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ORIGINAL ARTICLE

Predictors and Outcomes of Cardiac Surgery-Associated Delirium. A Single Centre Retrospective Cohort Study

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Background The predictors and independent outcome association of delirium after cardiac surgery are important and yet poorly characterised.

Methods We performed a retrospective observational study of cardiac surgery patients between January 2009 and March 2016. We defined delirium using ICD-10 diagnostic codes. Multivariable analysis was conducted to find independent associations between baseline variables, delirium, and key clinical outcomes.

Results We studied 2,447 study patients (28.7% female, median age was 66 [IQR 57–74] years). Delirium was coded for in 12.9% of patients overall, and in 22.9% of those aged >75 years. Increasing age, Charlson co-morbidity index, admission not from home, peripheral vascular disease, respiratory disease, preoperative atrial fibrillation, duration of cardiopulmonary bypass and nature of surgery were all independent predictors of delirium. Delirium was independently and strongly associated with increased risk of reintubation (OR 8.18 [95% CI 5.24–12.78]), tracheostomy (OR 10.44 [95% CI 5.91–18.45]), and increased length of stay by 113.7 [95% CI 99.7–127.7] ICU hours and 6.95 [95% CI 5.94–7.95] hospital days, but not 30-day mortality (OR 0.78 [95% CI 0.38–1.59]; p = 0.5).

Conclusions Delirium is common in cardiac surgery patients and increases with age. Delirium was the strongest predictor of reintubation, need for tracheostomy, and prolongation of intensive care unit (ICU) and hospital length of stay. Delirium prevention and attenuation are a priority in cardiac surgery patients.

Keywords Delirium • Cardiac surgery • Confusion • Reintubation • Tracheostomy

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Introduction

Cardiac surgery is the most common major surgery in the developed world. Improved surgical techniques, anaesthesia and postoperative care mean that its mortality is low [1]. However, as more complex cardiac surgery is applied to older and frailer patients, the focus of investigation and care is increasingly shifting to decreasing its medical complications. Among these, cardiac surgery-associated delirium (CSAD) appears to be growing in incidence [2]. CSAD may be associated with increased duration of mechanical ventilation, as well as prolonged intensive care and hospital length of stay, as summarised in a recent review [3].

However, despite such clinical studies, it remains unknown whether delirium causes, or is a consequence of such complications, or occurs in parallel with their development [4–6]. This uncertainty stems from the fact that studies of CSAD have often not adjusted for potential key confounders [7], and none have examined the independent association between CSAD and key medical complications such as reintubation or need for tracheostomy in detail.

Accordingly, we undertook an analysis of cardiac surgical procedures conducted over more than 6 years in a single centre to identify the independent predictors of CSAD and its independent association with key clinical outcomes. Specifically, we aimed to assess whether the occurrence of delirium was independently associated with several pre-defined postoperative complications, including reintubation, need for tracheostomy, and prolongation of intensive care unit (ICU) and in-hospital length of stay.

Methods

Ethics Approval

Ethics approval was obtained to conduct the study (LNR/16/Austin/239) and the need for informed patient consent was waived.

Details of Operative and Postoperative Care

All surgical procedures were overseen by a consultant cardiac surgeon. A balanced anaesthesia technique consisting of fentanyl, a propofol infusion and a volatile anaesthesia were typically used. Cardiopulmonary bypass was employed in almost all cases. Postoperative care occurred in the ICU under the direction of an ICU consultant in consultation with the treating cardiac surgeon. Sedation with propofol and analgesia with morphine or fentanyl were administered. The primary inotropes were milrinone and adrenaline, and the primary vasopressor noradrenaline. Typically, a mean arterial pressure of at least 65 mmHg and cardiac index of 2.3 l/min/m^2 were targeted.

Study Design and Source of Data

A database is *prospectively* collected on cardiac surgery patients by a dedicated data collector (MS) and submitted to the Australasian Society of Cardiac and Thoracic Surgeons (ASCTS) National Cardiac Surgery Database [8]. We conducted a retrospective analysis of this prospectively collected data. This database provided patient age, gender, body mass index, smoking history, diabetes, preoperative creatinine, hyperlipidaemia, hypertension, cerebro-vascular disease, peripheral vascular disease, respiratory disease, presence and severity of angina, severity of dyspnoea (New York Heart Association (NYHA) class), left ventricular ejection fraction, number of disease coronary vessels, preoperative atrial fibrillation, and recent myocardial infarction. This database also contained information of urgency of surgery, the presence of preoperative cardiogenic shock, use of inotropes (minimum of 4 hours in the postoperative period) and mechanical ventilation, as well as total times of aortic cross clamp, cardiopulmonary bypass, theatre time, and the nature of the surgical procedure. The later was classified as ''single valve surgery'', ''two or more valves'', isolated coronary artery bypass grafts (CABGs)'', ''CABGs and valve'', ''surgery involving the aorta'', and ''other''. Additional information included the initial duration of ventilation, need for reintubation and tracheostomy tube, development of stroke, pneumonia, new renal failure, requirement for postoperative renal replacement therapy, and mortality at 30 days.

Information obtained from the hospital administrative database included information related to the Charlson comorbidity index (CCI), initial ICU length of stay, the total number of ICU admissions (total ICU transfers), need for a Medical Emergency Team (MET) or respond blue call on the hospital ward. We also extracted the frequency of ICD-10 coding episodes for the development of anaemia, falls, pressure injury, and wound infection. Finally, it recorded the disposition at hospital discharge, in-hospital mortality, as well as ICU and hospital length of stay.

The primary outcome measure was obtained from ICD-10-based coding for delirium as recorded by hospital coding staff based on medical documentation, using the codes F05.0 ''Delirium not superimposed on dementia, so described''; F05.1 ''Delirium superimposed on dementia''; F05.8 ''Other delirium''; and F05.9 ''Delirium, unspecified''.

Details of Data Analysis

Data are presented as counts and percentages or as median (interquartile range). Continuous variables were compared using the Mann-Whitney U test while categorical variables were compared using the chi-square test for equal proportion. We assessed for differences between patients who were classified as having delirium in relation to baseline patient variables, as well as the details of intraoperative management and nature of the procedure. In addition, we assessed for associations with the development of delirium and several pre-defined postoperative complications, ICU and hospital length of stay, as well as ICU, in-hospital and 30-day mortality.

We used multivariable logistic regression analysis to identify independent variables associated with postoperative delirium. We used backwards selection including variables

with a two-sided p-value <0.1 in the full model. The following variables were considered: age, gender, BMI, serum creatinine, hypercholesterolaemia (yes vs. no), cerebrovascular disease (yes vs. no), angina score (0–4), congestive heart failure (yes vs. no), NYHA group, emergency surgery (yes vs. no), Charlson comorbidity index (0–2, 3–4, >4), admission source (home vs. other), peripheral vascular disease (yes vs. no), respiratory disease (yes vs. no), atrial fibrillation (yes vs. no), cardiopulmonary bypass time, type of surgery (CABG surgery, valve surgery, CABG + valve surgery, aortic surgery, other cardiac surgery). Model prediction was assessed by calculating the area under the receiver operating characteristics (ROC) curve.

We compared time to hospital discharge between patients with and those without delirium using the log-rank test and displayed it as Kaplan-Meier curves. Finally, we used multivariable linear regression analysis to assess the independent association between delirium and hospital length of stay. We considered the same variables as in the logistic regression model and retained variables with a two-sided p-value below 0.1 on backwards selection. We also evaluated the association between delirium and 30-day mortality using multivariable logistic regression analysis. Outcome measures were prospectively chosen on the basis of being likely causally related to delirium. A two-sided p value <0.05 was considered statistically significant in the final analyses.

Results

Details of the Cohort

Between 1 January 2009 and 31 March 2016, we identified 2,447 cardiac surgery patients (Table 1). Coronary risk factors were common: 316 (12.9%) had a previous history of myocardial infarction, 1,516 (62.0%) had a history of smoking, and 382 (15.6%) were current smokers. Diabetes was present in 766 (31.3%), and hyperlipidaemia and hypertension were present in 1,785 (73.0%) and 1,927 (78.7%) of patients, respectively.

Baseline Associations With the Development of CSAD

A total of 316 (12.9%) of patients were ICD-10 coded for postoperative delirium. Univariable analysis revealed multiple differences in baseline characteristics between patients with or without CSAD including older age, elevated preoperative creatinine, high CCI, admission ''not from home'', hyperlipidaemia, cerebrovascular and peripheral vascular disease, respiratory disease, angina, and the presence and severity of heart failure (Table 1). In addition, the number of diseased coronary vessels and the presence of preoperative atrial fibrillation were also associated with the development of CSAD.

Increasing age was strongly associated with the development of CSAD (Figure 1). Specifically, the frequency of CSAD in patients younger than 65 was less than 8.3%. In patients aged older than 75 years the frequency was 22.9% (130/566), and in those 85 years or older, it was 29.3% (12/41).

Perioperative Associations With the Development of Postoperative Delirium

Univariable analysis revealed several intraoperative factors associated with CSAD (Appendix). These included emergency surgery, the presence of cardiogenic shock or the need for mechanical ventilation or inotropes preoperatively. Patients experiencing delirium also had longer aortic cross clamp and cardiopulmonary bypass time and a longer duration of theatre. Finally, patients who experienced delirium were more likely to have combined CABGs/valve surgery or surgery involving the aorta, and less likely to have isolated CABGs.

Patients who experienced delirium were more likely to have received at least 4 hours of postoperative inotropes for low cardiac output (CO) or low systemic vascular resistance index (SVRI), and to receive perioperative blood products (see Appendix).

Multivariable Analysis for Risk Factors

Multivariable logistic regression analysis revealed that several pre and intraoperative variables were independently associated with CSAD. These included older age, higher Charlson co-morbidity index, admission from a source other than home, the presence of peripheral vascular disease (PVD), respiratory disease or preoperative atrial fibrillation, as well as longer cardiopulmonary bypass duration and surgical type (Table 2). The area under the curve for the receiver operator curve (AUROC) for the prediction of CSAD using this multiple variable-based prediction model was 0.76.

Differences in Patient Outcome Associated With Postoperative Delirium

Patients who experienced CSAD had longer duration of mechanical ventilation, ICU length of stay, and number of ICU transfers compared with patients without delirium (Table 3). They were also more likely to need re-intubation and tracheostomy. In addition, patients experiencing delirium were more likely to experience anaemia, falls, pressure injuries, renal failure, wound infection, strokes, transient ischaemic attacks, and pneumonia. They were also more likely to require renal replacement therapy, and receive a MET review or respond blue call following ICU discharge.

The median hospital length of stay was 6 days longer for patients experiencing CSAD, and such patients were less likely to be discharged home, and more likely to require rehabilitation (Table 3).

Multivariable Analysis Based Associations

Multiple variable linear regression analysis revealed several independent associations of CSAD with ICU and in-hospital length of stay (Table 4). For both outcome measures the occurrence of CSAD was the variable with the strongest association with length of stay. Thus, the presence of CSAD was independently associated with an additional 113.9 (95%

Table 1 Differences in baseline characteristics for cardiac surgery-associated delirium.

	Overall	No Delirium	Delirium	p-Value
Number	2,447	2,131	316	
Female gender N(%)	703 (28.7)	616 (28.9)	87 (27.5)	0.61
Age median (IQR) yr	66 (57–74)	65 (57–73)	72 (65–78.5)	<0.0001
Age ≥ 65 yr N(%)	1,367 (55.9)	1128 (52.9)	239 (75.6)	<0.0001
Age ≥ 75 yr N(%)	566 (23.1)	436 (20.5)	130 (41.1)	<0.0001
Body mass index	28.3 (25.3–31.6)	28.2 (25.2–31.6)	28.4 (25.4–31.4)	0.95
Median (IQR) kg/m^2				
Pre-op Cr (μmol/L)	86 (73–104)	85 (72.0–101.3)	93.0 (75.0–115.8)	<0.0001
Charlson co-morbidity index	4.0 (3.0–5.0)	4.0 (3.0–5.0)	5.0 (4.0–7.0)	<0.0001
Admitted from home	2,098 (85.7)	1,845 (86.6)	253 (80.1)	0.003
N(%)				
Hyperlipidaemia	1,786 (73.0)	1,560 (73.2)	226 (71.5)	0.03
N(%)				
No prior CVD	2,209 (90.3)	1938 (90.9)	271 (85.8)	0.004
Carotid disease	21 (0.9)	20 (0.9)	1 (0.3)	
Stroke	139 (5.7)	107 (5.0)	32 (10.1)	
TIA		64 (3.0)	12 (3.8)	
PVD N(%)	250 (10.6)	197 (9.2)	63 (19.9)	<0.0001
Respiratory disease N(%)				
None	2,070 (84.6)	1,833 (86.0)	237 (75)	<0.0001
Mild	268 (11.0)	206 (9.7)	62 (19.6)	
Mod	99 (4.0)	83 (3.9)	16 (5.1)	
Severe	10 (0.4)	9 (0.4)	1 (0.3)	
Angina type				
None	972 (39.7)	815 (38.2)	157 (49.7)	<0.0001
Stable	1,234 (50.4)	1,103 (51.8)	131 (41.5)	
Unstable	241 (9.8)	213 (10.0)	28 (8.9)	
Congestive cardiac failure	561 (22.9)	460 (21.6)	101 (32.0)	<0.0001
Dyspnoea NYHA				
1	1,029 (42.1)	916 (43)	113 (35.8)	<0.0001
2	902 (36.9)	794 (37.3)	108 (34.2)	
3	431 (17.6)	351 (16.5)	80 (25.3)	
4	82 (3.4)	67 (3.1)	15 (4.7)	
LVEF(%) (missing 58)				
Normal	1,616 (66.0)	1,429 (67.1)	187 (59.2)	0.002
Mild	446 (18.2)	389 (18.3)	57 (18.0)	
Mod	226 (9.2)	189 (8.9)	37 (11.7)	
Severe	101 (4.1)	82 (3.8)	19 (6.0)	
N(%)				
No. diseased vessels				
0	782 (32.0)	659 (31.1)	123 (39.3)	0.017
1	211 (8.6)	181 (8.5)	30 (9.6)	
2	435 (17.8)	384 (18.1)	51 (16.3)	
3	1,003 (41.0)	894 (42.2)	109 (34.8)	
Pre-existing AF	336 (13.7)	259 (12.2)	77 (24.4)	<0.0001
N(%)				

Abbreviations: yo, years old; Cr, creatinine; CVD, cerebro-vascular disease; TIA, transient ischaemic attack; PVD, peripheral vascular disease; CCS, Canadian Cardiovascular Class; NYHA, New York Heart Association; LVEF, left ventricular ejection fraction; AF, atrial fibrillation.

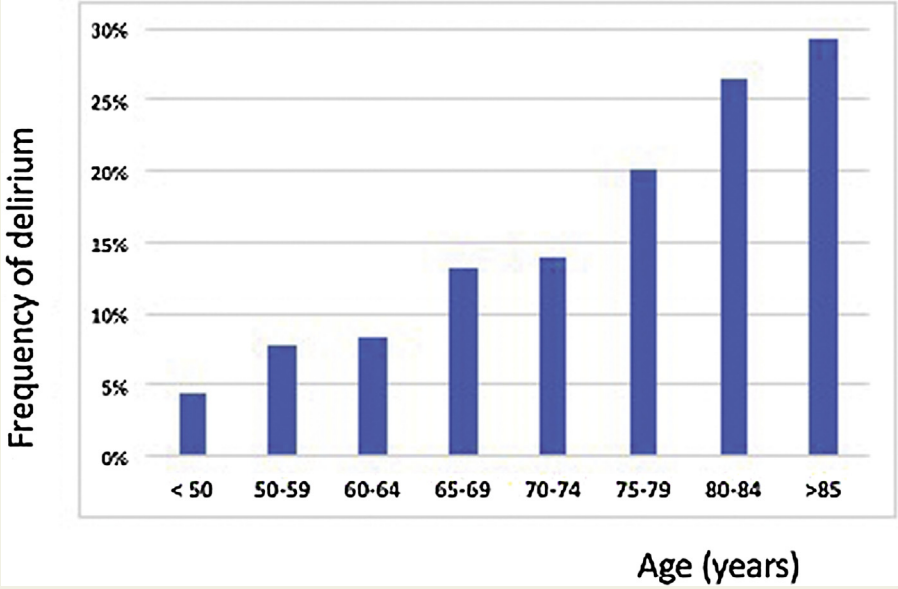

Figure 1 Bar diagram showing the frequency of postoperative delirium according to age category.

Table 2 **Multivariable logistic regression analysis showing predictors of delirium.**

Variable	n	Adjusted Odds Ratio (95% CI)	p Value
Age, per year	2,447	1.02 (1.01–1.04)	0.004
Male gender	1,744	1.33 (0.99–1.77)	0.053
Charlson comorbidity index			
3–4	997	2.20 (1.17–4.13)	0.014
>4	999	3.61 (1.82–7.15)	<0.001
Admission source home	2,098	0.64 (0.46–0.89)	0.009
Peripheral vascular disease	260	2.05 (1.44–2.91)	<0.001
Respiratory disease	377	1.67 (1.23–2.27)	0.001
Atrial fibrillation	336	1.62 (1.17–2.24)	0.003
CPB time, per hour	2,446	1.17 (1.05–1.30)	0.004
Type of surgery			
CABG only	1,307	1.00	
Valve(s) only	597	1.88 (1.31–2.70)	0.001
CABG + valve	222	2.15 (1.42–3.27)	<0.001
Aortic	228	3.30 (2.06–5.28)	<0.001
Other	93	1.88 (0.93–3.81)	0.080

Abbreviations: CPB, cardiopulmonary bypass; CABG, coronary artery bypass grafting.

CI 99.7–127.7) hours in ICU and an additional 6.95 (95% CI 5.94–7.95) days in hospital. Moreover, patients with delirium were statistically more likely to remain in hospital (even after censoring for death) up to 21 days, compared with patients without CSAD (Figure 2).

Independent associations with 30-day mortality included increasing age, type of surgery, emergency surgery, but not delirium (adjusted OR 0.78 [95% CI 0.38–1.59; p = 0.5]) (See Appendix). However, CSAD was the strongest independent predictor for the need for reintubation (OR 8.18 [5.24–12.78]) and tracheostomy (OR 10.44 [95%CI 5.91–18.45]) (Table 5).

Discussion

Key Findings

We conducted a large retrospective observational study of cardiac surgery patients to describe the incidence, risk factors

Table 3 **Differences in patient outcomes according to the presence or absence of delirium.**

	No Delirium	Delirium	p-Value
Number	2131	316	
Initial duration ventilation Median (IQR) hours	9 (6–13)	15 (10–42)	<0.001
Initial ICU LOS Median (IQR) hours	31 (21–51)	92 (45.3–165.5)	<0.001
Total ICU transfers N(%)			
1	1,997 (93.7)	254 (80.4)	<0.001
2	115 (5.4)	49 (15.5)	
≥3	19 (0.9)	13 (4.1)	
Total ICU hours Median (IQR)	39 (23–65)	104.5 (54.8–207)	<0.001
Re-intubation N(%)	41 (1.9)	51 (16.1)	<0.001
Tracheotomy N(%)	21 (1.0)	39 (12.4)	<0.001
Complications median (IQR)	0 (0-1)	2 (1-3)	<0.001
Anaemia N(%)	405 (19)	99 (31.3)	<0.001
Falls N(%)	11 (0.5)	8 (2.5)	<0.001
Pressure injury N(%)	35 (1.6)	36 (11.4)	<0.001
Wound infection N(%)	63 (3.0)	23 (7.3)	0.001
MET call N(%)	93 (4.4)	40 (12.7)	<0.001
Respond blue call N(%)	11 (0.5)	5 (1.6)	<0.001
Stroke N(%)	22 (1.0)	14 (4.4)	<0.001
TIA N(%)	16 (0.8)	7 (2.2)	0.012
Pneumonia N(%)	70 (3.3)	61 (19.3)	<0.001
New renal failure N(%)	88 (4.1)	64 (20.3)	<0.001
Renal replacement therapy N(%)	48 (2.3)	46 (14.7)	<0.001
Hospital LOS (total) Median (IQR) days	8 (7-12)	14 (10-24)	<0.001
Post-op hospital LOS Median (IQR) days	7 (6–9)	12 (8-21)	<0.001
Discharge destination N(%)			
Home	1,448 (67.9)	181 (57.3)	<0.001
HITH	441 (20.7)	20 (6.3)	
Died	50 (2.3)	10 (3.2)	
Local hospital	45 (2.1)	18 (5.7)	
Rehab	147 (6.9)	87 (27.5)	
30 day mortality N(%)	50 (2.3)	11 (3.5)	0.227

Abbreviations: ICU, Intensive care unit; LOS, length of stay; MET, medical emergency team; TIA, transient ischaemic; HITH, hospital in the home; IQR, interquartile range.

Delirium was not associated with hospital re-admission at 7 days (p = 0.871); 14 days (p = 0.934); 28 (p = 0.634); 90 days (0.201) or with the development of new AF (p = 0.077). Finally, there was no association with delirium and 30-day mortality on univariable analysis (OR1.5; 95% CI 0.773–2.92).

for and outcome associations of CSAD in the Australian setting. We found several important pre and perioperative risk factors for delirium. Moreover, we found that CSAD was the cardiac surgery associated complication with the strongest independent association with need for re-intubation and tracheostomy. Finally, the development of delirium was independently associated with markedly increased ICU and hospital LOS, and a higher likelihood of remaining in hospital for up to 21 days.

Comparison With Previous Studies

Multiple previous studies have been conducted to assess the epidemiology of CSAD. However, many of these studies are small, and fail to adjust for important baseline and

Table 4 **Multivariable linear regression analysis showing the association with ICU and postoperative hospital length of stay.**

	ICU length of stay (hours)		Hospital length of stay (days)	
	Adjusted est (95%CI)	p-Value	Adjusted est (95%CI)	p-Value
Delirium	113.7 (99.7 to 127.7)	<0.001	6.95 (5.94 to 7.95)	<0.001
Male gender	−13.5 (−24.0 to −3.0)	0.01	−1.13 (−1.87 to −0.38)	0.003
Creatinine	0.09 (0.03 to 0.1)	0.003	N/A	N/A
Hypercholesterolaemia	15.2 (4.6 to 25.8)	0.005	N/A	N/A
Lung disease	16.2 (3.4 to 29.0)	0.01	N/A	N/A
CCI >4	N/A	N/A	2.60 (1.63 to 3.56)	<0.001
Cerebrovascular disease	N/A	N/A	1.49 (0.39 to 2.58)	0.008
NYHA class 2	21.2 (7.6 to 34.9)	0.002	1.46 (0.49 to 2.43)	0.003
Atrial fibrillation	N/A	N/A	1.17 (0.17 to 2.16)	0.02
Emergency surgery	41.0 (30.8 to 51.2)	<0.001	2.35 (1.63 to 3.07)	<0.001
CPB time, per hour	14.7 (10.3 to 19.0)	<0.001	0.93 (0.63 to 1.24)	<0.001
Type of surgery				
Valve(s) only	7.8 (−6.0 to 21.6)	0.27	0.93 (−0.02 to 1.87)	0.06
CABG + valve	8.0 (−10.0 to 26.0)	0.38	1.90 (0.61 to 3.18)	0.004
Aortic	19.4 (−0.7 to 39.4)	0.058	0.97 (−0.39 to 2.34)	0.16
Other	27.4 (2.6 to 52.1)	0.03	1.81 (0.08 to 3.559)	0.04

Abbreviations: CCI, Charlson co-morbidity index; NYHA, New York Heart Association; CPB, cardio-pulmonary bypass; CABG, coronary artery bypass grafting.

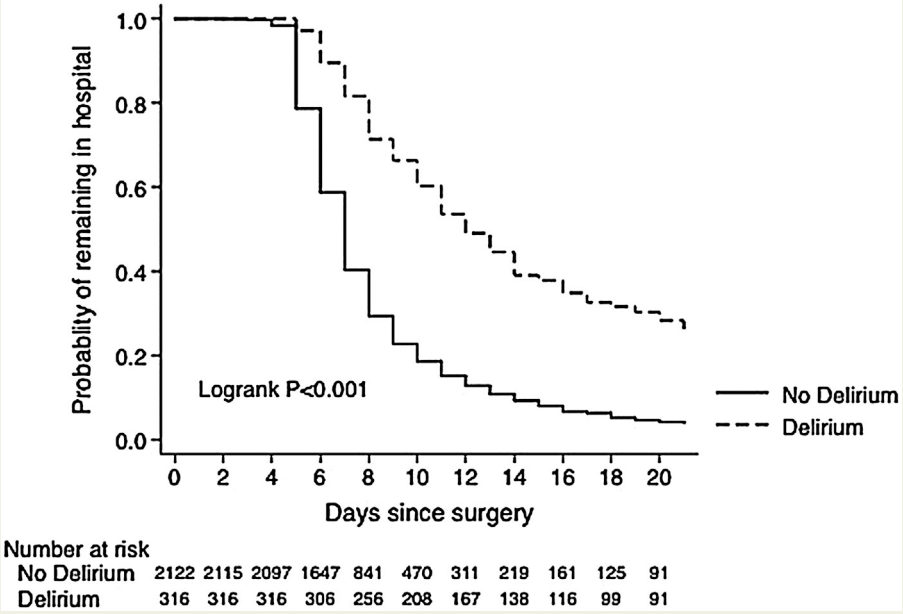

Figure 2 Kaplan–Meier curve showing probability of remaining in hospital with time amongst patients with and without delirium.

intraoperative co-variates [7]. Nonetheless, several of the predictors identified in our study accord with those seen in the systematic review by Gosselt and co-workers [7] and a recent review article by Indja et al. [3]. In Australia, Humphreys et al. assessed 180 isolated CABG patients with a mean age of 63.4 years and found that 35% developed delirium [9]. In contrast, Royse et al. recently reported on the effects of methylprednisolone on the incidence of delirium in a randomised controlled trial of 482 cardiac surgical patients [10]. They found an incidence of delirium of 10% in the control group using the confusion assessment method (CAM) method, which accords well with the 12.9% reported in our study. However, both these studies provided no information on independent predictors of delirium and no

Table 5 Multiple variable logistic regression analysis showing associations with re-intubation and need for tracheostomy.

Variable	Re-intubation		Tracheostomy	
	OR (95% CI)	p Value	OR (95% CI)	p Value
Delirium	8.18 (5.24–12.78)	<0.001	10.44 (5.91–18.45)	<0.001
Admitted from home	0.49 (0.30–0.81)	0.005	N/A	
Chronic lung disease	1.67 (1.01–2.77)	0.046	1.99 (1.09–3.64)	0.03
Cardiopulmonary bypass time, per hour	1.15 (1.01–1.30)	0.04	1.24 (1.07–1.43)	0.004
Emergency surgery	N/A		3.58 (2.03–6.29)	<0.001
Congestive heart failure	N/A		2.29 (1.31–4.01)	0.004

Shown are the adjusted odds ratios (95% confidence interval) and p-value.

information on the independent association of delirium with key clinical outcome, thus leaving uncertainty about how delirium, per se, contributes to complications.

Worldwide, Martin et al. studied 14,301 patients undergoing cardiac surgery, 981 of whom became delirious [11]. However, this study focussed on the association between CSAD and postoperative sepsis, and did not assess its relationship with respiratory complications. Krzych et al. developed a tool to screen for delirium amongst 5,781 cardiac surgical patients and developed a predictive model with an AUROC of 0.89 [12]. This model included postoperative variables, including cerebral ischaemia, which were not included in our model. However, unlike our study, Krzych did not report on the independent association between delirium with key postoperative complications.

Consistent with previous studies, we have also shown that the development of delirium is associated with prolongation of ICU [13,14] and hospital length of stay [14], and length of mechanical ventilation [13]. Mehta and co-workers reported that the development of delirium was associated with the need for tracheostomy [5]. However, this study was conducted in a heterogeneous cohort of ICU patients, not just in cardiac surgical patients. In addition, unlike the study presented here, it did not adjust for important other variables that may have contributed to this outcome.

Study Strengths and Limitations

Our study was conducted using databases with very few missing data, a prospectively designed analysis plan, and robust statistical analysis approaches. It is the largest Australian study to date exploring in detail the epidemiology and consequences of CSAD. It is the first study to reveal that CSAD is the strongest predictor of reintubation, need for tracheostomy and prolonged ICU and hospital LOS, with information which may assist the design of future interventional studies.

Despite these strengths, our study has several limitations including retrospective design and a single centre patient cohort. However, the data were prospectively collected by a trained data collector and the study centre is typical of other cardiac surgery centres in the developed world. We used ICD-10 coding for the primary outcome and in-hospital complications. As such, we cannot comment about the timing of delirium in relation to surgery or ICU stay, or whether the delirium was agitated or hypoactive in nature. Previous studies have suggested that the use of ICD-10 coding may underestimate the frequency of delirium [15,16]. However, our incidence accords well with that recently reported by Royse et al. [10], who used the CAM method for delirium assessment and such data collection was independent and not amenable to manipulation. A detailed analysis of the patient medical records may have revealed patients who were ''agitated'' or received anti-psychotic medications. However, such detailed analysis for more than 2,400 patients was deemed unfeasible. An additional problem is that many of the baseline associations with delirium may not be modifiable. However, we believe that the findings of our analyses permit clinicians to target the most at-risk population with preventative strategies. Finally, although we have identified several independent associations with delirium, these do not imply causality.

Study Implications

Our findings imply that delirium is a major postoperative complication affecting one eighth of patients overall, and almost one in three of those over 85 years of age. They also imply that such delirium contributes to increased postoperative morbidity and prolonged hospital stay. Importantly, they imply that delirium is a significant risk factor for reintubation, tracheostomy, and prolonged ICU length of stay. Finally, these findings suggest the need to target the prevention of this complication as a matter of priority in cardiac surgery patients [17].

Conclusions

Delirium affects one in eight patients undergoing cardiac surgery and one in three patients over 85 years of age, can be predicted with an acceptable degree of accuracy and is a key risk factor for reintubation, need for tracheostomy, and prolonged of ICU and hospital length of stay. As specific risk

factors for delirium were identified in this study, it is now possible to target preventive interventions in high risk groups. Our findings require confirmation in a prospective multi-centre study.

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All authors contributed significantly to the paper.

A/Prof Jones takes full responsibility for the integrity of the work.

Design: DJ, GM, SS, and RB.

Database extract: RR and MS.

Drafting and revision of manuscript: all.

Data analysis: DJ and JM.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.hlc.2018.01.007.

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