 Feb 6;10(1):16.

21. Maheshwari A, Dalton JE, Yared J-P, Mascha EJ, Kurz A, Sessler DI. The association between alcohol consumption and morbidity and mortality in patients undergoing coronary artery bypass surgery. J Cardiothorac Vasc Anesth. 2010 Aug;24(4):580–5.

22. Koch CG, Li L, Kaplan GA, Wachterman J, Shishehbor MH, Sabik J, et al. Socioeconomic position, not race, is linked to death after cardiac surgery. Circ Cardiovasc Qual Outcomes. 2010 May;3(3):267–76.

23. Kaplan GA, Keil JE. Socioeconomic factors and cardiovascular disease: a review of the literature. Circulation. 1993 Oct;88(4 Pt 1):1973–98.

24. Tang KL, Rashid R, Godley J, Ghali WA. Association between subjective social status and cardiovascular disease and cardiovascular risk factors: a systematic review and meta-analysis. BMJ Open. 2016;6.

25. Mackenbach JP, Cavelaars AEJM, Kunst AE, Groenhof F, EU Working Group on Socioeconomic Inequalities in Health. Socioeconomic inequalities in cardiovascular disease mortality An international study. Eur Heart J. 2000;21:1141–51.

26. Holme I, Hjermann I, Helgeland A, Lund-Larsen PG, Leren P. Coronary risk factors and socioeconomic status The Oslo Study. Lancet. 1976;1396–8.

27. Smith GD, Hart C, Watt G, Hole D, Hawthorne V. Individual social class, area-based deprivation, cardiovascular disease risk factors, and mortality: the Renfrew and Paisley Study. J Epidemiol Community Health. 1998 Jun;52(6):399–405.

28. Gonzalez MA, Artajejo FR, Calero JDR. Relationship between socioeconomic status and ischaemic heart disease in cohort and case-control studies: 1960-1993. Int J Epidemiol.

1998;27:350–8.

29. Alter DA, Naylor D, Austin P, Tu J V. Effects of socioeconomic status on access to invasive cardiac procedures and on mortality after acute myocardial infarction. N Engl J Med. 1999;341(18):1359–67.

30. Afilalo J, Eisenberg MJ, Morin J-F, Bergman H, Monette J, Noiseux N, et al. Gait speed as an incremental predictor of mortality and major morbidity in elderly patients undergoing cardiac surgery. J Am Coll Cardiol. 2010 Nov 9;56(20):1668–76.

31. Sepehri A, Beggs T, Hassan A, Rigatto C, Shaw-Daigle C, Tangri N, et al. The impact of frailty on outcomes after cardiac surgery: a systematic review. J Thorac Cardiovasc Surg. 2014 Dec;148(6):3110–7.

32. Grant MJ, Booth A. A typology of reviews: An analysis of 14 review types and associated methodologies. Health Info Libr J. 2009;26(2):91–108.

33. Tully PJ. Psychological Depression and Cardiac Surgery: A Comprehensive Review. JECT. 2012;44:224–32.

34. Connerney I, Shapiro PA, McLaughlin JS, Bagiella E, Sloan RP. Relation between depression after coronary artery bypass surgery and 12-month outcome: a prospective study. Lancet. 2001;358(9295):1766–71.

35. Stenman M, Holzmann MJ, Sartipy U. Association between preoperative depression and long-term survival following coronary artery bypass surgery — A systematic review and meta-analysis. 2016;

36. Poole L, Ronaldson A, Kidd T, Leigh E, Jahangiri M, Steptoe A. Pre-surgical depression and anxiety and recovery following coronary artery bypass graft surgery. J Behav Med. 2017;40:249–58.

37. Cserép Z, Balog P, Székely J, Treszl A, Kopp MS, Thayer JF, et al. Psychosocial factors and

major adverse cardiac and cerebrovascular events after cardiac surgery. Interact Cardiovasc Thorac Surg. 2010;11:567–72.

38. Mallik S, Krumholz HM, Lin ZQ, Kasl S V., Mattera JA, Roumains SA, et al. Patients With Depressive Symptoms Have Lower Health Status Benefits After Coronary Artery Bypass Surgery. Circulation. 2005;111(3):271–7.

39. Tully PJ, Baker RA, Turnbull D, Winefield H. The role of depression and anxiety symptoms in hospital readmissions after cardiac surgery. J Behav Med. 2008;31:281–90.

40. Gardner F V, Worwood E V. Psychological effects of cardiac surgery: a review of the literature. J R Soc Health. 1997;117(4):245–9.

41. Joseph HK, Whitcomb J, Taylor W. Effect of Anxiety on Individuals and Caregivers After Coronary Artery Bypass Grafting Surgery. Dimens Crit Care Nurs. 2015;34(5):285–8.

42. Tully PJ. Quality-of-Life measures for cardiac surgery practice and research: a review and primer. J Extra Corpor Technol. 2013;45(1):8–15.

43. Rumsfeld JS, MaWhinney S, McCarthy M, Shroyer AL, VillaNueva CB, O'Brien M, et al. Health-Related Quality of Life as a Predictor of Mortality Following Coronary Artery Bypass Graft Surgery. JAMA. 1999;281(14):1298–303.

44. Smith GD, Hart C, Blane D, Gillis C, Hawthorne V. Lifetime Socioeconomic Position and Mortality: Prospective Observational Study. Source BMJ Br Med J. 1997;314(7080):547–52.

45. Alter DA, Naylor CD, Austin P, Tu J V. Effects of socioeconomic status on access to invasive cardiac procedures and on mortality after acute myocardial infarction. N Engl J Med. 1999 Oct 28;341(18):1359–67.

46. Dickens CM, McGowan L, Percival C, Douglas J, Tomenson B, Cotter L, et al. Lack of a close confidant, but not depression, predicts further cardiac events after myocardial infarction. Heart. 2004 May;90(5):518–22.

47. Haustein K-O. Smoking and poverty. Eur J Cardiovasc Prev Rehabil. 2006 Jun;13(3):312–8.

48. Schwarz B, Schoberberger R, Rieder A, Kunze M. Factors delaying treatment of acute myocardial infarction. Eur Heart J. 1994 Dec;15(12):1595–8.

49. DiMatteo MR, Lepper HS, Croghan TW. Depression is a risk factor for noncompliance with medical treatment: meta-analysis of the effects of anxiety and depression on patient adherence. Arch Intern Med. 2000 Jul 24;160(14):2101–7.

50. Murphy BM, Elliott PC, Le Grande MR, Higgins RO, Ernest CS, Goble AJ, et al. Living alone predicts 30-day hospital readmission after coronary artery bypass graft surgery. Eur J Cardiovasc Prev Rehabil. 2008;15:210–5.

51. Cserép Z, Losoncz E, Balog P, Szili-Török T, Husz A, Juhász B, et al. The impact of preoperative anxiety and education level on long-term mortality after cardiac surgery. J Cardiothorac surgery2. 2012;7(86).

52. Gerber Y, Goldbourt U, Drory Y. Interaction between income and education in predicting long-term survival after acute myocardial infarction. Eur J Cardiovasc Prev Rehabil. 2008;15:526–32.

53. Badakhshan A, Arab M, Gholipour M, Behnampour N, Saleki S. Heart Surgery Waiting Time: Assessing the Effectiveness of an Action. Iran Red Crescent Med J. 2015;17(8).

54. Pell JP, Pell CH, Norrie J, Ford I, Cobbe SM. Effect of socioeconomic deprivation on waiting time for cardiac surgery: retrospective cohort study. BMJ. 2000;320:15–8.

55. Barbash IM, Gaglia MA, Torguson R, Minha S, Satler LF, Pichard AD, et al. Effect of marital status on the outcome of patients undergoing elective or urgent coronary revascularization. Am Heart J. 2013;166(4):729–36.

56. Norekvål TM, Fridlund B, Rokne B, Segadal L, Wentzel-Larsen T, Nordrehaug JE. Patient-reported outcomes as predictors of 10-year survival in women after acute myocardial

infarction. Health Qual Life Outcomes. 2010;8:140.

57. Afilalo J, Mottillo S, Eisenberg MJ, Alexander KP, Noiseux N, Perrault LP, et al. Addition of frailty and disability to cardiac surgery risk scores identifies elderly patients at high risk of mortality or major morbidity. Circ Cardiovasc Qual Outcomes. 2012 Mar 1;5(2):222–8.

58. Feuchtinger J, Halfens R, Dassen T. Pressure ulcer risk assessment immediately after cardiac surgery – does it make a difference? A comparison of three pressure ulcer risk assessment instruments within a cardiac surgery population.

59. van der Mast RC, van den Broek WW, Fekkes D, Pepplinkhuizen L, Habbema JD. Incidence of and preoperative predictors for delirium after cardiac surgery. J Psychosom Res. 1999 May;46(5):479–83.

60. Blumenthal JA, Lett HS, Babyak MA, White W, Smith PK, Mark DB, et al. Depression as a risk factor for mortality after coronary artery bypass surgery. Lancet. 2003 Aug 23;362(9384):604–9.

61. Tully PJ, Baune BT, Baker RA. Cognitive impairment before and six months after cardiac surgery increase mortality risk at median 11 year follow-up: a cohort study ☆. 2013;

62. Poole L, Ronaldson A, Kidd T, Leigh E, Jahangiri M, Cth F, et al. Pre-Operative Cognitive Functioning and Inflammatory and Neuroendocrine Responses to Cardiac Surgery. Ann Behav Med. 2016;50:545–53.

63. Institute of Medicine (US) Committee on Health and Behavior: Research Practice and Policy. Health and behavior : the interplay of biological, behavioral, and societal influences. National Academy Press; 2001. 377 p.

64. Grabas MPK, Hansen SM, Torp-Pedersen C, Bøggild H, Ullits LR, Deding U, et al. Alcohol consumption and mortality in patients undergoing coronary artery bypass graft (CABG)-a register-based cohort study. 2BMC Cardiovasc Disord. 2016;16(219).

65. Bluman LG, Mosca L, Newman N, Simon DG. Preoperative Smoking Habits and Postoperative Pulmonary Complications*. Chest. 1998;113:883–9.

66. Saxena A, Shan L, Reid C, Dinh DT, Smith JA, Shardey GC, et al. Impact of smoking status on early and late outcomes after isolated coronary artery bypass graft surgery. J Cardiol. 2013;61:336–41.

67. Jones R, Nyawo B, Jamieson S, Clark S. Current smoking predicts increased operative mortality and morbidity after cardiac surgery in the elderly □. Interact Cardiovasc Thorac Surg. 2011;12:449–53.

68. Pagano D, Freemantle N, Bridgewater B, Howell N, Ray D, Jackson M, et al. Social deprivation and prognostic benefits of cardiac surgery: observational study of 44 902 patients from five hospitals over 10 years. BMJ. 2009;338.

69. Thomsen T, Villebro N, Møller AM. Interventions for preoperative smoking cessation. Cochrane database Syst Rev. 2014 Jan;3:CD002294.

70. Critchley JA, Capewell S. Mortality Risk Reduction Associated With Smoking Cessation in Patients With Coronary Heart Disease. JAMA. 2003;290(1):86–97.

71. Wagner BD, Grunwald GK, Rumsfeld JS, Hill JO, Ho PM, Wyatt HR, et al. Relationship of Body Mass Index With Outcomes After Coronary Artery Bypass Graft Surgery. Ann Thorac Surg. 2007;84:10–6.

72. Wigfield CH, Lindsey JD, Muñoz A, Chopra PS, Edwards NM, Love RB. Is extreme obesity a risk factor for cardiac surgery? An analysis of patients with a BMI ≥ 40. Eur J Cardio-thoracic Surg. 2006;29(4):434–40.

73. Rockx MAJ, Fox SA, Stitt LW, Lehnhardt KR, McKenzie FN, Quantz MA, et al. Is obesity a predictor of mortality, morbidity and readmission after cardiac surgery? Can J Surg. 2004 Mar;47(1):34–8.

74. Rumsfeld JS, Alexander KP, Goff DC, Graham MM, Ho PM, Masoudi FA, et al. Cardiovascular health: the importance of measuring patient-reported health status: a scientific statement from the American Heart Association. Circulation. 2013 Jun 4;127(22):2233–49.

75. World Health Organization. In: Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, June 19-22, 1946; signed on July 22, 1946, by the representatives of 61 States (Official Records of the World Health Organizatio.

76. Heidenreich PA, Spertus JA, Jones PG, Weintraub WS, Rumsfeld JS, Rathore SS, et al. Health Status Identifies Heart Failure Outpatients at Risk for Hospitalization or Death. 2006;

77. Hoekstra T, Jaarsma T, Van Veldhuisen DJ, Hillege HL, Sanderman R, Lesman-Leegte I. Quality of life and survival in patients with heart failure. Eur J Heart Fail. 2013;15(1):94–102.

78. Biering K, Nielsen TT, Rasmussen K, Niemann T, Hjollund NH. Return to Work after Percutaneous Coronary Intervention: The Predictive Value of Self-Reported Health Compared to Clinical Measures. PLoS One. 2012;7(11):e49268.

79. Székely A, Nussmeier NA, Miao Y, Huang K, Levin J, Feierfeil H, et al. A multinational study of the influence of health-related quality of life on in-hospital outcome after coronary artery bypass graft surgery. Am Heart J. 2011;161:1179–1185.e2.

Supplementary Table 1. Risk factors included in EuroSCORE II
Age
Female
Renal impairment CC 50-85 CC ≤ 50 On dialysis
Extracardiac arteriopathy
Poor mobility
Previous cardiac surgery
Chronic lung disease
Active endocarditis
Critical preoperative state
Diabetes on insulin
NYHA II III IV
CCS class 4 angina
LV function Moderate (LVEF 31%-50%) Poor (LVEF 21%-30%) Very poor (LVEF 20% or less)
Recent MI
Pulmonary hypertension 31-55 mmHG ≥ 55
Urgency Urgent Emergency Salvage
Weight of procedure Single non-CABG 2 procedures 3 or more procedures
Surgery on thoracic aorta

Supplementary Table 2. Initial, general search strategy in the PubMed database for each included factor. All searches included 'Cardiac surgery'.

Factor	Type of search terms	Search terms	Full search
Cardiac surgery	MeSH	Cardiac Surgical Procedures Coronary Artery Bypass Cardiac Valve Annuloplasty	((((""Cardiac Surgical Procedures""[Mesh]) OR (((heart surgery) OR cardiac surgery) OR cardiac surgical procedures))) OR (((""Coronary Artery Bypass""[Mesh]) OR (((coronary artery bypass graft) OR CABG) OR coronary artery bypass surgery))) OR (((""Cardiac Valve Annuloplasty""[Mesh]) OR ((((heart valve surgery) OR heart valve annuloplasty) OR heart valve replacement) OR heart valve repair))
	Free-text	heart surgery / cardiac surgery / cardiac surgical procedures coronary artery bypass graft / CABG / coronary artery bypass surgery heart valve surgery / heart valve annuloplasty / heart valve replacement / heart valve repair	
Depression	MeSH	Depressive Disorder Depression	((((""Depressive Disorder""[Mesh]) OR ""Depression""[Mesh]) OR depression) OR depressive disorder) OR depressed mood
	Free-text	Depression / depressive disorder / depressed mood	
Anxiety	MeSH	Anxiety Disorders Anxiety	((((""Anxiety Disorders""[Mesh]) OR ""Anxiety""[Mesh]) OR Anxiety) OR anxiety disorder) OR anxiety symptoms
	Free-text	Anxiety / anxiety disorder / anxiety symptoms	
Health-related quality of life	MeSH	Quality of Life	(((""Quality of Life""[Mesh]) OR quality of life) OR health-related quality of life
	Free-text	Quality of life / health-related quality of life	
Education	MeSH	Educational Status Education	(((""Educational Status""[Mesh]) OR ""Education""[Mesh]) OR educational status) OR educational level
	Free-text	Educational status / educational level	
Income	MeSH	Socioeconomic Factors Health Status Disparities	(((((((""Socioeconomic Factors""[Mesh]) AND income)) OR ""Health Status Disparities""[Mesh]) OR income) OR health disparities) OR health inequality) OR health inequity
	Free-text	Income / health disparities / health inequality / health inequity	
Cohabitation	MeSH	Marital Status	((((""Marital Status""[Mesh]) OR cohabitation status) OR cohabitation) OR marital status) OR living alone
	Free-text	Cohabitation status /cohabitation / marital status / living alone	
Physical functioning	MeSH	Physical Fitness	(((""Physical Fitness""[Mesh]) OR physical functioning) OR physical activity) OR functional status
	Free-text	physical functioning / physical activity / functional status	
Frailty	MeSH	Frailty Frail Elderly	((((""Frailty""[Mesh]) OR ""Frail Elderly""[Mesh]) OR frail) OR frailty) OR functional decline
	Free-text	Frail / frailty / functional decline	

Cognition	MeSH	Cognitive Dysfunction	((((""Cognitive Dysfunction""[Mesh]) OR cognitive dysfunction) OR cognitive impairment) OR cognitive functioning) OR cognitive performance
	Free-text	Cognitive dysfunction / cognitive impairment / cognitive functioning / cognitive performance	
Alcohol	MeSH	Alcoholism Alcoholics	(((((""Alcoholism""[Mesh]) OR ""Alcoholics""[Mesh]) OR alcohol) OR alcoholism) OR alcoholics) OR alcohol consumption
	Free-text	Alcohol / alcoholism / alcoholics / alcohol consumption	
Smoking	MeSH	Smoking Tobacco Smoking Cigarette Smoking	(((((""Smoking""[Mesh]) OR ""Tobacco Smoking""[Mesh]) OR ""Cigarette Smoking""[Mesh]) OR smoking) OR tobacco smoking) OR cigarette smoking
	Free-text	Smoking / tobacco smoking / cigarette smoking	
Obesity	MeSH	Obesity Overweight Body Mass Index Adiposity	(((((((((""Obesity""[Mesh])) OR ""Overweight""[Mesh])) OR ""Body Mass Index""[Mesh]) OR ""Adiposity""[Mesh]) OR obesity) OR overweight) OR BMI) OR adiposity
	Free-text	Obesity / overweight / BMI / adiposity	