Predictors of readmission after elective coronary artery bypass graft surgery

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Abstract

Objective: We sought to examine potential predictors of readmission after coronary artery bypass graft (CABG) surgery.

Design/setting: We analysed routinely collected data of CABG patients who have used the public hospital system of Victoria, Australia from July 1998 to June 2003. In total, 6627 patients were selected by linking records of elective surgery waiting time data (Elective Surgery Information System), emergency department data (Victorian Emergency Minimum Dataset) and hospital discharge data (Victorian Admitted Episodes Dataset).

Measurements: The outcome measures were 7-day, 30-day and 6-month readmissions. Possible predictors included were age, gender, Charlson comorbidity index, waiting times, length of stay in the hospital, and frequency of emergency department (ED) visits before CABG surgery.

Results: 7.1%, 15.2%, and 32.3% of the study population were readmitted at 7 days, 30 days and 6 months respectively. In a multivariable regression model Charlson comorbidity index was associated with 30-day (OR = 1.18; 95% CI 1.11–1.24; $P \leqslant 0.01$) and 6-month readmission (OR = 1.20; 95% CI 1.15–1.26; $P < 0.01$). Multiple ED visits were associated with 7 day (OR = 1.75; 95% CI 1.28–2.38; $P < 0.01$), 30 day (OR = 1.53; 95% CI 1.22–1.93; $P < 0.01$) and 6 month (OR = 1.80; 95% CI 1.49–2.18; $P < 0.01$) readmission. Waiting time was not a statistically significant predictor of readmission.

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What is known about the topic?
Coronary artery bypass graft (CABG) surgery results in a significant rate of readmission, which is costly and may be preventable if those who are at risk of readmission can be identified in advance.

What does this paper add?
This study is a retrospective cohort study, to analyse the routinely collected data of patients who have had CABG surgery in the public hospital system of Victoria.

What are the implications for practitioners?
Charlson comorbidity and frequency of emergency department visits are potential indicators that could be used to identify patients at risk of readmissions.

CARDIOVASCULAR HEALTH is an Australian government National Health Priority Area. Coronary heart disease (CHD) is the largest single cause of death in Australia, accounting for 19.5% of deaths in 2002.[1] Coronary artery bypass graft (CABG) surgery is a common procedure used in treating patients with CHD. The number of CABG procedures performed in Australia has remained steady between 1995 and 2000, at a little over 17 000.[2] The number of CABG operations in Victoria performed electively in public hospitals is estimated to have been about 1500 per year between 1998 and 2003. The high number of CABG surgeries performed in Australian settings highlights the importance of investigating the predictors of readmission in Australian settings, as this has not been examined to date.

CABG surgery is associated with a significant risk of mortality and morbidity, including a signif-

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icant rate of readmissions, which are costly and often preventable.[3] An investigation of the predictors of readmission will assist in identifying at-risk patients. The incidence of readmission after CABG surgery has been reported by analysing routinely collected data in some countries.[4-6] However, the findings have not been consistent between geographical locations, highlighting the importance of examining this question in specific local settings before any recommendations can be made on the use of these indicators even in a local context.

The data collection of the Victorian Department of Human Services (DHS) reflect public hospital activity across a diverse range of hospitals servicing a state population estimated to be below five million people in December 2003. These data are particularly comprehensive and reliable, as hospitals depend on accurate, timely data provision for their funding and performance monitoring, with the associated penalties and bonuses.[7] As the data are collected centrally, there is a standardisation of the data collected and their coding. This allows the derivation of predictors such as the waiting time, the Charlson comorbidity index, and the length of stay (LOS). A linkage of waiting list and hospital morbidity data provides an excellent opportunity to examine the independent associations between routinely collected information and readmissions after CABG surgery.

Methods

Study design

This study is a retrospective cohort study, to analyse the routinely collected data of patients who have had CABG surgery in the public hospital system of Victoria. The information was extracted from the following linked databases.

- Elective Surgery Information System (ESIS): contains details of patients waiting for elective surgery, and the data relating to their waiting period.
- Victorian Emergency Minimum Dataset (VEMD): contains patient, diagnosis, and timing details of emergency department visits.
- Victorian Admitted Episodes Dataset (VAED): contains a large amount of detailed information relating to patients and each inpatient episode, including diagnoses and procedures.

The data linkage process between the VAED and VEMD datasets has already been validated.[8] The method used was stepwise deterministic linkage, where repeated passes are made in an attempt to find matches, using a range of key data items. In the linked data, case identifiers were assigned and were unrelated to potentially identifying variables within the data.

Data

Patients were selected who had CABG surgery between 1 July 1998 and 30 June 2003. The waiting list records were matched to a consolidated database. The study population comprised 6627 selected admissions.

The admission when CABG surgery was performed is the index admission, and provides the index admission and discharge dates. For all inpatient records where the admission date was after the index discharge date, the number of days was calculated from the index discharge date to the admission date of the episode. These calculations were used to identify readmissions (and thereby set the appropriate binary outcome variable) for the three categories of interest — 7 days, 30 days and 6 months. Inpatient admissions for any diagnosis were potentially readmissions. Similarly, an index admission date was used to derive emergency department (ED) visits, defined as none, one, or multiple ED visits of any kind in the 90-day period before the index admission.

We defined the Charlson comorbidity index as a score based on summing the weighted scores assigned to 19 conditions, a variation of the Deyo method using ICD-10 codes as designed by Sundararajan and colleagues.[9] Urgency is a three category variable (urgent, semi-urgent and non-urgent) in the ESIS data. Non-urgent patients (less than 1% of the study population) were combined with semi-urgent patients for the analysis, and referred to as non-urgent.

Waiting time is a derived variable, which is calculated to show the number of days within the total waiting time (the difference between waiting list registration and surgery dates) that the patient was classified as being ready for surgery. This was converted to weeks, and all values above 13 weeks were combined and given a value of 14, as the distribution was highly skewed.

Statistical methods

Potential predictors were selected from those directly available from the population data, as well as some that could be derived. Three separate admission variables, each with two categories, were used to define the outcome variable. Logistic regression methods were used to evaluate the associations between potential predictors in the database and the three separate outcome measures. As a first step, age-adjusted single predictor models were fitted to each outcome. Multivariate models were then fitted to evaluate the combined effects of all predictors. A manual forward-selection process was used to evaluate the significance of including an additional predictor into the base model with age. Results are presented as odds ratios and corresponding 95% CI. *P* values are two sided with 5% level of significance. The statistical analysis was conducted in Stata version 8.[10] Ethics approval was sought and granted by the Ethics Committee of the Department of Human Services.

Results

The success rate of matching waiting list records to the DHS consolidated database was high (about 83%), and data were extracted to form a new database for the CABG patients. Between July 1998 and June 2003, 6627 patients underwent CABG surgery and had follow-up data. Selected characteristics of the study population are summarised in Box 1. Of the study population, 22.2% ($n = 1471$) were female.

Overall, 54.8% ($n = 3632$) of the waiting list records were categorised as urgent. There were 42 in-hospital deaths (0.63%; 95% CI, 0.46%–0.86%) during the index admission. Of those deaths, 61.2% were of patients classified on the waiting list as urgent. The number of observed deaths in the urgent category did not differ significantly from the expected number ($P > 0.05$). Of the 42 deaths, 23.8% were female ($n = 10$). All patients in the urgent category (55% of the study population) waited 30 days or fewer, with the average being 8.5 days. For the remaining 45% the average wait was 41.7 days. A total of 2138 patients (32.3%) were readmitted within 6 months after the CABG surgery.

Box 2 presents age-adjusted results for the association between each predictor and readmission after 7 days, 30 days and 6 months. For all three outcomes age was a significant predictor. Waiting time was not a statistically significant predictor of readmission. Female sex increased the likelihood of readmission within 30 days ($P < 0.01$) in the regression model. The Charlson comorbidity index was a significant predictor for each readmission outcome (P values all < 0.01). Multiple ED visits increased the likelihood of readmission within 7 days ($P < 0.01$), 30 days ($P < 0.01$) and 6 months

1 Readmitted patients and population summary data

	Study population	Readmission within 7 days	Readmission within 30 days	Readmission within 6 months
All patients (% [n])	100.0 (6627)	7.1 (469)	15.2 (1010)	32.3 (2138)
Males (% [n])	77.8 (5156)	7.0 (360)	14.4 (744)	31.6 (1627)
Females (% [n])	22.2 (1471)	7.4 (109)	18.1 (266)	34.7 (511)
Age (mean [SD])	64.6 (±9.7)	65.7 (±10.0)	65.4 (±10.1)	66.3 (±9.7)
Index LOS (mean [SD])	8.5 (±8.2)	8.9 (±3.9)	9.3 (±9.1)	9.4 (±8.2)
Charlson comorbidity index (mean [SD])	0.84 (±1.1)	0.96 (±1.2)	1.06 (±1.3)	1.03 (±1.3)
Wait days (mean [SD])	24.0 (±38.9)	24.1 (±43.5)	23.1 (±39.6)	22.8 (±38.9)

2 Age-adjusted univariate analysis of association between potential predictors and readmission ($n = 6627$)

	Readmission within 7 days			Readmission within 30 days			Readmission within 6 months		
	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*
Age (years)	1.01	(1.002–1.022)	0.02	1.01	(1.003–1.017)	< 0.01	1.03	(1.022–1.033)	<0.01
Female	1.01	(0.81–1.27)	0.90	1.26	(1.08–1.48)	< 0.01	1.03	(0.91–1.17)	0.61
Charlson comorbidity index	1.10	(1.01–1.18)	0.03	1.19	(1.13–1.26)	< 0.01	1.23	(1.17–1.28)	< 0.001
Urgency of surgery									
Urgent (reference)	1.00			1.00			1.00		
Non-urgent	0.93	(0.77–1.12)	0.48	0.87	(0.76–1.00)	0.05	0.89	(0.80–0.98)	0.02
Wait (count of ready weeks)	1.00	(0.99–1.00)	0.93	1.00	(0.99-1.00)	0.48	1.00	(0.99–1.00)	0.12
Count of not ready days	1.00	(1.00–1.00)	0.12	1.00	(1.00–1.00)	0.09	1.00	(1.00–1.00)	0.09
Index length of stay (days)	1.01	(1.00–1.02)	0.18	1.02	(1.01–1.03)	< 0.01	1.05	(1.03–1.06)	< 0.01
Emergency department visits									
None (reference)*	1.00			1.00			1.00		
Single*	1.33	(1.04–1.69)	0.02	1.14	(0.96–1.37)	0.14	1.13	(0.98–1.30)	0.09
Multiple*	1.75	(1.29–2.37)	< 0.01	1.62	(1.29–2.04)	< 0.01	1.91	(1.58–2.30)	< 0.01

* In previous 90 days

($P < 0.01$). A single ED visit was a significant predictor for 7-day readmission ($P = 0.02$).

The results from a multivariable logistic model fitted to each outcome are displayed in Box 3. In the multivariable model for 30-day readmissions, age was not a significant predictor when adjusting for other variables ($P = 0.2$). Multiple emergency department visits before the index admission (the admission during which the CABG was completed) was a significant predictor ($P < 0.01$) of all three readmission outcomes, and had the strongest associations as measured by odds ratios. A single ED visit was also a significant predictor of 7-day readmissions. The Charlson comorbidity index was a significant predictor ($P < 0.01$) of 30-day and 6-month readmissions.

Discussion

The predictors with the strongest associations with readmissions are the Charlson comorbidity index, and the number of ED visits before the CABG surgery. The association between the Charlson index and 7-day readmission was not found to be significant when adjusting for other predictors, although it was for 30-day and 6-month readmissions. As in other studies,[6,11] this study relies on data linkage. Unlike other studies, however, the starting point for the collection of the data is not a surgical database, or a surgical department data collection, but the full public hospital population data for the state. This approach lessens the chance of variations in data quality between cardiac units of different hospitals, and we can expect a greater uniformity in the quality of the data relating to readmissions. By using a state-wide routine data collection database, we were able to avoid the problems of follow up, recall bias, and incomplete readmission data.

The results found for patients in the Victorian public system are in many ways similar to those reported in the United States. For example, the distribution of patients having CABG surgery is almost identical to that in Pennsylvania: 77.8% males in Victoria, as compared with 77.9% in

3 Multivariate logistic model of association between potential predictors and readmission ($n = 6627$)

	Readmission within 7 days			Readmission within 30 days			Readmission within 6 months		
	OR	95% CI	*P*	OR	95% CI	*P*	OR	95% CI	*P*
Age	1.01	(1.006–1.027)	0.03	1.00	(0.999–1.014)	0.20	1.02	(1.02–1.03)	< 0.01
Female	0.99	(0.79–1.25)	0.94	1.25	(1.06–1.46)	< 0.01	1.00	(0.88–1.14)	0.94
Charslon comorbity index	1.08	(1.00–1.17)	0.06	1.18	(1.11–1.24)	< 0.01	1.20	(1.15–1.26)	< 0.01
Index length of stay	1.01	(0.99–1.02)	0.31	1.01	(1.00–1.03)	< 0.01	1.03	(1.02–1.05)	< 0.01
Urgency of surgery									
Urgent (reference)	1.00			1.00			1.00		
Non-urgent	0.91	(0.74–1.11)	0.43	0.88	(0.76–1.01)	0.08	0.90	(0.80–1.01)	0.09
Wait (ready weeks)	1.02	(0.99–1.05)	0.30	1.00	(0.99–1.03)	0.26	1.00	(0.98–1.02)	0.90
Days not ready	1.00	(1.00–1.00)	0.90	1.00	(1.00–1.00)	0.10	1.00	(1.00–1.00)	0.07
Emergency department visits									
None (reference)*	1.00			1.00			1.00		
Single*	1.34	(1.05–1.71)	0.02	1.14	(0.95–1.37)	0.16	1.12	(0.97–1.30)	0.12
Multiple*	1.75	(1.28–2.38)	< 0.01	1.53	(1.22–1.93)	< 0.01	1.80	(1.49–2.18)	< 0.01

* In previous 90 days.

Pennsylvania. This, compared with the fact that males have about 66% of the CHD in the Australian population, suggests that females are having a lower than expected rate of CABG surgery. Possible explanations which have been put forward are that females have different disease patterns due to smaller coronary arteries, or are being referred for surgery later than males.[4]

The factor of primary interest in this study is the 30-day readmission, the rate of which has been the measure used in almost all studies that look at readmission. The overall rate of 15.2% is very close to the New York State rate of 15.3%,[6] and the Pennsylvania rate of 13.1% (which does not include all readmissions).[12] These rates compare favourably with the rate in Alabama, which in the period 1995–2000 rose from 15% to 19%.[3] In Alabama it was noted that the increasing readmission rate was associated with a decrease in the duration of hospitalisation.

The average LOS for CABG patients in our study was 8.5 days. Pennsylvania had an average post-operative LOS of 6.4 days, whereas in Alabama the average LOS went from 11.8 days to 9.6 days over the period 1995–2000. In the multivariate model, LOS was positively associated with a greater risk of 30-day and 6-month readmission, although the effect was not strong. Perhaps cases of likely 7-day readmission were avoided by keeping patients in hospital longer.

In the study population there were 42 deaths during the surgical admission. This in-hospital mortality (0.63 %) is lower than that observed in virtually all published studies. This may be partly explained by the criterion of only including elective surgery patients in the study. US studies may have included emergency patients who may have been less stable than those put on a waiting list. Such a patient would probably have a higher risk profile. If so, such patients would also be likely to have a higher risk of mortality. The reasons for the relatively low mortality in Victoria might become more apparent if a larger study were possible, including all CABG performed in the state — both emergency and private hospital surgery. It was beyond the scope of this study to link data to a register of death, but this could be worthwhile in any subsequent study, both to confirm the low mortality rate found here, and to obtain the mortality rate 30 days after surgery. The 30-day mortality is used as a quality indicator for hospitals in the United Kingdom, although there is no specific target in place.

Waiting time was not a statistically significant predictor of readmission. The classification of patient urgency has a great bearing on the waiting time, as urgent patients (who make up 55% of the study population) are virtually guaranteed a maximum waiting time of 30 days, partly because of the deterrent effect of large hospital penalties if the period is exceeded. Semi-urgent patients (44% of the study population) have a recommended waiting time of no more than 90 days. Of the semi-urgent patients, 88.7% had their surgery within 90 days, which is within the hospital performance target set by the Department of Human Services. In the age-adjusted analysis, the waiting time was not found to be a significant predictor of the readmission rate. However, it is possible that the effect of waiting time may have been masked by other variables. For example, patients with a greater degree of comorbidity (a known risk factor) may have waited a shorter time. This expectation was not supported by the correlation between the waiting time and the Charlson comorbidity index, which was modest although negative, as expected ($r = -0.013$). Even when included in the multivariate model with significant predictors, as well as age and sex, the waiting time remained insignificant as a predictor ($P > 0.05$).

The female gender was associated with 30-day readmissions, but not the other readmission categories. While the 30-day result is consistent with most other studies, the other results are more difficult to explain. With the longer period for 6-month readmissions, the reason for readmission is less likely to be directly related to the CABG surgery. This is consistent with the Swedish study, which did not find a gender difference in relation to the readmission risk after an extended follow up, and adjusting for the disease severity.[4]

Whenever a patient arrives at the ED of a Victorian public hospital, a visit record is generated, even if the patient leaves without being treated, irrespective of whether the visit results in a hospital admission or not. These data enabled another predictor not previously used in other studies to be derived. The lack of prior use may be because of the difficulty in capturing the data. It requires a linkage to a data collection based on an emergency patient administration system. Fortunately, the raw data exists in Victoria in the form of the VEMD, and these data were linked to the waiting list and admission data. The predictor relating to ED visits was derived from VEMD data simply by counting the number of visits in the 90-day period preceding the index admission, and categorising the result as zero, single or multiple visits. This proved to be a good predictor of all categories of readmission. Other variables could potentially be derived from the VEMD data and evaluated by similar methods. Perhaps an ED visit index could be constructed, taking into account the frequency of ED visits within different periods, weighted by the priority category of each visit. Such an index would have the advantage of being available before admission, unlike comorbidities, which may not be diagnosed beforehand.

The Charlson comorbidity index was found to be a good predictor in two categories of readmission. No other studies have tested it as a predictor of readmission, although there are studies which test it as a predictor of postoperative mortality.[13] This result should not come as a surprise, as such an application of the index fits its original intent.

In summary, readmission after CABG surgery in Victoria is not insignificant. It occurs at rates similar to other published rates, predominantly from the United States where the collection and publication of such data is well established. Hospital mortality is comparatively low. There would also appear to be less difficulty in managing patients optimally in Victoria than in the public systems of other countries, where waiting times are generally longer. The Charlson comorbidity index and the ED visit data were good predictors of readmissions and would be useful if they were available to clinicians responsible for discharge planning. An indicator relating to prior ED visits would be especially useful as it could easily be derived and available before admission. The waiting time did not predict the readmission outcome in any time category when other variables were controlled for. Our study suggests that, with low mortality and waiting times, the capacity for providing CABG surgery in Victoria is adequate. A more extensive study that includes follow-up data on patient mortality, patients cancelled from the waiting list, and private hospital surgery would appear to be warranted in enhancing our understanding of CABG surgery outcomes and risks.

Competing interests

The authors declare that they have no competing interests.

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