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The role of depression and anxiety symptoms in hospital readmissions after cardiac surgery

Phillip J. Tully · Robert A. Baker · Deborah Turnbull · Helen Winefield

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Abstract The objective of this study was to determine the association between depression, anxiety and general stress symptoms with hospital readmissions after coronary artery bypass graft surgery. Two hundred and twenty six coronary artery bypass graft patients completed baseline self-report measures of depression, anxiety and stress and 222 patients completed these measures after surgery on the hospital ward. The hospital readmission outcomes at six months were analyzed using multivariable proportional hazard models. When analyzed as continuous variables in multivariable analyses, preoperative anxiety and postoperative depression predicted readmissions independent of medical covariates. In multivariable analyses with dichotomized anxiety, depression and stress, more than two-fold increase in readmission risk was attributable to preoperative anxiety and postoperative depression, independent of covariates. These results lend further support to previous research that has shown the symptoms of depression and anxiety are associated with morbidity following coronary artery bypass graft surgery. The findings highlight the need to develop suitable interventions for anxiety and depression among coronary artery bypass graft surgery patients.

P. J. Tully · R. A. Baker (✉)
Cardiac and Thoracic Surgical Unit, Department of Medicine, Flinders Medical Centre and Flinders University, Level 6 Flinders Private Hospital, Bedford Park, Adelaide, SA 5042, Australia
e-mail: Rob.Baker@fmc.sa.gov.au

P. J. Tully · D. Turnbull · H. Winefield
School of Psychology, The University of Adelaide, Adelaide, SA, Australia

H. Winefield
Department of Psychiatry, The University of Adelaide, Adelaide, SA, Australia

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Introduction

Coronary artery disease (CAD) is a progressive condition most commonly caused by atherosclerotic plaque disease, characterized by occlusion in the coronary arteries that supply blood to the heart (Julian et al. 1998). Reduced blood flow or ischemia to the myocardium results in angina pectoris and dyspnea (Morrow et al. 2005). Coronary artery bypass graft (CABG) surgery is a common technique to treat CAD, and new conduits are grafted around blockages using harvested sections of artery or reversed vein (Morrow et al. 2005).

Symptoms of anxiety and unipolar depression are common psychological disturbances among patients with CAD, including those undergoing CABG surgery (Bankier et al. 2004; Pignay-Demaria et al. 2003). It is recognized that depression portends an independent risk for CAD morbidity (Lett et al. 2004; Davidson et al. 2006), yet accumulating evidence suggests that interrelated emotions such as anxiety and stress are also risk factors for mortality, myocardial infarction (MI) and unstable angina (Bunker et al. 2003; Kubzansky et al. 2005; Kubzansky et al. 2006; Kubzansky et al. 1997; Rothenbacher et al. 2007; Rozanski et al. 1999; Suls and Bunde 2005). These findings are not surprising given that depression and anxiety have overlapping symptoms that correlate in the moderate range (Clark and Watson 1991; Ninan and Berger 2001), and that these two negative emotions have been reported to share a common underlying component of general negative affect (NA) (Clark and Watson 1991). Specifically, NA is the general disposition towards experiencing negative

emotional states characterized by distress, worry, pessimism, irritability and restlessness (Watson 2000).

The broadening of psychological risk factors for cardiac morbidity corresponds in a timely fashion to empirical research that has examined the interrelation between anxiety and depression, emphasizing their common and unique symptoms, and the general tendency to experience NA (Clark and Watson 1991). Specifically, Clark and Watson (1991) proposed a tripartite model in which depression and anxiety share general negative affect symptoms such as irritability and restlessness, and thus these symptoms are not unique to either anxiety or depression. Specific anxiety symptoms exclusively reflect physical hyperarousal and somatic tension (e.g. trembling, shakiness) whereas depressive symptoms are characterized by anhedonia (i.e. the loss of interest or pleasure) and typical symptoms include hopelessness, crying and suicidal ideation (Clark and Watson 1991). This latent tripartite structure has been supported in a broad range of clinical and medical settings (Cook et al. 2004; Geisser et al. 2006; Teachman et al. 2007; Watson et al. 1995), and may prove useful for interpretation of the role of negative emotions in patients with coronary artery disease. Importantly, the addition of theoretically driven research on psychological and cardiac outcomes may foster novel understandings of disease-affect relationships as other authors have shown (Oxlad et al. 2006b).

The main limitation of research on negative emotions on CABG patient outcomes is that typically only depression is assessed thus precluding a potential role of anxiety. Given that depression and anxiety are interrelated and do not occur in isolation, it is necessary to analyze these negative emotional states concurrently rather than separately in relation to cardiac outcomes. However, in previous CABG studies attributing an independent risk to depression, it cannot be ruled out that conceptually related affective states (i.e. anxiety) also confer CAD event risk. Moreover, it is indeed possible that cardiac morbidity previously attributed to depression or anxiety is confounded by shared variance with general negative affect symptoms that are measured within poorly constructed self-report inventories (Clark and Watson 1991). To overcome these shortcomings of previous CABG studies we propose to study psychological variables and hospital readmission outcomes using the tripartite model as a theoretical framework. Specifically, we aim to examine the potential role of depression, anxiety and general NA on cardiac outcomes. Consistent with review evidence supporting an association of both depressive and anxiogenic symptoms with CAD morbidity implicating a common disposition to NA (Suls and Bunde 2005), we hypothesize that general stress symptoms (i.e. NA) will be associated with an increased risk of unplanned hospital readmissions after CABG surgery.

Methods

Patients

The sample for this study consisted of patients undergoing first-time CABG surgery between January 1999 and December 2005 at the Flinders Medical Centre, South Australia. There were 681 CABG cases evaluated for inclusion in the study. Inclusion criteria were: age >18 years, isolated CABG procedure with cardiopulmonary bypass (CPB), able and willing to provide informed consent. Patients were ineligible for the following reasons (n = 443): residency outside South Australia (n = 156), language, reading, writing or vision difficulty (n = 82), emergency surgery (n = 60), refused (n = 53), suspected or diagnosed dementia or met criteria for baseline confusion with the Short Portable Mental Status Questionnaire (SPMSQ) (Eissa et al. 2003) (n = 27), participating in another cardiac surgery study (n = 26), other (n = 14), unable to give informed consent (n = 12), psychotic, personality or developmental disorder (n = 8), health reasons (n = 5). A total of 238 patients were recruited at baseline, with patients excluded from final analysis for the following reasons; death before surgery (n = 1), surgery postponed indefinitely (n = 3), switched to surgery without CPB intraoperatively (n = 8). The final baseline sample was 226 patients (time 1), and 4 declined participation immediately post-surgery (time 2, n = 222). All patients provided informed consent and this study received ethics approval from the respective hospital and university institutions (approval numbers: 57/067, H-148-2006).

Measures

The components of the tripartite model were measured with the depression anxiety stress scale (DASS) (Lovibond and Lovibond 1995), a 42 item self-report measure that consists of three scales (depression, anxiety, stress) (for review see Lovibond 1998). Participants were asked to rate how often they experienced each of the symptoms over the preceding week on a four point likert scale. Examples of depression scale items include "I couldn't seem to experience any positive feeling at all" and "I just couldn't seem to get going." The anxiety scale contains such items as "I felt scared without any good reason" and "I felt I was close to panic." The stress scale includes items such as "I tended to over-react to situations" and "I found myself getting impatient when I was delayed in any way."

Confirmatory factor analysis has supported a latent structure of anhedonia, physiological hyperarousal and general distress factors (Brown et al. 1997; Clara et al. 2001) indicating it is an appropriate measure of the tripartite model. The DASS has a uniform factor structure,

high internal consistency and test retest reliability (Clara et al. 2001; Crawford and Henry 2003) and has been used with cardiac surgery patients (Andrew et al. 2000; Oxlad et al. 2006a). In statistical analyses with dichotomized DASS scores, a mild level from normative data (Lovibond and Lovibond 1995) was adopted on all subscales: depression ≥10, anxiety ≥8, stress ≥15, as is consistent with previous studies (Oxlad et al. 2006a). Patients completed the DASS at preadmission clinic in the week before scheduled surgery and again four days after surgery on the hospital ward, in a fashion similar to other pre and post test design studies of CABG patient mood state (Oxlad et al. 2006a; Andrew et al. 2000).

Readmission outcome

The dependent variable in this study was time in days to the first unplanned readmission related to coronary artery bypass procedure or cardiovascular or vascular causes, within six months of surgery. Readmission data were ascertained from patient telephone interview at six months and confirmed via an electronic database that links eight of South Australia's metropolitan hospitals. Electronic readmission data were extracted by the first author (P.J.T.) using the principal diagnosis at readmission and up to fifteen additional diagnoses that were ascertained by the treating physician and coded according to International Classification of Disease (ICD) criteria version 10 (World Health Organization 2007). Hospitals were contacted for patient notes if not available on the electronic database (3 patients). A board certified cardiothoracic surgeon and a perfusionist (R.A.B.), blinded to patient psychological distress results, independently coded readmissions according to whether they were related to surgery, cardiovascular disease or vascular diseases, or other. Cardiovascular or vascular readmissions were recorded for ICD codes I00-I99, with the exception of deep vein thrombosis, pericardial effusion and cardiac tamponade that were classed as surgery related. Other readmissions related to coronary bypass procedures included coagulation management, wound management, pneumonia or respiratory complications, atypical chest pain, pleural effusion, revascularization procedures and gastrointestinal obstructions. Mortality was ascertained from the National Death Index, provided by the Australian Institute of Health and Welfare.

Statistical analysis

Data were analyzed using SPSS® 12.0.1 statistical software package (SPSS Inc., Chicago, IL). Patients with hospital readmission, and patients identified with mild levels of depression, anxiety and stress, were compared on baseline demographic, clinical and surgical variables. Quantitative data were compared with independent samples *t*-tests or Mann–Whitney *U*-tests (depending on variable distribution), while categorical data were analyzed with the χ^2 statistic, with Fisher's two-tailed exact test used where appropriate. Partial correlation coefficients were performed between DASS scales at the same observation period, to ascertain the interrelation between scales adjusting for shared variance.

Baseline demographic, clinical and surgical variables were selected as potential covariates for morbidity based on previous research (Hannan et al. 2003; Heijmans et al. 2003; Jarvinen et al. 2003; Jones et al. 1996; Shroyer et al. 2003; Steuer et al. 2002; Tu et al. 1997). We analyzed age (quartiles), female sex, left ventricular ejection fraction (LVEF), urgency of surgery (elective vs. urgent), chronic lung disease, congestive heart failure (CHF), diabetes mellitus, peripheral vascular disease (PVD), renal disease, previous MI within 90 days, hypertension, and Canadian Cardiovascular Society (CCS) Angina grade III/IV (versus CCS I/II) and psychoactive medication use (i.e. antidepressants, sedatives, anxiolytics and antihypnotics). These covariates were forced into adjusted Cox proportional hazard models, testing for time (days) to the first unplanned readmission. Multivariable hazard models were performed with DASS subscale continuous scores, and again as dichotomized variables, forcing each variable into the hazard model. The rationale for simultaneous forced entry of psychological variables was to assess the association between morbidity and each conceptually related domain of the tripartite model, as each of the tripartite factors are interrelated and occur concurrently. We performed secondary hazard model analyses in the same fashion described above, though we entered only the stress scores at the second step, and depression and anxiety scores at the third step of the regression models. Here the rationale was to determine the role of depression and anxiety on readmission outcomes controlling for the effects of general NA. During data screening we did not find any outliers that influenced hazard models, and multicollinearity statistics were acceptable as determined by squared multiple correlations <.90 (Tabachnick and Fidell 2000) and inspection of correlations between regression coefficients. The proportionality of hazards assumption was checked initially by entering covariates as interactions with time, and also ascertained graphically in final models via examination of the baseline hazards function plot and also the log-minus-log plot of survival function.

Results

The sample was predominantly male (83%) with a mean age of 63 years, and the mean DASS scores are shown in

Table 1. The results show that patients experiencing a subsequent readmission had higher preoperative anxiety and postoperative depression scores in comparison to non-readmitted patients. When baseline DASS sub scale scores were dichotomized at a mild level of negative affect symptoms or greater, 47 (20.1%) patients had depressive symptoms, 71 (31.4%) had anxious symptoms and 49 (21.7%) had mild stress. At postoperative assessment, 52 (23.5%) patients had scores indicative of depression, while 101 (45.5%) patients had mild anxious symptoms, and 43 (19.4%) had mild stress. Partial correlation coefficients between DASS scale scores for the same observation period were modest as shown in Table 2, suggesting moderate interrelations between scales controlling for variance shared with other dimensions of the tripartite model.

There were no associations between psychological status and demographic or clinical variables suggesting patients were not reporting higher distress due to physical morbidity. The recruited sample medication list was screened for antidepressants, sedatives, anxiolytics and antihypnotics, and four patients were on Benzodiazepine's (3 Temazepam, 1 Diazepam) and one patient was taking a tricyclic antidepressant (Amitriptyline). The use of psychoactive medication was associated with a trend for dichotomized mild anxiety symptoms, χ^2 (1) = 4.26, P = .05. There was no association between use of psy-

Table 1 Baseline characteristics for readmitted and non-readmitted patients

Demographic and clinical variables	Readmitted n = 72	Not readmitted n = 154	P
Age M (SD)	62.9 (9.7)	63.2 (9.7)	.80
Age quartiles ≤56	22 (31%)	40 (26%)	
57–64	21 (29%)	39 (25%)	
65–70	37 (24%)	37 (24%)	
≥71	38 (25%)	38 (25%)	.67
Sex (% female)	11 (15%)	27 (18%)	.67
Angina CCS class III/IV	23 (32%)	54 (35%)	.91
Congestive heart failure	6 (8%)	10 (6%)	.62
LVEF ≥60	50 (69%)	116 (75%)	
45–59	13 (18%)	25 (16%)	
31–45	8 (11%)	9 (6%)	
≤30%	1 (1%)	4 (3%)	.48
Urgent procedure	13 (18%)	25 (16%)	.73
Hypertension	49 (68%)	90 (58%)	.17
Myocardial infarction <90 days	20 (28%)	36 (23%)	.49
Smoking history	46 (64%)	112 (73%)	.25
Chronic lung disease	18 (25%)	26 (17%)	.16
Peripheral vascular disease	15 (21%)	20 (13%)	.12
Diabetes mellitus	18 (25%)	29 (19%)	.28
Renal disease	3 (4%)	2 (1%)	.18
Surgical median (range)			
Procedure time (min)	144 (59–221)	146 (51–247)	.94
Time on CPB (min)	54 (22–106)	53 (23–116)	.88
Time cross clamp (min)	32 (0–66)	31 (0–68)	.94
Time ICU (hours)	23 (3–191)	23.5 (3–191)	.40
≥3 grafts	35 (49%)	80 (52%)	.67
Postoperative length of stay	6.0 (4–36)	5.0 (2–18)	.19
DASS scores M (SD)			
Baseline[a]			
Depression	6.0 (6.3)	5.5 (5.7)	.59
Anxiety	7.7 (6.9)	5.9 (6.3)	.05
Stress	9.8 (8.5)	9.3 (8.4)	.71
Postoperative[b]			
Depression	8.2 (9.0)	5.9 (7.0)	.04
Anxiety	9.7 (8.7)	8.9 (7.6)	.50
Stress	8.5 (9.1)	8.1 (8.5)	.76

CCS Class, Canadian Cardiovascular Society; CPB, cardiopulmonary bypass; ICU, intensive care unit; LVEF, left ventricular ejection fraction

[a] n = 226

[b] n = 222

Table 2 Partial correlations between measures of depression, anxiety and stress

Preoperative	1	2	3
1. Preoperative depression	–		
2. Preoperative anxiety	.43*[a]	–	
3. Preoperative stress	.39*[b]	.50*[c]	–
Postoperative	**4**	**5**	**6**
4. Postoperative depression	–		
5. Postoperative anxiety	.31*[d]	–	
6. Postoperative stress	.40*[e]	.60*[f]	–

* $P < .001$

Preoperative $n = 226$; Postoperative $n = 222$

[a] Adjusted for preoperative stress

[b] Adjusted for preoperative anxiety

[c] Adjusted for preoperative depression

[d] Adjusted for postoperative stress

[e] Adjusted for postoperative anxiety

[f] Adjusted for postoperative depression

choactive medications and mild depressive symptoms, χ^2 (1) = 1.21, $P = .28$, or any association with medications and stress, χ^2 (1) = 1.01, $P = .30$.

Within six-months of CABG there were 72 (32%) readmissions related to the surgical procedure, cardiovascular or vascular disease. The most common readmission causes were infection, respiratory complications and pleuritic chest pain (all 13.9%), arrhythmia (12.5%), angina (11.1%) and CHF (9.7%) (Table 3). One patient that died of MI was censored from all hazard modeling analyses. There were no baseline differences in demographic, clinical, or surgical variables between patients that had a readmission and those that did not.

Primary multivariable analysis of hospital readmissions

Continuous DASS scores

The multivariable hazard models with simultaneous entry of each psychological construct show the risk attributable to negative affective states for the interrelated dimensions of the tripartite model. When DASS sub-scale scores were entered simultaneously as continuous variables in a hazard model adjusted for all covariates, only a one-point increase in baseline anxiety score was found to increase readmission risk, and this was by 12%, HR = 1.12 (95% CI 1.04–1.20), $P = .002$, and these results are shown in Table 4. The covariates associated with a trend towards significantly increased readmission risk were hypertension ($P = .06$), PVD ($P = .09$), CCS class III/IV ($P = .09$), age range 65–70 years ($P = .18$) and LVEF 31–45% ($P = .17$). General stress was also associated with a trend towards a significantly reduced readmission risk, HR = .96, (95% CI .91–1.01), $P = .12$.

Table 3 Readmission causes and classification

Principal cause	*N*	Percentage of total
Cardiovascular or vascular		
Angina	8	11.1
Arrhythmia	9	12.5
Heart failure	7	9.7
Myocardial infarction	3	4.2
Stroke	1	1.4
Vascular (aortic aneurysm and dissection)	2	2.8
Cardiovascular subtotal	30	41.7
Surgical		
Atypical chest pain (sternotomy, myofascial)	2	2.8
Deep vein thrombosis	2	2.8
Gastrointestinal complication or obstruction	2	2.8
Infection	10	13.9
Leg cellulitis	1	1.4
Other	2	2.8
Pericardial effusion	1	1.4
Pleural effusion	1	1.4
Pleuritic chest pain	10	13.9
Respiratory complication	10	13.9
Revascularization procedure	1	1.4
Surgical subtotal	42	58.5
Total	$N = 72$	100

The multivariable adjusted hazard model for postoperative DASS sub-scale scores showed that a one-point increase in depression scale score was associated with an increased risk of readmission, HR = 1.08 (95% CI 1.03–1.14), $P = .004$, as shown in Table 4. In addition, a one point increase in stress scale score was associated with a reduction in readmission risk, HR = .94 (95% CI .88–1.00), $P = .04$. Among the covariates, PVD was associated with a significantly increased risk of readmission, HR = 1.96 (95% CI 1.07–3.59), $P = .03$, and the covariates associated with a trend towards increased readmission risk included age range 65–70 years ($P = .11$), age ≥ 71 ($P = .07$) and hypertension ($P = .12$).

Dichotomized DASS scores

Following analysis with DASS scores as continuous variables, the dichotomized psychological variables were entered into hazard models simultaneously to determine the combined contributions of a mild level of each negative affect construct. The multivariable hazard model showed

Table 4 Multivariable adjusted hazard models of six month readmission with continuous and dichotomized psychological variables

DASS scores	Hazard ratio[a]	95% Confidence interval	*P*
Continuous			
Time 1			
Depression	.96	.89–1.03	.21
Anxiety	1.12	1.04–1.20	.002
Stress	.96	.91–1.01	.12
Time 2			
Depression	1.08	1.03–1.14	.004
Anxiety	1.00	.94–1.07	.95
Stress	.94	.88–1.00	.04
Dichotomized			
Time 1			
Depression	.80	.38–1.68	.56
Anxiety	3.14	1.66–5.94	<.001
Stress	.38	.17–.82	.02
Time 2			
Depression	2.06	.97–4.40	.06
Anxiety	.82	.44–1.52	.53
Stress	.77	.34–1.78	.55

[a] Adjusted for age quartiles, female sex, LVEF, urgency of surgery, chronic lung disease, CHF, diabetes mellitus, PVD, renal disease, previous MI, hypertension, CCS class III/IV and psychoactive medication use

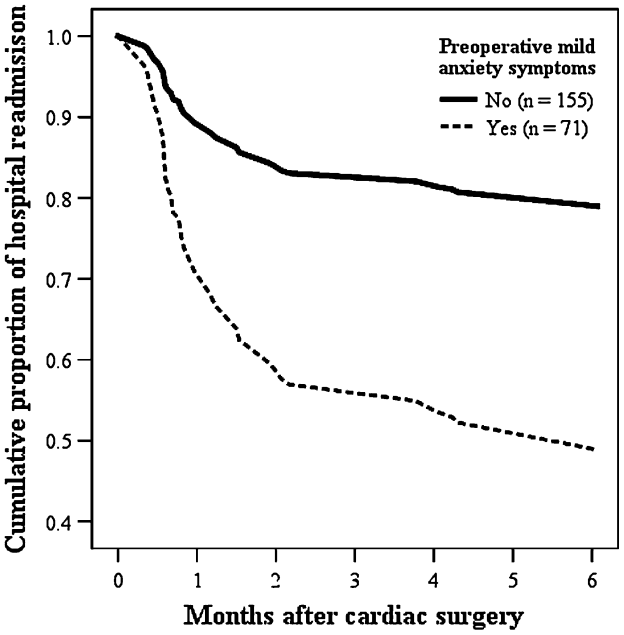

Fig. 1 Adjusted survival function of patient readmission for preoperatively anxious and non-anxious cardiac surgery patients. Coronary artery bypass graft patient adjusted cumulative survival in months after surgery for six-month readmission is plotted for patients with mild anxiety symptoms before surgery (depression anxiety and stress scale (DASS) anxiety score ≥8; $n = 71$) against patients without anxiety symptoms before surgery (DASS anxiety score ≤7; $n = 155$). The Cox-proportional hazard model for preoperative anxiety symptoms is adjusted for age quartiles, female sex, LVEF, urgency of surgery, chronic lung disease, CHF, diabetes mellitus, PVD, renal disease, previous MI, hypertension, CCS class and psychoactive medication use, HR = 3.14 (95% CI 1.66–5.94), $P < .001$

that baseline dichotomized anxiety was associated with a three-fold increased readmission risk, HR = 3.14 (95% CI 1.66–5.94), $P < .001$, supporting the model with continuous data (results shown in Table 4). The adjusted survival function for patients with baseline dichotomized anxiety symptoms in Fig. 1 shows divergent survival curves. The dichotomized stress variable was however associated with a reduced readmission risk, HR = .38 (95% CI .17–.82), $P = .02$. The covariates associated with a nearly two-fold increased risk of readmission included PVD, HR = 1.92 (95% CI 1.06–3.50), $P = .03$, and also hypertension HR = 1.83 (95% CI 1.05–3.18), $P = .03$. Covariates associated with a trend towards a increased readmission risk included age range 65–70 years ($P = .15$), age ≥ 71 ($P = .13$), CCS class III/IV ($P = .19$) and LVEF 31%–45% ($P = .13$).

The multivariable hazard model for postoperative dichotomized DASS scores showed that depression was associated with a trend towards increased readmission risk, HR = 2.06 (95% CI .97–4.40), $P = .06$. Among the covariates, PVD was associated with a two-fold increased readmission risk, HR = 2.13 (95% CI 1.15–3.89), $P = .02$. The covariates associated with a trend towards increased readmission risk included age ≥71 ($P = .14$), CCS class III/IV ($P = .18$) and hypertension ($P = .11$).

Secondary multivariable analysis of hospital readmissions

In secondary analyses, we repeated the hazard models in the same fashion described above, though we entered stress scores at the second step, followed by depression and anxiety scores at the third step. The aim was to determine whether the risk attributable to depression and anxiety reported in Table 4 was independent of general stress. The results were unchanged and supported significant effects for preoperative anxiety and postoperative depression in both continuous and dichotomized analysis, even after adjustment for stress. Specifically, preoperative anxiety was again associated with a 12% increased readmission risk in continuous analysis while a three-fold increased risk of readmission was also attributable to preoperative dichotomized anxiety. The results specific to depression also supported an 8% increased readmission risk attributable to a one-point increase in postoperative depression score. A trend was again supported for a two-fold increased readmission risk and postoperative depression in dichotomized analyses. Taken together, the results suggest that the

readmission risk attributable to depression and anxiety was upheld after adjustment for the effects of conceptually interrelated general stress symptoms. When stress scores were entered before depression and anxiety, results showed that preoperative stress was associated with a significantly reduced readmission risk in dichotomized analyses, HR = .38 (95% CI .17–.82), P = .01. Continuous analysis supported a reduced readmission risk attributable to increased postoperative stress and this was again by 6%.

Discussion

The relationship between negative emotions and cardiovascular diseases is one of the most studied in psychosomatic and health research. Readmission following cardiac surgery places a significant burden on the healthcare system (Lubitz et al. 1993) and is therefore an important area of study for health resources planning. This research adds to previous studies by using an empirically supported model of depression and anxiety to interpret the association with CABG patient outcomes where an increased risk of readmission was associated with preoperative anxiety and postoperative depression. Both depression and anxiety have been implciated in lower concordance to cardiac rehabilitation programs (Komorovsky et al. in press) and this may partly explain our findings. However and surprisingly, increased stress lowered the readmission risk in the preoperative and postoperative period in continuous and dichotomized analyses respectively. Overall, the main hypothesis that morbidity would be associated with higher general stress was not supported.

The six-month readmission rate in the present study was 32% and the most common causes were for infections, pleuritic chest pain, respiratory complications, arrhythmia and angina as is consistent with previous readmission studies (Jarvinen et al. 2003; Hannan et al. 2003). The present results lend further support to the role of preoperative anxiety in adverse CABG patient outcomes (Tully et al. 2008). Our findings suggest that elevated anxious hyperarousal symptoms reported prior to surgery portend greater morbidity risk, although there was no association between postoperative anxiety and morbidity. It is possible that physical anxiety symptoms measured after surgery tap in to general physical discomfort or autonomic arousal rather than anxious affect (Andrew et al. 2000), suggesting our results are potentially biased towards an effect for baseline anxiety. The findings for anhedonic depression support previous research where post cardiac event depression predicted cardiac related hospital readmission with a mixed cohort of patients after CABG or MI (Levine et al. 1996). Nonetheless, the observation that the DASS variables attained significance in adjusted hazard models, yet only depression and anxiety were bivariately associated with readmission indicates the possible influence of moderator and suppressor variables. The present findings warrant replication given the interrelation between DASS measures and the differential pattern of results perioperatively. One possible explanation for our results is that depression and anxiety may exert a causal influence on each other with each negative emotion more dominant at one particular time point over the perioperative period (e.g. anxiety preoperatively), as has been reported elsewhere in a study employing structural equation modelling (Duits et al. 1999). Another explanation is that the increased risk attributable to depression and anxiety symptoms are perhaps capitalizing on chance variation and require replication in larger samples.

In the present study, an increase in stress postoperatively was paradoxically associated with a 6% reduction in readmission risk when analyzed as a continuous variable. The dichotomized analyses also showed that postoperative stress was associated with a reduced readmission risk. While this was a surprising observation, it was possible that patients reporting higher stress, and therefore with lower readmission risk, used problem focused or emotion focused coping strategies (Shelley and Pakenham 2007) and were more likely to adhere to rehabilitation guidelines and engage in more health promoting behaviors. Nevertheless, our findings may not generalize to other studies as we utilized a definition of stress as general state-NA, the symptoms of which are common to depression and anxiety. This contrasts to previous cardiovascular research where stress is inconsistently defined and measured as other reviewers have noted (Bunker et al. 2003; Holmes et al. 2006). For example, stress may be operationalized to include muscle tension and autonomic arousal that overlaps anxious symptomatology. Thus, there are limited studies to directly compare our results with, although the underlying general NA construct as we have defined here parallels the trait NA that forms part of the Type-D personality construct. Future studies would be required to clarify the role of NA, as some research suggests that trait NA, in combination with the tendency to inhibit one's expression of negative emotions in social situations (i.e. Type-D personality), is predictive of cardiac outcomes and not merely the presence of NA in isolation (Denollet et al. 1996; for review see Denollet and Van Heck 2001). Thus future research should consider whether state or trait NA is a predictor of morbidity among CABG candidates, and explore the association with coping strategies.

The present findings contrast to previous studies with CABG patients where it has been found that preoperative depressive symptoms measured with two items from the medical outcomes study health questionnaire are associated with all-cause readmissions (Saur et al. 2001). Also, Oxlad

et al. (2006a) found that preoperative depression and postoperative anxiety, measured with the DASS, increased the risk for cardiac readmissions adjusted for time spent on CPB. The difference in findings may be partly explained by variation in methodology. For example, Oxlad et al (2006b; 2006a) measured depression and anxiety symptoms, but not general stress, on average 50 days before surgery and only recorded coronary heart disease (CHD) readmissions. Whereas in this study we assessed mood in the week preceding CABG surgery and included surgery related readmissions (e.g. infections, atypical chest pain). Furthermore, the recent study of Oxlad et al. (2006a) did not control for medical comorbidity in hazard models. This may confound results as it has been previously reported that CABG patients may endorse depression and anxiety items due to physical discomfort rather than emotional disturbance (Andrew et al. 2000). Given the paucity of research on this important outcome variable, further research is required to determine the impact of these negative emotions and the role of somatic symptoms on hospital readmission. It is largely unknown whether the DASS variables are related to other outcomes such as quality of life, graft patency and repeat revascularization in CABG populations, and further research should explore such endpoints.

The present findings have important practical and theoretical implications. Indeed, these results suggest interventions should target both anxiety and depression symptoms, rather than either in isolation. There are few randomized controlled trials (RCT) to treat depression and anxiety post-CABG, with one nurse led intervention paradoxically associated with more readmissions compared to a control group (Lie et al. 2007), while another RCT reported lower depression levels in the control group compared to the intervention group whom underwent exercise and behavior modification (Sebregts et al. 2005). Recently, a nurse led cognitive-behavioral intervention demonstrated greater depressive symptom reduction at 3 months though at 6 months there was modest difference (Doering et al. 2007). The findings of a diverse range of RCT interventions for anxiety (e.g. education, phase I rehabilitation, telenursing) have also been inconsistent with some interventions associated with lower anxiety (Ku et al. 2002; Sorlie et al. 2007), while others have reported no treatment effects (Shuldham et al. 2002; Tranmer and Parry 2004). Interventions targeting general stress or NA are limited with a recent notable exception reported by Karlsson et al. (2007) who showed that patients randomized to expanded cardiac rehabilitation after MI or CABG had reduced depression, anxiety and Type-D personality trait scores. Several RCT interventions have targeted depression following a myocardial infarction with anti-depressant medication or cognitive-behavioral intervention with reductions in mood but not mortality (Berkman et al. 2003; Glassman et al. 2002). It is not known whether these results will necessarily translate to patients undergoing an invasive surgical revascularization procedure such as CABG. Regardless, reducing emotional distress before and after CABG is likely to be important to an uncomplicated physical recovery and improved subjective quality of life. The prevalence of major depression is widely reported to be around 20% among CABG patients (Connerney et al. 2001; Fraguas Junior et al. 2000) though the prevalence of clinically relevant anxiety varies between 8.3% and 55% depending on the type of self-report measure or diagnostic interview (Rafanelli et al. 2006; Rothenbacher et al. 2007; Rothenhausler et al. 2005; Rymaszewska et al. 2003). These patients may benefit from individually tailored psychological and rehabilitation support to maintain health promoting behaviors and educate patients (Rozanski et al. 1999; Hermele et al. 2007). Given the present findings, it could be argued that distressed CABG patients may benefit from an intervention targeting negative emotions and fostering useful coping strategies commenced before scheduled surgery and maintained in the postoperative period alongside cardiac rehabilitation with lengthy follow-up.

This study's main strength is that we have interpreted the contribution of negative affect to readmission outcomes using a theoretical framework supported by empirical research. Secondly, this study has also adopted blinded coding of hospital readmissions. One limitation of this study is however that the DASS may not capture the full breadth of symptomatology endorsed by the tripartite model (Crawford and Henry 2003), and that the symptoms of other pertinent negative emotions such as anger and hostility were not measured (Kubzansky et al. 2006). We did not gather any information from patients on non-pharmacological treatments such as visiting a psychologist or psychiatrist or attendance at cardiac rehabilitation. In addition, this study was performed on patients recruited from a single hospital site with 72 endpoints. The study would have been underpowered to determine large differences in analyses with dichotomized variables, while the hazard models with adjustment for numerous covariates are potentially biased according to regression model criteria (Banyak 2004). Furthermore, we have excluded patients with dementia and those undergoing emergency surgery or a concomitant procedure, suggesting our results may not necessarily generalize to higher risk populations. We also draw the reader's attention to this study's endpoint inclusive of non-CHD related readmissions (e.g. infection, respiratory complications) when interpreting these findings.

In conclusion, this preliminary study showed that preoperative physiological hyperarousal anxiety symptoms and postoperative anhedonic depressive symptoms are associated with a significantly increased risk of readmission following CABG. Further research should investigate

the role of tripartite factors in cardiac outcomes, and explore the association with different coping styles. These findings highlight the need to develop suitable interventions for anxiety and depression before and after CABG surgery.

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