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ORIGINAL ARTICLE

Outcomes of Redo Valve Surgery in Indigenous Australians☆

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Background Rheumatic heart disease often leads to valve surgery at a young age in our Indigenous population. Anticoagulation can be problematic and therefore repeat surgery to replace degenerated bioprosthetic valves is common. We sought to examine outcomes following redo valve surgery in this population.

Methods Data from our institutional database was reviewed from 1992 to 2017. During this period, 82 redo valve surgeries were performed in 73 patients identifying as Aboriginal and Torres Strait Islander. We compared this study group to Indigenous patients undergoing primary valve surgery (n = 389) and non-Indigenous patients undergoing redo valve surgery (n = 154).

Results Redo patients had a median age of 29.5 years (IQR 24, 44), 59% were female, and they had significant comorbidities. The 30-day mortality in this cohort was 6% (EuroSCORE II 3.57), and they had significant morbidity. The median time to repeat surgery in those who had previous mitral valve surgery was 6.3 years, with no difference between mitral valve repair or replacement at the index procedure.
Compared to non-Indigenous patients undergoing redo valve surgery, the Indigenous patients were significantly younger with higher left ventricular function but a greater proportion of pulmonary hypertension. There were no significant differences in short-term outcomes.
Compared to Indigenous patients undergoing primary valve surgery, the Indigenous redo patients were significantly younger with more co-morbidities. There was no difference in 30-day mortality, but the redo patients did have significantly greater resource utilisation (increased hospital and intensive care unit (ICU) lengths of stay, ventilation and blood transfusion) and poorer long-term survival.

Conclusions Indigenous patients presenting for redo valve surgery represent a complex and comorbid group of patients, with outcomes worse than expected in a young population, albeit comparable within study groups. Time from original surgery was short at 6 years, and thus a strategy must be in place in terms of planning future surgeries in this cohort of predominantly young rheumatic heart disease patients.

Keywords Rheumatic heart disease • Cardiac surgery • Aboriginal

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Introduction

Rheumatic fever and consequent valvular rheumatic heart disease remain a significant public health concern within the Indigenous Australian population, comprising Aboriginal and Torres Strait Islander Peoples [1]. As a result, valve surgery is often necessary at a young age. For many reasons, mostly cultural and geographic, bioprosthetic valve replacement or valve repair are the preferred procedures for these patients. Unfortunately, the durability of these procedures in this young population is limited, and many patients require reoperative surgery, often at a relatively young age.

While there are studies documenting the outcomes of patients in general following rheumatic valve surgery in Australia [2], and studies looking specifically at the outcomes following all cardiac surgery in the Indigenous Australian population [3–5], there has not been a report of the outcomes specifically related to redo valve surgery in this group.

Our institution undertakes a large number of Indigenous Australian surgeries, having a long history with the Northern Territory for over 25 years. Approximately 20% of the current case load at our institution identify as Indigenous Australian.

The aim of the current study was to examine the outcomes of redo valve surgery in the Indigenous Australian population at Flinders Medical Centre over the past 25 years, specifically looking at patient characteristics, procedures and outcomes, and comparing this group to non-Indigenous patients undergoing redo valve surgery and to Indigenous patients undergoing first time valve surgery.

Methods

Data Source and Study Setting

This observational study was performed at the Flinders Medical Centre using prospectively collected data from the Flinders Cardiac Surgery Research Database. During the study period, February 1992 to July 2017, 9,792 procedures were performed. Ethics approval for this audit was waived according to the South Australia Local Health Network (SALHN) Office for Research Quality Assurance versus Research Project Exemption Guidelines v1 (01.12.2016).

Clinical data definitions were based on those reported by the Australian and New Zealand Society of Cardiac and Thoracic Surgeons (ANZSCTS) National Database [6]. Mortality was defined as death in hospital or within 30 days from surgery. Patient survival was ascertained by identification within the National Death Index provided to our institution by the Australian Institute of Health and Welfare Approval EC355(2). The combined morbidity endpoint included incidence of stroke, myocardial infarction, postoperative dialysis, mechanical ventilation >48 hours, deep sternal wound infection or return to the operating theatre. Acute kidney injury was defined according to the serum creatinine criteria of the renal Risk, Injury, Failure, Loss of renal function and End-stage renal disease (RIFLE) classification as postoperative creatinine greater than 150% baseline. The database meets the Australian Commission on Safety and Quality in Health Care (ACSQHC) National Operating Principles for Australian Clinical Quality Registries [https://www.safetyandquality.gov.au/wp-content/uploads/2014/09/Framework-for-Australian-Clinical-Quality-Registries.pdf]. Database managers and staff meet weekly to undertake quality assurance processes. All investigators had access to the entire database and study population data.

Indigenous Australians were identified in the registry as being of Australian Aboriginal and/or Torres Strait Islander descent as recorded by self-reporting of ethnicity either at the time of initial consultation or on admission to hospital, in specific registry fields. 1,186 procedures were performed upon Indigenous patients, with 490 valve surgeries, of which 82 were reoperative valve procedures. These 82 procedures in 73 patients comprised our core group analysed for this study. We examined the outcomes of these patients, and compared them to all 389 Indigenous patients undergoing first time valve surgery over the same period, and to 154 procedures in 151 non-Indigenous patients undergoing redo valve surgery.

Statistical Analysis

Patient demographics, procedural and outcome data were compared in the following groups:

1. Indigenous vs non-Indigenous patients undergoing redo valve surgery
2. Indigenous patients undergoing redo vs primary valve surgery
3. Indigenous patients undergoing redo mitral valve surgery where previous procedure was valve repair vs replacement.

All statistics were performed with Stata v 15.1 (StataCorp LLC, College Station, TX, USA). Continuous variables are reported as median with interquartile range, and are compared using the Wilcoxon rank-sum test. Categorical variables are reported as number of patients and group percentage, and compared using the Fisher's exact test for variables with binary measures and Pearson's chi-squared test for categorical variables. Survival follow-up time was calculated for each patient's procedure as duration between the date of surgery and the census date (June 2017) and group survival estimates plotted as Kaplan-Meier survival curves. Survival data was compared using the log rank test for equality of the survival function. A p-value of <0.05 was considered statistically significant for all analyses without adjustment for multiple comparisons.

Results

Indigenous Patients Undergoing Redo Valve Surgery

During the study period, 82 reoperative valve procedures were performed on 73 Indigenous patients at our institution. The demographics and comorbidities of this core group are

described in Table 1. Indigenous patients were young (median age 29.5 years at the time of surgery) with a significant burden of comorbidities, including chronic lung disease, renal dysfunction, atrial fibrillation, and pulmonary hypertension. The primary indication for valve surgery in this cohort was rheumatic heart disease in the great majority (71 cases, 86.6%). Other indications for surgery included: infective endocarditis in five cases (three patients); dilated aorta resulting in aortic regurgitation in two cases; myxomatous valve in one case; and congenital heart disease in three cases (two bicuspid aortic valve, one double outlet right ventricle). Of the 71 patients with rheumatic heart disease, only 20 (28%) were documented to have been on benzathine penicillin G secondary prophylaxis at the time of their surgery.

Table 1 Patient characteristics of the Indigenous and non-Indigenous redo valve surgery groups.

	Indigenous n = 82	Non-Indigenous n = 154	P value
Demographics:			
Age, years, median (IQR)	29.5 (24,44)	67 (57,74)	<0.001
Male	34 (41%)	104 (68%)	<0.001
BSA, median (IQR)	1.68 (1.57, 1.87)	1.88 (1.74, 2.01)	<0.001
Comorbidities:			
Diabetes mellitus	14 (17%)	30 (19%)	0.6
On insulin	2 (2%)	6 (4%)	0.72
Chronic lung disease	38 (46%)	43 (28%)	0.014
Severe COPD	5 (6%)	11 (7%)	1.00
Renal dysfunction	15 (18%)	19 (12%)	0.45
Median pre-op creatinine	72.5 (60,95)	97 (80,126)	0.001
On dialysis	7 (9%)	4 (3%)	0.11
Peripheral vascular disease	5 (6%)	18 (12%)	0.17
Atrial fibrillation	25 (30%)	22 (14%)	0.006
Cerebrovascular disease	7 (9%)	20 (13%)	0.29
Pulmonary hypertension			0.001
Moderate	27 (33%)	52 (34%)	
Severe	31 (38%)	14 (9%)	
NYHA Class			0.22
Class I	11 (13%)	22 (14%)	
Class II	31 (38%)	35 (23%)	
Class III	28 (34%)	30 (19%)	
Class IV	11 (13%)	16 (10%)	
LV function (Ejection fraction)			0.028
Normal (>60%)	62 (76%)	76 (49%)	
Mild (46-60%)	10 (12%)	27 (18%)	
Moderate (30-45%)	8 (10%)	19 (12%)	
Severe (<30%)	2 (2%)	10 (6%)	
EuroSCORE II, median (IQR)	3.67 (2.84, 5.93)	4.33 (2.73, 8.38)	0.43
Operative status:			
Elective	69 (84%)	129 (84%)	0.92
Urgent	11 (13%)	19 (12%)	
Emergency	2 (2%)	5 (3%)	
Preoperative cardiogenic shock	8 (10%)	4 (3%)	0.069
Preoperative inotropes	8 (10%)	8 (5%)	0.6
Preoperative IABP	2 (2%)	4 (3%)	1.00
Pre-op ventilation	5 (6%)	5 (3%)	0.33

Abbreviations: IQR, interquartile range; BSA, body surface area; COPD, chronic obstructive pulmonary disease; NYHA, New York Heart Association; LV, left ventricular; IABP, intra-aortic balloon pump; pre-op, preoperative.

Table 2 Operative characteristics of the Indigenous redo valve surgery group.

Number of previous sternotomies:	
One	66 (80.5%)
Two	15 (18.3%)
Three	1 (1.2%)
Median time from previous surgery, years (IQR)	6.3 (4.2, 9.3)
Procedures:	
Mitral valve replacement alone	36
Aortic valve replacement alone	9
Repair of prosthetic mitral valve dehiscence	1
Repair of prosthetic aortic valve dehiscence	1
MVR + TVR	11
MVR + AVR	11
MVR + AVR + TVR	4
MVR + CABG	1
MVR + AVR + CABG	1
MVR + AVR + Maze + removal of LA clot	1
AVR + aortic surgery	2
AVR + CABG	2
AVR + removal of LA clot	1
Resection of subaortic membrane + RV-PA conduit	1
Cardiopulmonary bypass time, min, median (IQR)	113 (88, 161)
Aortic cross clamp time, min, median (IQR)	76.5 (62, 101)

Abbreviations: IQR, interquartile range; MVR, mitral valve replacement; AVR, aortic valve replacement; TVR, tricuspid valve replacement; CABG, coronary artery bypass grafts; LA, left atrial; RV-PA, right ventricle to pulmonary artery.

The operative characteristics of the core study group are described in Table 2. The majority of patients had undergone one previous sternotomy and the median time to reoperation was 6.3 years, with over 80% of procedures involving surgery on the mitral valve, either alone (36 procedures, 44%), or in combination with another procedure (30, 36.6%).

Outcomes for the core group are described in Table 3. The 30-day mortality was 6% (5/82), higher than anticipated by the EuroSCORE II for the group of 3.67. One other patient died at 6 weeks post surgery while still in hospital, giving an in-hospital mortality of 7% (6/82) for the study period. As described in Table 4, these patients required significant support in the postoperative period, reflected in a median intensive care unit (ICU) length of stay of 67.9 hours and median hospital stay of 8 days. Almost one third of the group (31.3%) exited operating theatre on inotropes, with six (7%) needing intra-aortic balloon pump (IABP) support, and two (2%) requiring extracorporeal membrane oxygenation (ECMO).

At our most recent linkage with the National Death Index in June 2017, 11 patients from this cohort had died out of hospital since discharge. Of these, seven had mitral valve replacement, either alone or in combination; three had aortic valve replacement; and one was a replacement of right ventricle to pulmonary artery conduit. The total mortality was 21% (17/82) at a median survival follow-up time of 3.5 years (IQR 1.1-6.9).

Indigenous vs Non-Indigenous Patients Undergoing Redo Valve Surgery

In comparison to non-Indigenous patients also undergoing redo valve surgery during the study period (Table 1), the Indigenous patients were significantly younger, had a smaller body surface area, and were more likely to be female. In addition, the Indigenous patients had a higher proportion of lung disease, severe pulmonary hypertension and atrial fibrillation. However, they did have better left ventricular function. The median EuroSCORE II of these two populations were comparable (Indigenous redo: 3.57 (IQR: 2.84, 5.93); non-Indigenous redo: 4.33 (IQR: 2.73, 8.38); $p = 0.43$).

The outcomes of these two groups are compared in Table 3. Despite the differences in baseline characteristics, there were no significant differences in these outcomes. The total mortality was 14% (21/154) at a median survival follow-up time of 7.8 years (IQR 2.8-13.5). Kaplan-Meier survival curves for non-Indigenous patients undergoing redo surgery are shown in Figure 1. The survival rate was significantly lower following redo procedures in Indigenous patients compared with non-Indigenous ($p = 0.0468$).

Indigenous Patients Undergoing Redo vs Indigenous Primary Valve Surgery

The comparison of demographics and comorbidities for Indigenous patients undergoing redo vs primary valve surgery is reported in Table 4. The redo patients were significantly younger, perhaps indicating more aggressive rheumatic heart disease; had a higher incidence of pulmonary hypertension; and were more likely to have preoperative cardiogenic shock. The median EuroSCORE II was also significantly higher in the redo group compared to the primary valve surgery group (redo: 3.57 (IQR: 2.84, 5.93); primary valve group: 1.06 (0.74, 1.62); $p < 0.001$).

In comparison to Indigenous patients undergoing first time valve surgery, as expected, the redo patients had significantly longer procedure times (246.5 minutes (IQR: 198, 307) vs 159.5 minutes (IQR: 130, 203); $p < 0.001$), total bypass times (113 minutes (IQR: 88, 161) vs 80.5 minutes (IQR: 61, 110); $p < 0.001$) and cross clamp times (76.5 minutes (IQR: 62, 101) vs 62 minutes (IQR: 45.5, 86.5); $p < 0.001$).

The outcomes of these two groups are compared in Table 5. The redo group had significantly longer ICU and total hospital lengths of stay, higher rates of blood transfusion and a higher proportion of prolonged ventilation. There was no

Table 3 Outcomes of the Indigenous and non-Indigenous redo valve surgery groups.

Variable	Indigenous n = 82	Non-Indigenous n = 154	P value
30-day mortality	5 (6%)	8 (5%)	0.78
IABP in ICU	6 (7%)	16 (10%)	0.49
ECMO	2 (2%)	1 (0.6%)	0.58
Return to theatre	5 (6%)	13 (9%)	0.8
Stroke	1 (1%)	9 (6%)	0.1
Prolonged ventilation (>48 hours)	19 (23%)	23 (15%)	0.16
Pneumonia	17 (21%)	20 (14%)	0.19
Blood transfusion	62 (76%)	110 (75%)	1.0
Sternal wound infection	1 (1.2%)	0 (0%)	0.35
Acute kidney injury	15 (19%)	17 (18%)	1.0
Requiring dialysis	3 (4%)	6 (4%)	1.0
Median ICU stay, hours (IQR)	67.9 (25.3, 158.5)	50.6 (26.5, 120)	0.46
Median hospital stay, days (IQR)	8 (6, 13)	8 (6, 13)	0.66
Combined morbidity*	23 (28%)	40 (26%)	0.76

Abbreviations: IABP, intra-aortic balloon pump; ICU, intensive care unit; ECMO, extracorporeal membrane oxygenation; IQR, interquartile range.
*Combined morbidity endpoint, combined incidence of stroke, myocardial infarction, postoperative dialysis, mechanical ventilation >48 hours, deep sternal wound infection or return to theatre.

difference in 30-day mortality, but both outcomes are significantly higher than predicted by the EuroSCORE II (redo: 3.57; primary valve: 1.06). The total mortality was 13% (48/369) at a median survival follow-up time of 6.7 years (2.7-11.9). Kaplan-Meier survival curves for Indigenous patients undergoing primary and redo surgery are shown in Figure 1. The survival rate was significantly lower following redo procedures in Indigenous patients compared with primary procedures (p = 0.0025).

Indigenous Patients Undergoing Redo Mitral Valve Surgery, Comparing Index Procedure Valve Repair vs Replacement

Of the 82 procedures performed in the patient cohort, 66 were redo mitral valve surgery, either alone or in combination. The preoperative characteristics differed significantly with regard to age, with the non-mitral surgery (nMVS) group being older (median age of 43.5 years (IQR: 30, 54) vs median age of 28.5 years (IQR 24, 40) in the mitral valve (MVS) group, p = 0.006); sex, with a male predominance in the nMVS group (81% of patients) vs a female predominance in the MVS group (32% male only), p < 0.001; and chronic lung disease, with the nMVS group having lung disease only in 19% of patients vs 53% in the MVS group, p = 0.023. In addition, the MVS group were more symptomatic, with 33 patients (50%) being in NYHA Classes III/IV vs only 6 patients (38%) in the nMVS group, p = 0.018. The median EuroSCORE II was comparable in the two groups (nMVS: 4.17 (IQR: 2.7, 6.21); MVS group: 3.53 (IQR: 2.84, 5.93).

Of the redo patients who had mitral valve surgery (n = 66), two patients had repair of a prosthetic para-valvular leak (both mechanical valves), 64 underwent mitral valve replacement: 28 (43%) had a tissue valve replacement; 36 (54.5%) had a mechanical valve replacement. At their most recent surgery prior to this operation, 36 patients had undergone a mitral valve repair (MVRep), and 28 had undergone a replacement (MVR); in two patients, there had been no intervention on the mitral valve. In the patients who had a mitral valve repair at their most recent surgery, the time interval to surgery was 6 years (IQR4.1, 9.3), which was not significantly different from those who had a previous replacement at 6.5 years (IQR 4.9, 7.9); p = 0.59. However, looking at those patients who had a mitral valve replacement alone (Table 6), the cross clamp times were significantly shorter in those who had a previous MVRep vs a previous MVR (62 mins vs 69.5 mins; p = 0.043), with trends towards shorter procedure times and total bypass times. Also, patients with a previous MVRep had significantly less acute kidney injury, and trends towards shorter ICU and hospital lengths of stay and a lower combined morbidity endpoint.

Discussion

This review sought to describe the characteristics and outcomes of Indigenous Australian patients presenting for redo valve surgery. From our institutional results, this is a young, predominantly female population, which is expected given the primary pathology in the majority was rheumatic heart disease. Unfortunately, both acute rheumatic fever and rheumatic heart disease have one of the highest incidences in the world in Indigenous Australian population [7]. In the Northern Territory, the prevalence of rheumatic heart disease in

Table 4 Patient characteristics of the Indigenous redo valve surgery and Indigenous primary valve surgery groups.

	Redo valve n = 82	Primary valve n = 369	P value
Demographics:			
Age, years, median (IQR)	29.5 (24,44)	40 (29,51)	<0.001
Male	34 (41%)	158 (43%)	0.9
BSA, median (IQR)	1.68 (1.57, 1.87)	1.75 (1.6, 1.92)	0.13
Comorbidities:			
Diabetes mellitus	14 (17%)	72 (20%)	0.64
On insulin	2 (2%)	16 (4%)	0.55
Chronic lung disease	38 (46%)	127 (34%)	0.057
Severe COPD	5 (6%)	27 (7%)	0.82
Renal dysfunction	15 (18%)	58 (16%)	0.74
On dialysis	7 (9%)	20 (5%)	0.32
Peripheral vascular disease	5 (6%)	7 (2%)	0.046
Atrial fibrillation	25 (30%)	71 (19%)	0.036
Cerebrovascular disease	7 (9%)	25 (7%)	0.63
Pulmonary hypertension			<0.001
Moderate	27 (33%)	139 (38%)	
Severe	31 (38%)	69 (19%)	
NYHA Class			0.17
Class I	11 (13%)	58 (16%)	
Class II	31 (38%)	109 (30%)	
Class III	28 (34%)	79 (21%)	
Class IV	11 (13%)	34 (9%)	
LV function (Ejection fraction)			0.89
Normal (>60%)	62 (76%)	261 (71%)	
Mild (46-60%)	10 (12%)	57 (14%)	
Moderate (30-45%)	8 (10%)	33 (9%)	
Severe (<30%)	2 (2%)	5 (1%)	
EuroSCORE II, median (IQR)	3.67 (2.84, 5.93)	1.06 (0.74, 1.62)	<0.001
Operative status			0.13
Elective	69 (84%)	335 (91%)	
Urgent	11 (13%)	25 (7%)	
Emergency	2 (2%)	9 (2%)	
Preoperative cardiogenic shock	8 (10%)	10 (3%)	0.01
Preoperative inotropes	8 (10%)	15 (4%)	0.2
Preoperative IABP	2 (2%)	5 (1%)	0.63
Pre-op ventilation	5 (6%)	16 (4%)	0.56

Abbreviations: IQR, interquartile range; BSA, body surface area; COPD, chronic obstructive pulmonary disease; NYHA, New York Heart Association; LV, left ventricular; IABP, intra-aortic balloon pump.

Indigenous Australians is 22.1 per 1,000 (37 times higher than non-Indigenous residents of the NT) and 66% of these patients are women [1]. Echocardiographic screening of high risk children in northern and central Australia demonstrated a prevalence of definite or borderline rheumatic heart disease of 23.5 per 1,000, higher than that of a large study of Ugandan children at 14.8 per 1,000 [8]. Although a young group, these patients have significant comorbidities, with very high proportions of chronic lung disease, diabetes and renal dysfunction. Several other studies have also reported high levels of comorbidities in Indigenous patients [3,4]. In addition, many presented late for surgery, as evidenced by the high incidence of preoperative cardiogenic shock and urgent or emergent status. This may be related to a failure of follow-up and ongoing medical management after their previous surgery, an issue frequently noted in this population. A study

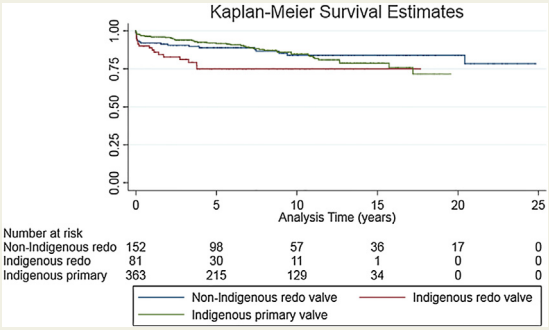

Figure 1 Kaplan-Meier survival estimates for Indigenous redo (red), non-Indigenous redo (blue) and Indigenous primary groups (green). Median (IQR) follow-up time for each group was 3.5 (1.1-6.9) years, 7.8 (2.8-13.5) years and 6.7 (2.7-11.9) years respectively. Survival for the Indigenous redo group was significantly different to non-Indigenous redo group (p = 0.0468) and primary Indigenous group (p = 0.0025) respectively.

from Brisbane reported that 14% of patients post valve surgery did not attend for their first outpatient review at 2–6 weeks post-op [5]. This may be due to issues with access to health care, geographical remoteness, and lack of understanding and education. These issues with compliance and engagement with health services are reflected in the low documented rates of secondary prophylaxis seen in our cohort. The current Australian guideline for the prevention, diagnosis and management of acute rheumatic fever and rheumatic heart disease [18] recommends secondary prophylaxis with 3–4 weekly benzathine penicillin G (BPG) to continue to age 40 years or longer in patients with previous cardiac valve surgery. Of the 71 cases in which rheumatic heart disease was the primary indication for the initial surgery, only 15 of these were aged over 40 years, thus at least 56 should have been on BPG. However, from our records, only 20 patients were. It is known that compliance with BPG reduces the incidence of recurrent episodes of acute rheumatic fever and progression of valve disease, and this is an area for ongoing optimisation.

The perioperative mortality in this young population undergoing redo valve surgery was high at 6%. No published study has previously examined the outcomes in this particular population. Russell et al. reported a 2.9% mortality in Indigenous Australians undergoing valve surgery for rheumatic heart disease; however, of this group only 13.5% were undergoing redo surgery [2]. The increased mortality seems to be specific to valve surgery: Prabhu et al. demonstrated equivalent 30-day mortality between Aboriginal (1.3%) and non-Aboriginal patients (1.4%) after isolated coronary artery bypass surgery [3]. Of note, the mortality predicted for our group by the EuroSCORE II was significantly lower at 3.57. However, a number of factors must be taken into consideration when using this scoring system in this situation: firstly, the EuroSCORE II has not been validated in the Indigenous Australian population, and is, in fact, drawn from a very different cohort of patients than we describe; in addition, it gives significant weighting to age, thus a lower EuroSCORE II in our population whose median age is only 29 years is not truly reflective of the level of comorbidity. Interestingly, Lehman et al. similarly found an excess mortality compared to EuroSCORE values in an Indigenous population undergoing cardiac surgery, especially in the younger patients [9].

Table 5 Outcomes of the Indigenous primary and redo valve surgery groups.

Variable	Redo valve n = 82	Primary valve n = 369	P value
30-day mortality	5 (6%)	1 (2%)	0.19
IABP in ICU	6 (7%)	17 (5%)	0.4
ECMO	2 (2%)	1 (0.2%)	0.14
Return to theatre	5 (6%)	31 (8%)	1.0
Stroke	1 (1%)	3 (0.8%)	0.56
Prolonged ventilation (>48 hours)	19 (23%)	49 (13%)	0.039
Pneumonia	17 (21%)	59 (16%)	0.33
Blood transfusion	62 (76%)	208 (56%)	0.004
Sternal wound infection	1 (1.2%)	6 (2%)	1.0
Acute kidney injury	15 (19%)	48 (13%)	1.0
Requiring dialysis	3 (4%)	10 (3%)	0.71
ICU stay, hours, median (IQR)	67.9 (25.3, 158.5)	30.6 (24, 75.1)	0.005
Hospital stay, days, median (IQR)	8 (6, 13)	7 (5,10)	0.008
Combined morbidity*	23 (28%)	87 (24%)	0.4

Abbreviations: IABP, intra-aortic balloon pump; ICU, intensive care unit; ECMO, extracorporeal membrane oxygenation; IQR, interquartile range.
*Combined morbidity endpoint, combined incidence of stroke, myocardial infarction, postoperative dialysis, mechanical ventilation > 48 hours, deep sternal wound infection or return to theatre.

Table 6 Outcomes of the Indigenous isolated mitral valve replacement group.

	Previous repair n = 20	Previous replacement n = 16	Significance
Time since previous surgery, year, median (IQR)	6 (4.2, 9.6)	6.5 (4.8, 7.9)	p = 0.94
Procedure time, minutes, median (IQR)	205.5 (169.5, 246)	227.5 (192, 279.5)	p = 0.15
CPB time, min, median (IQR)	92 (63, 112.5)	107.5 (82, 125)	p = 0.13
Aortic cross clamp time, min, median (IQR)	62 (39.5, 73)	69.5 (63, 88.5)	p = 0.043
30-day mortality	1 (5%)	1 (6%)	p = 1.0
Prolonged ventilation (>48 hours)	1 (5%)	5 (31%)	p = 0.069
ICU stay, hours, median (IQR)	46.9 (28.9, 83.8)	69 (26.4, 213.7)	p = 0.29
Hospital stay, days, median (IQR)	7 (6,9)	10 (6.5, 13)	p = 0.13
Acute kidney injury	0 (0%)	7 (44%)	p = 0.002
Transfusion	12 (60%)	12 (75%)	p = 0.48
Combined morbidity*	2 (10%)	5 (31%)	p = 0.2

Abbreviations: IQR, interquartile range; CPB, cardiopulmonary bypass; ICU, intensive care unit

*Combined morbidity endpoint = combined incidence of stroke, myocardial infarction, postoperative dialysis, mechanical ventilation >48 hours, deep sternal wound infection or return to theatre.

The morbidity outcomes were also very significant, with almost a quarter of the cohort being ventilated for more than 48 hours, a median ICU stay of almost 3 days and 8 days in total in hospital. This raises medical concerns, of course, but also creates an economic burden on our health care system. The reasons for the poor outcomes are multi-factorial. As discussed, this is a population with significant comorbidities. In addition, many of these patients are malnourished, have low haemoglobins, and are current smokers. Cultural issues also impact on their recovery, being far from home, lack of support, level of engagement with physiotherapy.

The long-term survival for the Indigenous redo group varied significantly from both the non-Indigenous redo group and the primary Indigenous group highlighting the increased risk of early death in these patients. This has not previously been reported in this cohort, however, this mortality is in keeping with the known poor outcomes of patients with severe rheumatic heart disease. Lawrence et al. described an excess mortality of 56% in Indigenous patients of the Northern Territory with rheumatic heart disease when compared to unaffected age and sex matched individuals [19]. A recent review also from the Northern Territory Rheumatic Heart Disease database described a mortality of 10% at 6 years in patients with severe rheumatic heart disease; this high mortality was most notable in the 15–24 year old age group, of whom 22% had died at 10 years post diagnosis [20].

In comparison to Indigenous patients undergoing primary valve surgery, the redo patients were younger, perhaps indicative of more aggressive rheumatic heart disease in this group, and also had more pulmonary hypertension, likely due to prolonged exposure to valve dysfunction. As expected, the EuroSCORE II was higher for the redo patients. The rate of mortality was not different between the groups; however again, it was higher than predicted by the EuroSCORE II in both of these groups. Morbidity outcomes were worse in the redo population. Given the weighting of age as a predictor of outcome in Risk Score Calculators, the fact this group are considerably younger should confer outcome benefits. Given this was not observed, the burden of co-morbidity may be thought causal to the observed outcomes. Interestingly, a number of studies have now shown that, in the current era, the addition of a redo sternotomy to a procedure does not confer increased morbidity and mortality; this is clearly not so in this group of patients [10,11]. However, we do acknowledge that this is not a propensity-matched population and thus it is hard to draw definitive conclusions regarding this.

In comparison to non-Indigenous undergoing redo valve surgery during the same time period, the Indigenous patients were younger with better left ventricular function; however, they also had lower body surface areas, a higher proportion of females, more lung disease and more pulmonary hypertension. Consequently, the EuroSCORE II values between the two groups were comparable. As described, there were no differences in short-term outcomes between these groups. However, given that the median age of the Indigenous patient group was 29.5 years compared to a median age of 67 years in the non-Indigenous group, one would reasonably expect that the younger group would fare better than the older group, rather than no worse. However, a lower rate of long-term survival was seen in the Indigenous group.

The choice of valve replacement option is worth noting. A significant proportion (45%) of this young population underwent bioprosthetic mitral replacement, despite our understanding of the limited longevity of tissue mitral valves and indeed of a likelihood of reduced long-term survival with

bioprosthesis compared to mechanical valve replacement in the mitral position in young people [12,13]. Russell et al., in a comprehensive review of valve surgery for rheumatic heart disease in Australia, reported mechanical mitral valves inserted in 52% of the Indigenous cohort, with 48% undergoing repair or bioprosthesis [14]. These proportions are similar to ours, with the exception that repair was not conducted in the redo setting which we are reporting. Of course, this is a young female cohort, many of whom wish to have a family and thus avoid the complications of warfarin in pregnancy. In addition, compliance with warfarin remains a significant issue in Indigenous populations. A number of reasons contribute to this, including geographical remoteness, nomadic culture, education and understanding, and support of family and community. A study from Fiji examined the reasons for warfarin non-compliance in a young rheumatic heart disease population following valve surgery: youth, lack of understanding of the reasons for warfarin therapy, and time taken to travel to a heart clinic of more than one hour were predictors of warfarin non-compliance [15]. Although a similar study has not been performed in the Indigenous Australian population, many of the same factors exist. As such, the expectation with many of these patients is that repeat valve surgery will be necessary in a number of years.

In terms of time to repeat surgery on the mitral valve, this was not different between those patients who underwent a repair or a bioprosthetic replacement of their mitral valve in the first instance, and was relatively short at 6 years. Yakub et al. reported on their experience with mitral valve repair in a similarly young rheumatic heart disease population and found a freedom from reoperation at 10 years of 87% with a freedom from valve failure of 73% [16]. The techniques being used at our institution for repair of these valves have been significantly modified in recent years and we hope to achieve improved durability with our current repairs. This is an important consideration, as Kim et al. recently reported that, while patients with mitral valve repair have similar early mortality compared to valve replacement, valve related morbidity is significantly less with repair [17]. In addition, it is our impression that the surgery to replace a previously repaired valve is less complicated compared to repeat replacement, and thus one would hope to see improved outcomes in this situation. Although our data began to support this observation, the numbers really are too small to conclusively show this.

Summary and Implications for Practice

The implications for our practice are in terms of planning for the chronic nature of the disease in this cohort. Thus we aim to repair valves if at all possible in the first instance, and with improved techniques, hope to obtain more durable results with this. We also now consider alternative approaches for the second procedure, such as right thoracotomy, to avoid another sternotomy until perhaps the following surgery. This review also informs our expectations in terms of the postoperative course of these patients and helps us in planning for this, both in terms of preoperative optimisation and postoperative management. Importantly, the most significant contributions to lessening the morbidity and mortality of this group lie more in prevention, health education and improvement of socioeconomic factors in order to prevent rheumatic fever and rheumatic heart disease.

Limitations

This is a single centre observational study of prospectively collected data, analysed retrospectively. Although our institution does perform a significant proportion of the cardiac surgery from the Northern Territory, we are not able to capture the entire cohort of Indigenous patients presenting for redo valve surgery with this report. In particular, children under the age of 16 are referred to paediatric hospitals and are not operated upon at Flinders Medical Centre, thus this study does not capture outcomes of rheumatic heart disease in children. However, a number of procedures reported in this series were operated in paediatric centres for their index or previous procedures. Since the incidence of co-morbidities was not balanced between groups, differences in patient outcomes may be attributed to factors other than specifically the patient's Indigenous status or surgery type. Furthermore, redo patients were defined broadly as having any previous valve surgery and therefore included multiple redo procedures. We were also limited by the small number of patients who did not have mitral valve surgery (n = 16), such that these comparisons are underpowered and are reported with the intention to generate hypotheses for future larger studies.

A significant limitation in the collection of ethnicity data is the determination of who is Indigenous. There are two issues, one is that ethnicity is self-selected, and some Aboriginal and Torres Strait Islanders will not feel comfortable identifying themselves as Indigenous, and, secondly, there is a reluctance by administrative and medical staff to actually ask the question with regards to ethnicity and it is often only gained from a ''perception'' of ethnicity. Our institution has now introduced processes to routinely ask patients if they identify as being of Aboriginal and/or Torres Strait Islander origin, however, for this study, we are not able to report whether patients have been specifically asked, nor whether patients have correctly responded.

Conclusion

Our report highlights the outcomes of Indigenous Australians undergoing redo valve surgery whose outcomes are much worse than expected given their age. Due to the chronic nature of the disease in this cohort, our current approach is to attempt valve repair in the first instance, and consider alternative approaches for the second procedure. Importantly, the most significant contribution to lessening the morbidity and mortality of this group lies more in prevention, health

education and improvement of socioeconomic factors in order to prevent rheumatic heart disease.

Disclosures

Associate Professor Jayme S Bennetts is a Consultant and Advisory Board Member for Medtronic and Edwards Life-Sciences, and has received grants form Medtronic, Edwards LifeSciences and Abbott.

Dr Gregory D Rice is a Proctor for Edwards LifeSciences.

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