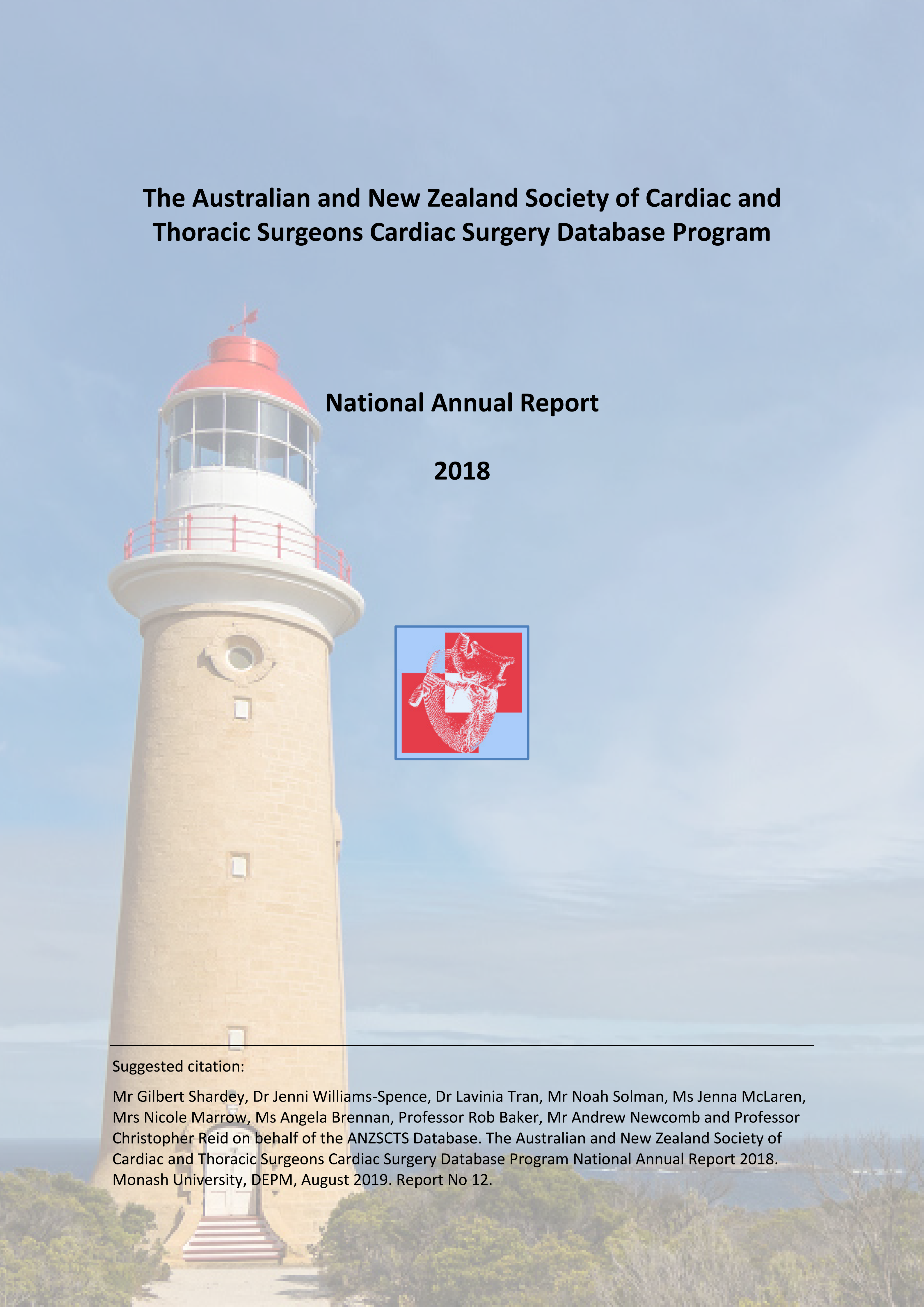
ANZSCTS Cardiac Surgery Database Program

National Annual Report

2018



The Australian and New Zealand Society of Cardiac and Thoracic Surgeons Cardiac Surgery Database Program

National Annual Report

2018

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Abbreviations

AKIN	Acute Kidney Injury Network
ANZSCTS	Australian and New Zealand Society of Cardiac and Thoracic Surgeons
AVR	Aortic valve replacement
BITA	Bilateral internal thoracic artery
BMI	Body mass index
CABG	Coronary artery bypass graft
CL	Control limit
CO	Cardiac output
CPB	Cardiopulmonary bypass
DNRI	Derived new renal insufficiency
DSWI	Deep sternal wound infection
eGFR	Estimated glomerular filtration rate
GEPA	Gastroepiploic artery
GM	Geometric mean
ICU	Intensive care unit
ITA	Internal thoracic artery
KDIGO	Kidney Disease Improving Global Outcomes
KPIs	Key performance indicators
LITA	Left internal thoracic artery
LVD	Left ventricular dysfunction
LVF	Left ventricular function
MI	Myocardial infarction
MV	Mitral valve
MVR	Mitral valve replacement
NCA	New cardiac arrhythmia
NRBC	Non-red blood cell
NRI	New renal insufficiency
NSTEMI	Non-ST elevation myocardial infarction
OM	Observed mortality
PLOS	Procedural length of stay
RA	Radial artery
RAMR	Risk-adjusted mortality rate
RBC	Red blood cell
Re-op	Re-operation
RIFLE	Risk, Injury, Failure, Loss of Kidney Function, End-stage Kidney Disease
RITA	Right internal thoracic artery
RRT	Renal replacement therapy
SCTS	Society for Cardiothoracic Surgery
STEMI	ST-elevation myocardial infarction
STS	Society of Thoracic Surgeons
SV	Saphenous vein
SVR	Systemic vascular resistance
SWEDEHEART	Swedish Web-system for Enhancement and Development of Evidence-based Care in Heart Disease Evaluated According to Recommended Therapies
Tri/Pulm	Tricuspid or pulmonary
TAVR	Transcatheter aortic valve replacement
TMVR	Transcatheter mitral valve replacement

Acknowledgements

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We gratefully acknowledge contributions made by the ANZSCTS Cardiac Surgery Database Steering Committee, the ANZSCTS Cardiac Surgery Database Research Committee, the ANZSCTS Registry Data Custodian – Professor Chris Reid, and the Chairman of the Steering Committee and Clinical Lead – Mr Gil Shardey.

We also acknowledge the ANZSCTS Cardiac Surgery Database data and project management staff at the Centre for Cardiovascular Education in Therapeutics at Monash University (Dr Jenni Williams-Spence, Dr Lavinia Tran, Mr Noah Solman, Ms Jenna McLaren, Mrs Nicole Marrow, Mr Mark Lucas, and Ms Jill Edmonds), who are critical to the success of all the activities of the Program.

During 2018, the Registry Data Custodian, Professor Chris Reid, was supported by a National Health and Medical Research Council Fellowship that provided salary support to contribute to initiatives such as the ANZSCTS Database.

The work of the ANZSCTS Database relies on the efforts of surgeons, data managers, and other relevant hospital staff who contribute data.

Photograph by Mark Lucas 2018 ©

Foreword

For the past twelve years, the ANZSCTS Database Program has published a National Annual Report. There were 40 units enrolled in the Program in 2018. Regrettably, three were unable to submit the proportion of cases required for analysis and inclusion, so that this report describes the data from surgery performed in 37 National public and private hospital cardiac surgical units.

Data presented in this report provide unit comparisons for procedures performed in the 2018 calendar year. Thirty-day follow up dictates that procedural outcomes are collected to the end of January 2019. Information is also presented as pooled (four or five year) and annual (five years), data.

The Program is not a mere compendium of cases. Therefore, unit outcomes are compared against a set of Key Performance Indicators. Heads of units are notified of outlying status in accordance with the ANZSCTS Database's outlier management procedure (Appendix A).

Units are de-identified by random coding. The report demonstrates unit performance compared to other contributing units, and the group average.

Overall, in the five-year period, although there is variation in practice, most participating Australian cardiac surgical units had satisfactory outcomes for key performance indicators (mortality and complications).

This year's report also examines the incidence of new renal insufficiency in all of the patients included in the Database over the last decade. It shows that, as intended, the ANZSCTS Database definition for new renal insufficiency captures only the more severe cases of renal impairment, hence the relatively poor outcomes and long-term survival of patients within this cohort.

The Society continues its mission to ensure that high standards are maintained in all units performing cardiac surgical procedures in Australia and where indicated, assist units to achieve that standard.

Mr Gil Shardey

Chairman
ANZSCTS Database Program
Steering Committee

Key Messages

- The 2018 report includes data on 62,839 procedures performed between 2014 and 2018 in 37 public and private units in Australia.
- Isolated coronary artery bypass graft (CABG) surgery continued to be the most commonly performed procedure, accounting for 48.7% of the total caseload in 2018.
- Of the 6,872 CABG procedures reported by contributing hospitals in 2018, 60.5% were elective, 36.7% were urgent and 2.78% were emergency or salvage. The proportion of elective cases decreased since 2014.
- There was a 20.5% reduction in the proportion of isolated CABG patients with normal left ventricular function between 2014 and 2018.
- Between 2014 and 2018, there was a steady decrease in the proportion of redo CABG procedures from 2.10% to 1.24%.
- In 2018, single or bilateral internal thoracic artery (ITA) use was 94.4% for on-pump patients and 96.5% for off-pump patients, while the rate of radial artery use was 38.4% and 24.0% for on-pump and off-pump patients, respectively.
- Use of arterial and venous conduits has remained similar over time, with saphenous vein conduits accounting for 46.2% of anastomoses, ITA grafts accounting for 37.1%, and the radial artery for 16.7% in 2018.
- CABG patients with a pre-operative creatinine level ≥200 µmol/L had higher incidence of permanent stroke, deep sternal wound infection and re-operation for bleeding, and a five-fold increase in the incidence of derived new renal insufficiency (DNRI).
- The observed mortality rates for isolated CABG and isolated aortic valve replacement (AVR) procedures were comparable to those reported by the New Zealand, SWEDEHEART, SCTS and STS registries.
- Of the 3,043 isolated valve procedures reported to the ANZSCTS Database in 2018, 14.7% were redo, and 1,632 were single aortic operations.
- There was a slight increase in the proportion of male patients presenting for isolated valve surgery over the last five years, progressing from 58.2% in 2014 to 62.3% in 2018.
- All units were within the 99.7% control limit for observed mortality for patients having AVR and AVR with CABG between 2014 and 2018.
- There was significant variation between units for isolated CABG, AVR, and CABG with AVR patients with respect to post-operative complications, particularly new cardiac arrhythmia, re-operation for bleeding, and readmission.
- Resource utilisation, including duration of intensive care unit stay and ventilation, pre- and post-procedural length of stay, and the rate of blood product use, also varied markedly between units.
- DNRI was more common in older patients with insulin-dependent diabetes and other key comorbidities, and in those undergoing redo and more complex procedures.
- DNRI was also more common in patients who received RBC products, particularly where more than two units of product were transfused.
- Rates of post-operative complications and mean resource utilisation were markedly higher in patients with DNRI, particularly in those requiring haemofiltration.
- For all cardiac surgery patients, seven-year survival was 26% lower in patients with DNRI.

Introduction

The ANZSCTS Cardiac Surgery Database Program 2018 National Annual Report presents data on patient characteristics and unit performance for a range of key performance indicators (KPIs), including post-operative complications and mortality. This year, the topic of post-operative renal insufficiency has been explored as an additional theme. The data is organised by procedure type, as follows:

- Section 1: Isolated CABG
- Section 2: Post-operative Renal Insufficiency
- Section 3: Isolated Valve
- Section 4: Valve with CABG
- Section 5: Other Cardiac Surgery

Key Performance Indicators

The ANZSCTS Database collects data for a range of KPIs based on clinically relevant surgical outcomes; these are defined in detail in Appendix B.

The KPIs that are peer reviewed to benchmark and monitor the performance of units are:

- Mortality (risk-adjusted and/or observed)
- Permanent stroke
- Derived new renal insufficiency
- Deep sternal wound infection
- Re-operation for bleeding

Units that fall outside of the 99.7% control limit for any of these KPIs are managed according to the Database outlier escalation policy (Appendix A).

The additional performance indicators which are presented in this report are:

- New cardiac arrhythmia
- Duration of intensive care unit (ICU) stay
- Duration of ventilation
- Red blood cell transfusions
- Non-red blood cell transfusions
- Pre- and post-procedural length of stay

These metrics may be used by units to benchmark their individual performance against other units at the National level.

Contributing units

In 2001, the ANZSCTS with the support of the Victorian Department of Health and Human Services developed a Program to collect and report data on cardiac surgery performed in Victorian hospitals. The Program expanded to National coverage, producing annual reports to inform its participants since 2002 for Victorian units, and since 2007 at a National level.

The 2018 report delivers a detailed analysis of data, providing an overview of annual trends and outcome measures based on KPIs. The data includes reported cardiac procedures performed in the 2018 calendar year, with follow up data to 31st January 2019, from 37 public and private cardiac units. The 2018 data is presented adjacent to pooled data for the preceding four years, and as part of average annual data over five years, to show trends in outcomes. Where the number of cases in the current year is low (sections 3 and 4), pooled data includes the current year. Details of data preparation and key variable definitions are presented in Appendix C.

The cardiac units listed in Table 1 contributed data to this report. Some units joined the Program more recently, therefore have not provided data over the full five years. Only units that submitted greater than 66% of their expected caseload in 2018 are included in sections 1, 3, 4 and 5 of the report.

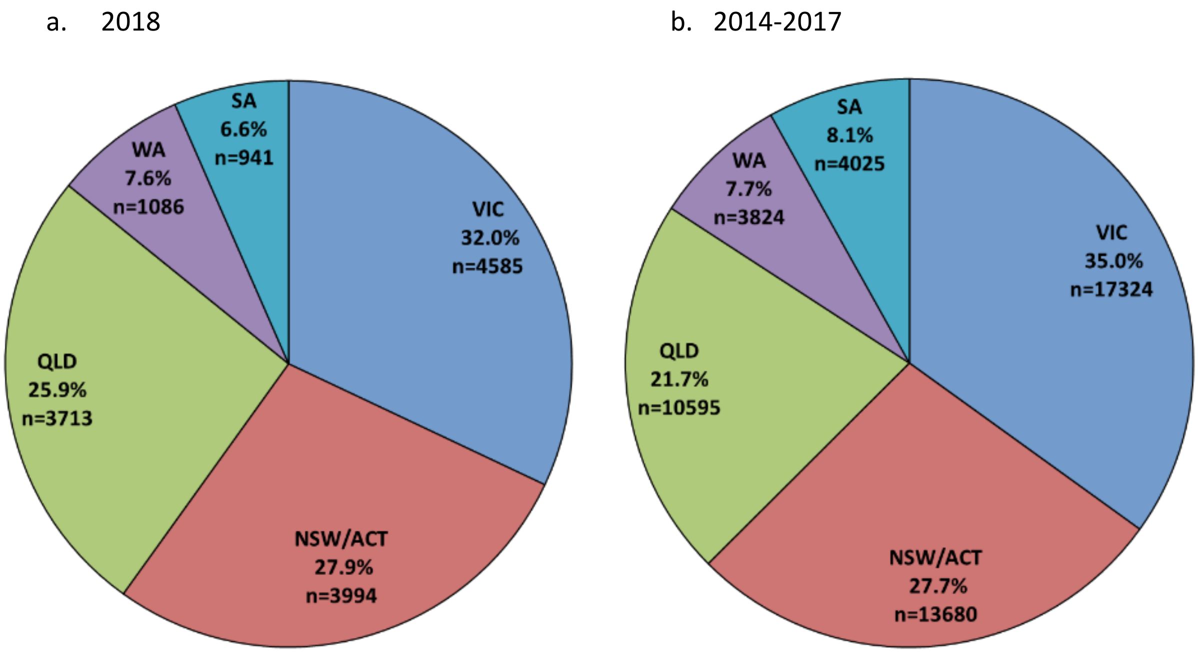
Table 1. Hospital participation

Contributing Hospitals	Hospital Type	2014	2015	2016	2017	2018
VICTORIA						
Alfred Hospital	Public	●	●	●	●	●
Austin Hospital	Public	●	●	●	●	●
Cabrini Private Hospital	Private	●	●	●	●	●
Epworth Eastern	Private	●	●	●	●	●
Epworth Richmond	Private	●	●	●	●	●
University Hospital Geelong	Public	●	●	●	●	●
Jessie McPherson Private Hospital	Private	●	●	●	●	●
Monash Medical Centre	Public	●	●	●	●	●
Peninsula Private Hospital	Private	●	●	●	●	†
Royal Melbourne Hospital	Public	●	●	●	●	●
St Vincent's Hospital (Melbourne)	Public	●	●	●	●	●
Warringal Private Hospital	Private				○	●
NEW SOUTH WALES						
John Hunter Hospital	Public	●	●	●	●	●
Lake Macquarie Private Hospital	Private	●	●	●	●	●
Liverpool Hospital	Public	●	●	●	●	●
North Shore Private Hospital	Private				○	†
Prince of Wales Hospital	Public	●	●	●	●	●
Royal Prince Alfred Hospital	Public	●	●	●	●	●
Royal North Shore Hospital	Public	●	●	†	†	●
St George Hospital	Public	†	●	●	●	●
St George Private Hospital	Private				○	●
Strathfield Private Hospital	Private				○	†
St Vincent's Hospital (Sydney)	Public	†	●	●	●	●
Westmead Hospital	Public	●	●	●	●	●
Westmead Private Hospital	Private				○	●
AUSTRALIAN CAPITAL TERRITORY						
Canberra Hospital	Public	†	●	●	●	●
QUEENSLAND						
Gold Coast University Hospital	Public		●	●	●	●
Greenslopes Private Hospital	Private				○	●
St Vincent's Private Hospital Northside	Private	●	●	●	●	●
John Flynn Private Hospital	Private				○	●
Mater Hospital	Private	●	●	●	●	●
Prince Charles Hospital	Public		●	●	●	●
Princess Alexandra Hospital	Public		●	●	●	●
Townsville Hospital	Public	●	●	●	●	●
Sunshine Coast University Private Hospital	Private					●
SOUTH AUSTRALIA						
Flinders Hospital	Public	●	●	●	●	●
Royal Adelaide Hospital	Public	●	●	●	●	●
WESTERN AUSTRALIA						
Fiona Stanley Hospital	Public		○	●	●	●
Sir Charles Gairdner Hospital	Public	●	●	●	●	●
St John of God Subiaco Hospital	Private	●	●	●	●	●

● Hospital engaged and contributing
○ Hospital engaged but contributing <12 months
† Hospital engaged but contributed insufficient data (<66% of expected caseload)

The proportion of total cardiac surgery operations performed in participating Australian units is reported by jurisdiction (Figure 1).

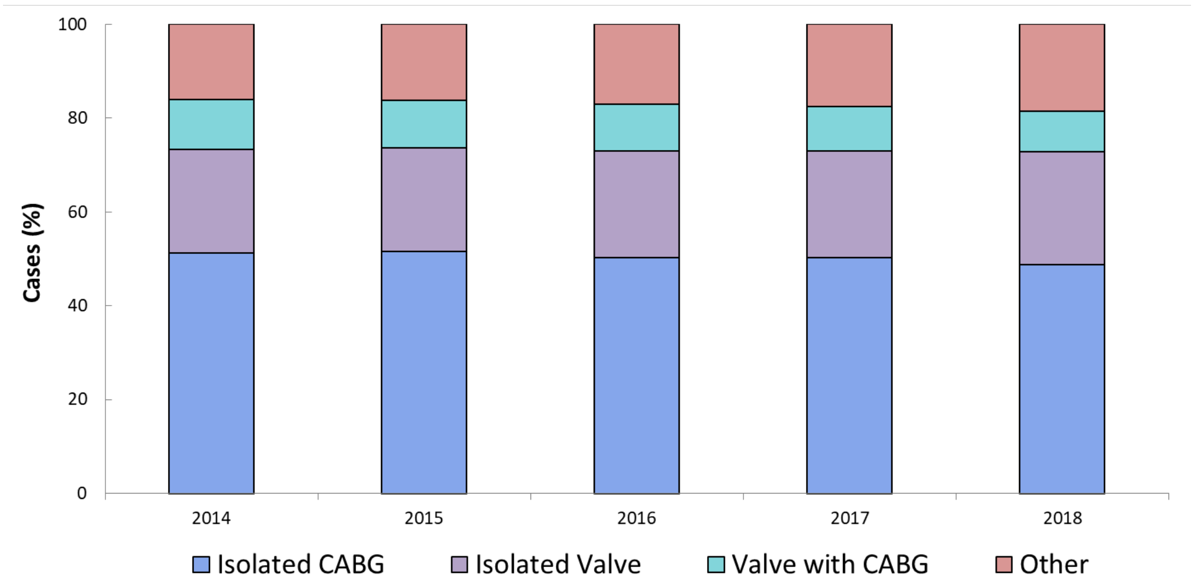
Figure 1. Proportion of cardiac procedures reported by contributing units in each jurisdiction



Overview of procedure types

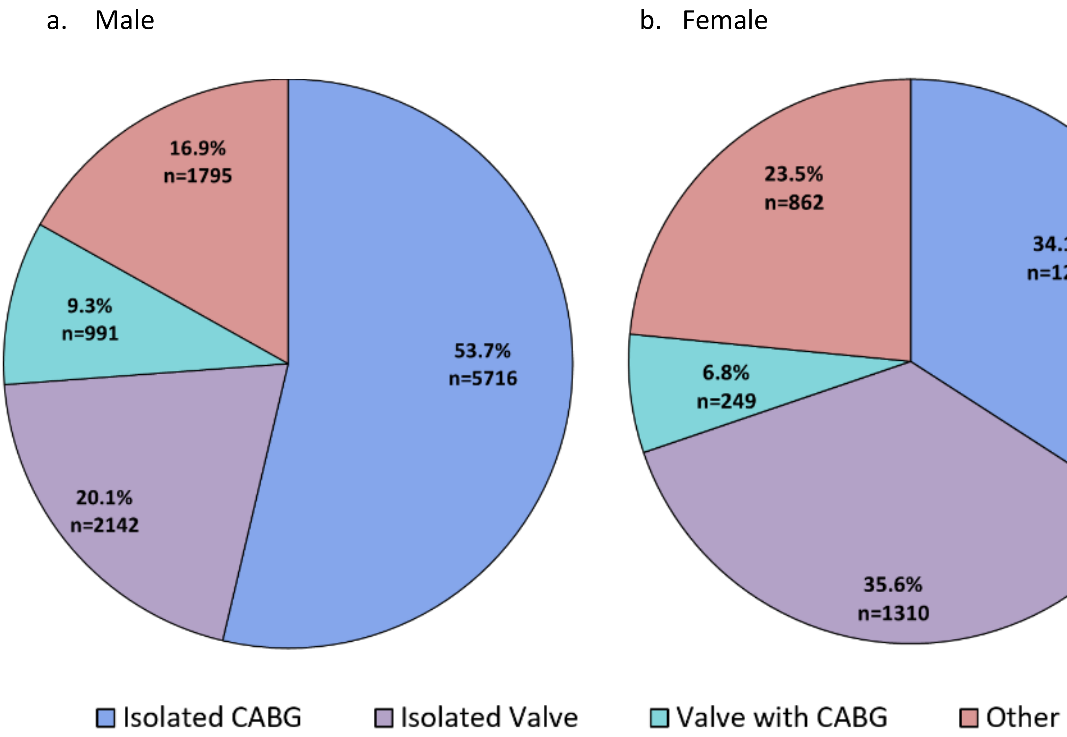
Isolated coronary artery bypass graft (CABG) surgery continued to be the most commonly performed procedure at the majority of hospitals, accounting for 48.7% of total procedures in 2018 (Figure 2). This figure decreased slightly over the last five years, from a starting point of 51.2%. The lower proportion of isolated CABG procedures in 2018 corresponded to small increases in the proportion of valve with CABG and 'other' surgery categories.

Figure 2. Cardiac procedure types performed by year



There were sex-based differences in the distribution of procedure types (Figure 3). Overall, women underwent a higher proportion of isolated valve and 'other' procedures, compared with men. In contrast, men had more CABG procedures, with or without valve surgery, which is consistent with the higher prevalence of coronary artery disease in men[1].

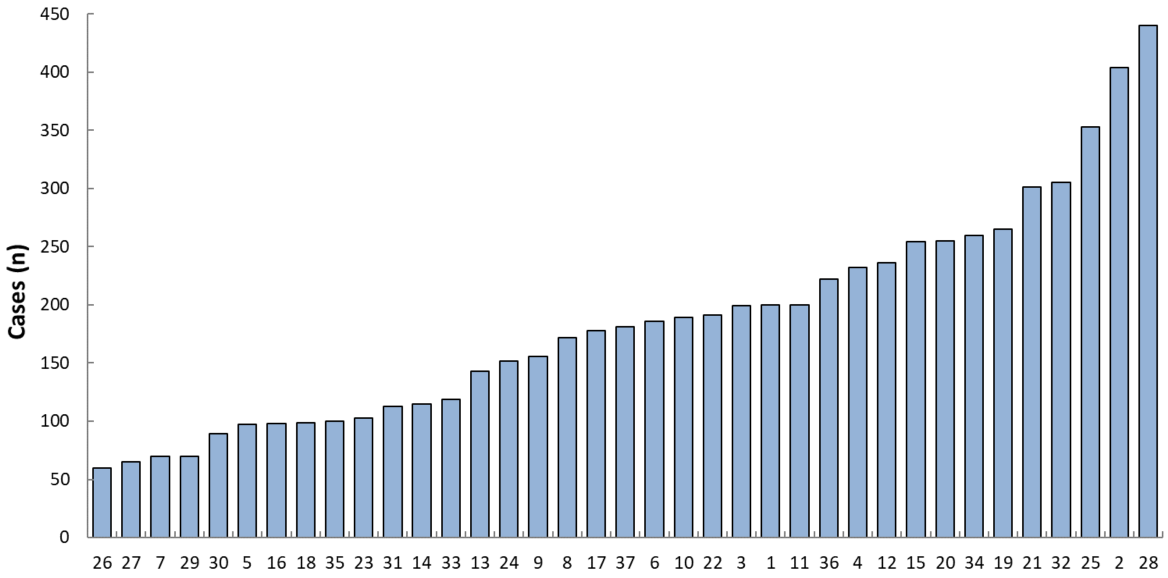
Figure 3. Cardiac procedure types by sex, 2018



1. Isolated CABG

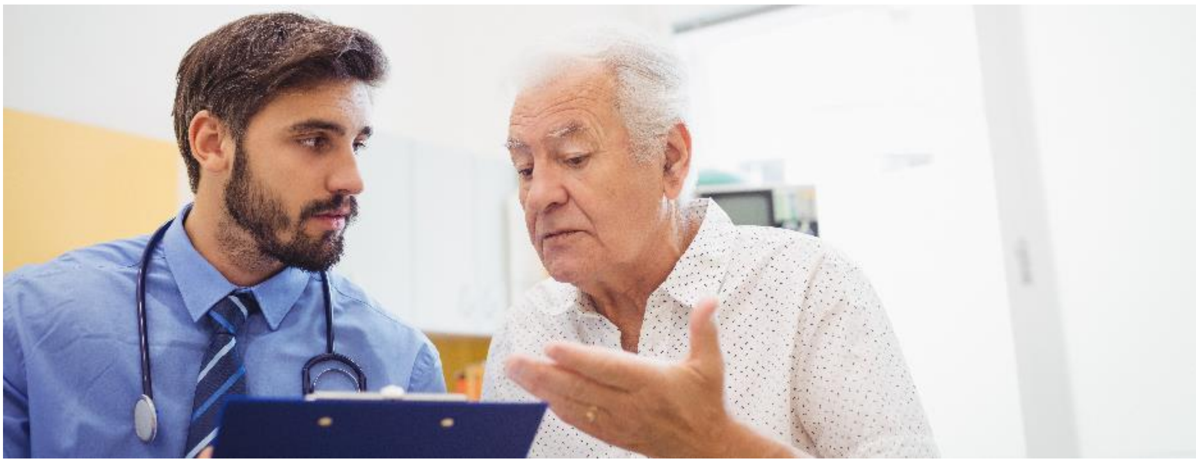
There was a wide range in the number of isolated CABG procedures performed in each unit that contributed to the ANZSCTS Database in 2018 (Figure 4). The lowest volume unit submitted 60 cases, while the highest contributed 440.

Figure 4. Isolated CABG procedures performed by unit, 2018



1.1 Patient characteristics

The risk profile of isolated CABG patients has changed significantly over the past few decades, with patients increasingly presenting later in life and with more comorbidities[2–5]. Key patient characteristics that influence the outcomes of surgery include clinical status, sex, age and comorbidities. The frequency of these factors in the Australian cardiac surgery patient population are explored in the following sections.

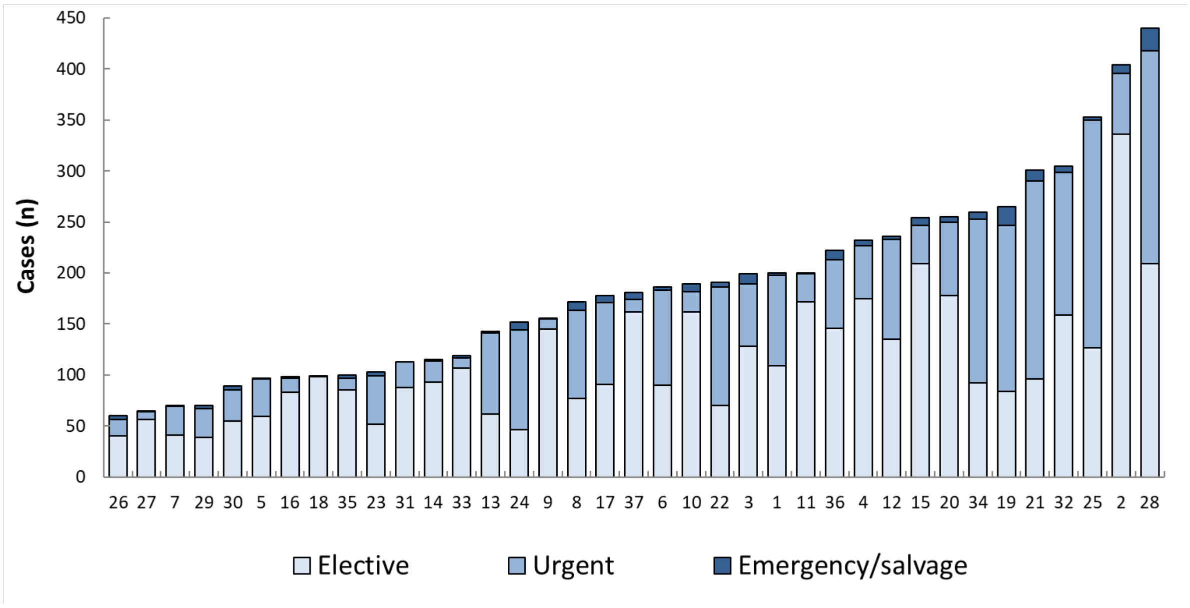


1.1.1 Clinical status

The proportion of cases deemed elective or urgent varied markedly between units (Figure 5a). The proportion of elective cases decreased overall by 12.7% since 2014, with a corresponding increase in urgent cases (Figure 5b). The frequency of emergency and salvage cases remained consistent around an average of 3.05%.

Figure 5. Clinical status of isolated CABG patients

a. Unit in 2018



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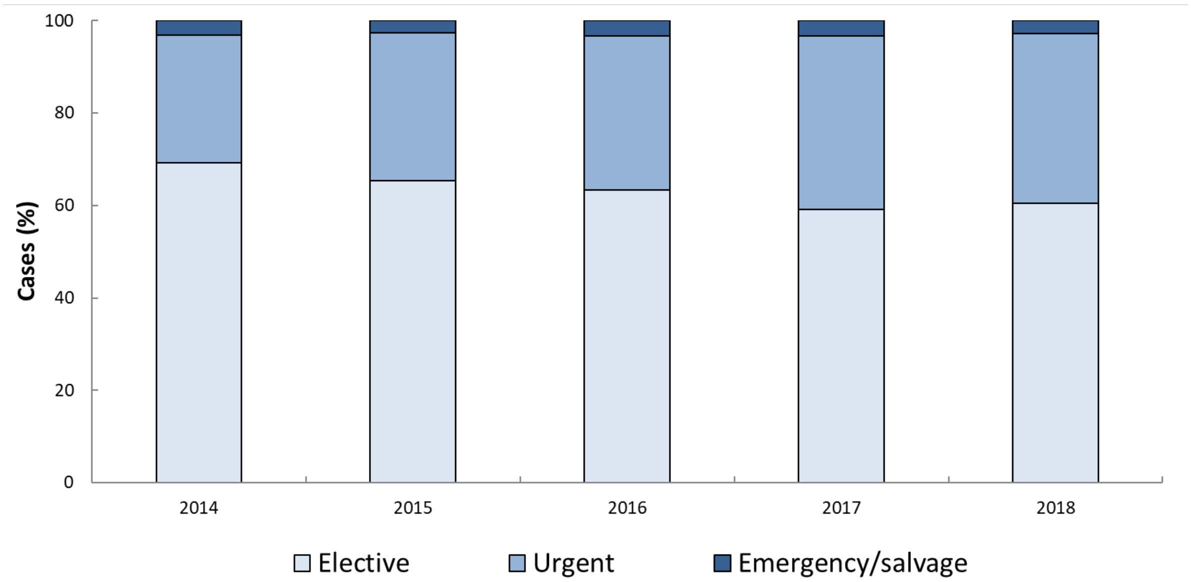
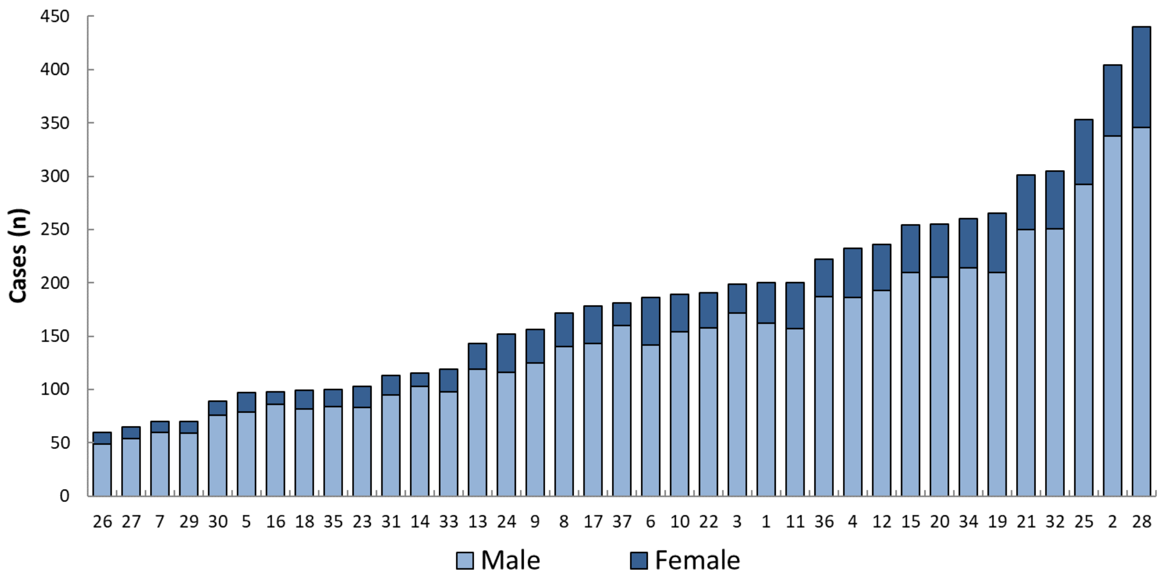


1.1.2 Sex and age

The ratio of male to female isolated CABG patients was similar between units and steady over the last five years, with 81.9% of this cohort being male (Figure 6a and b). This ratio is consistent with that reported by The Society for Cardiothoracic Surgery (SCTS) in Great Britain and Ireland in 2015, the SWEDEHEART Registry in 2018, and the New Zealand Cardiac Surgery National Report 2016[6–8].

Figure 6. Sex of isolated CABG patients

a. Unit in 2018



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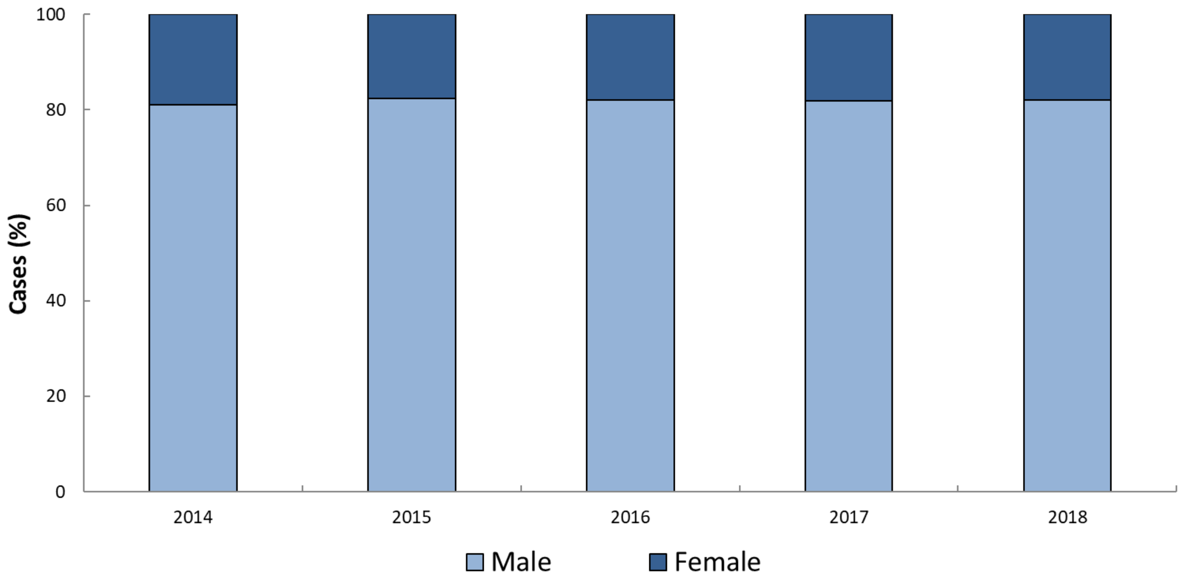
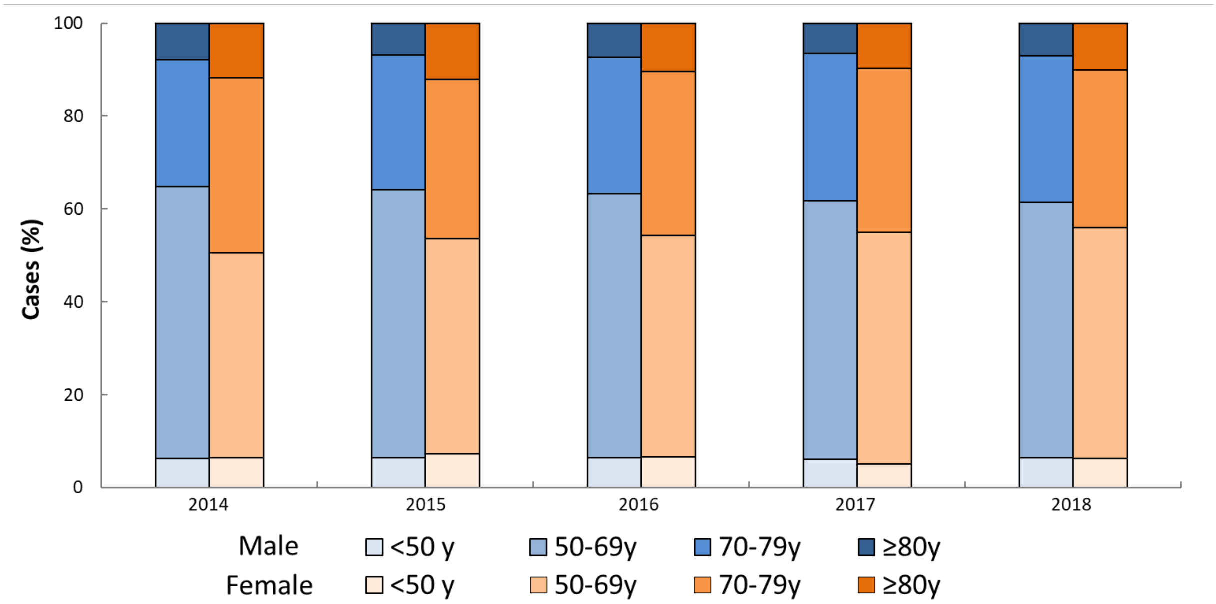


As in previous years, the majority of male isolated CABG patients were under 70 years, however this has decreased over time (Figure 7). Compared with males, a larger proportion of female patients were aged 70 years and over. It is well understood that women commonly present later in life, which is consistent with this finding[9].

Figure 7. Age groupings for male and female isolated CABG patients, 2014-2018

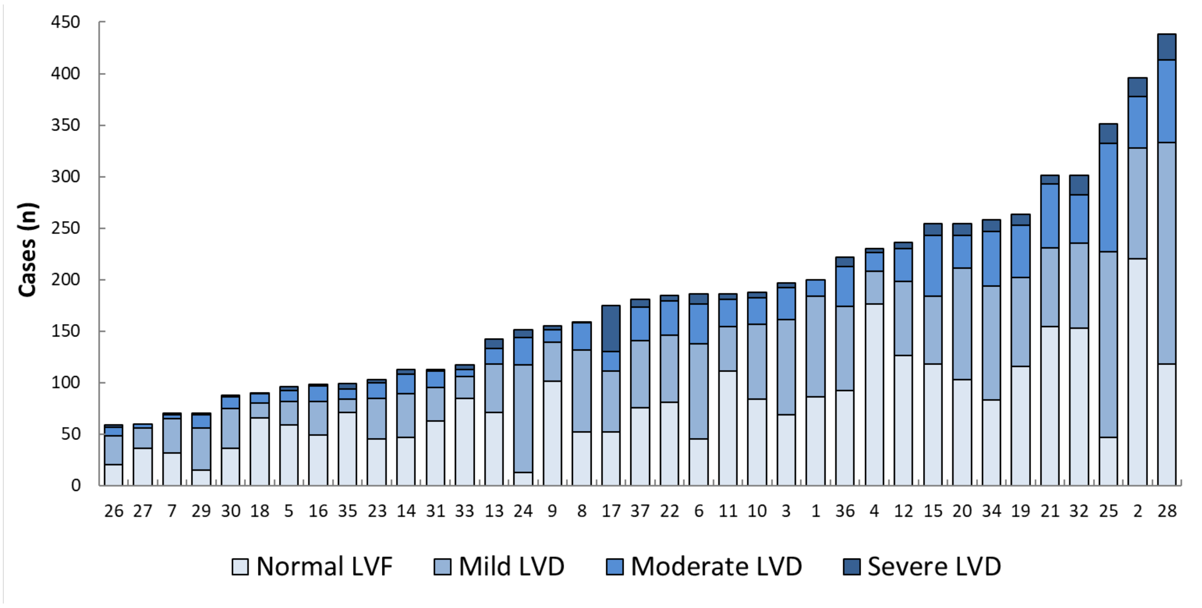


1.1.3 Left ventricular function

The majority of patients presenting for isolated CABG at each unit had either normal left ventricular function (LVF) or mild left ventricular dysfunction (LVD; Figure 8a). There was a 20.5% decrease in the proportion of patients with normal LVF between 2014 and 2018, while the proportion of patients with mild, moderate or severe LVD increased (Figure 8b).

Figure 8. Isolated CABG: pre-procedure LV function

a. Unit in 2018



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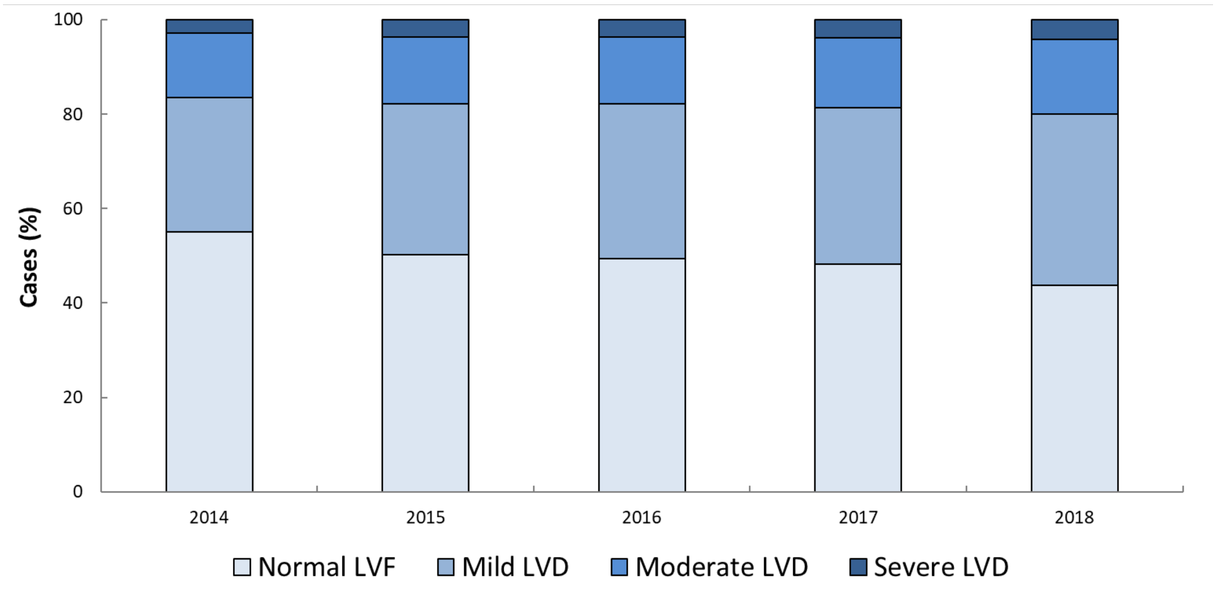
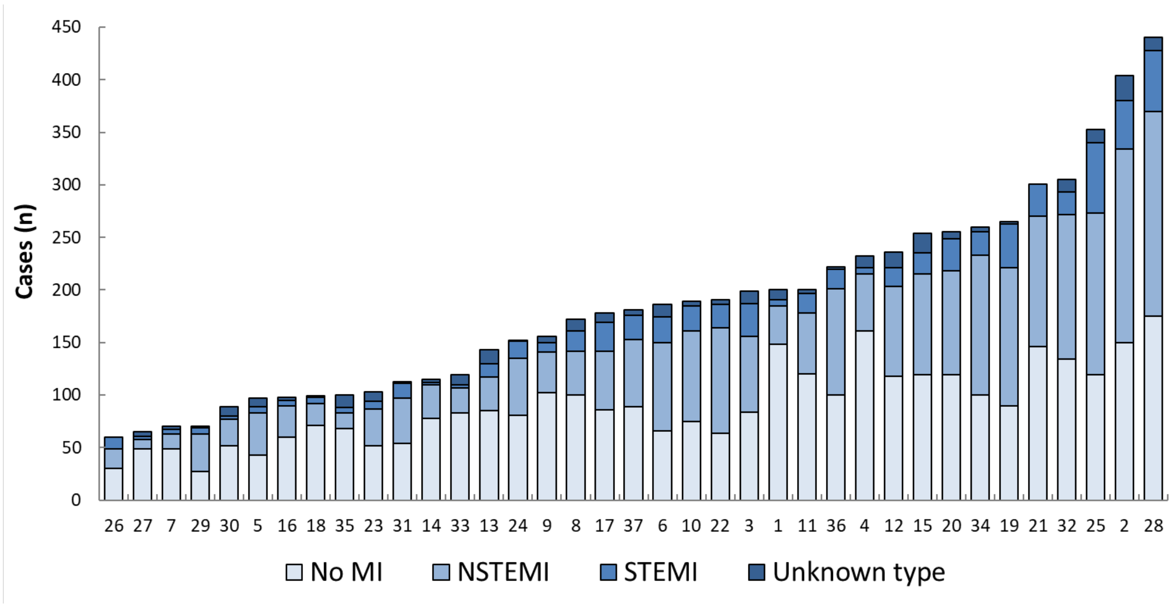


1.1.4 Previous myocardial infarction

The rates of non-ST elevation myocardial infarction (NSTEMI) and ST elevation myocardial infarction (STEMI) were consistent between units (Figure 9a). Slightly less than half the isolated CABG cohort had no previous myocardial infarction (MI) in 2018, while 37.3% presented with prior NSTEMI and 10.0% had a previous STEMI (Figure 9b).

Figure 9. Isolated CABG: prior MI

a. Unit in 2018



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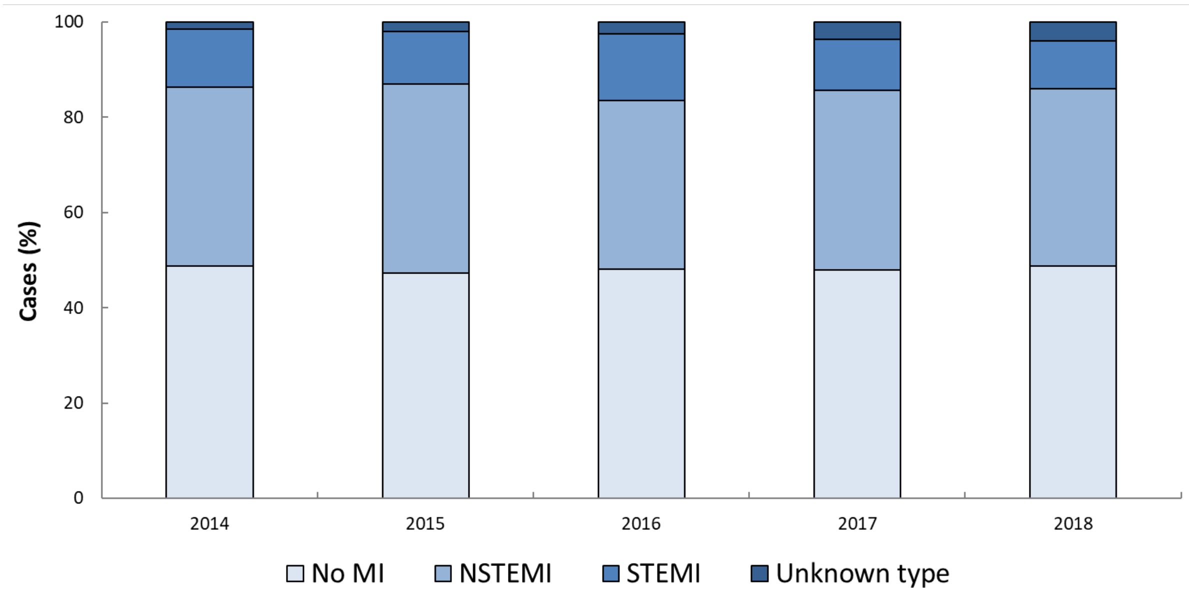
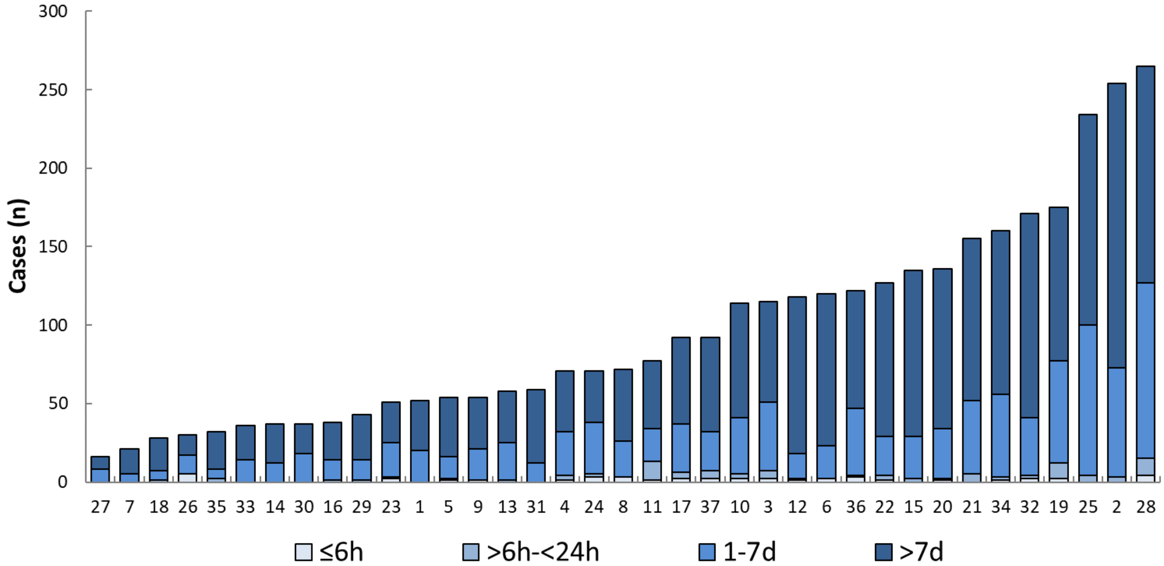


1.1.5 Timing of prior myocardial infarction

The majority of previous MIs occurred more than seven days prior to procedure for all units, and on average every year since 2014 (Figure 10a and b). Over the last five years, 1.23% of MIs occurred less than six hours before isolated CABG.

Figure 10. Isolated CABG: timing of pre-procedure MI

a. Unit in 2018



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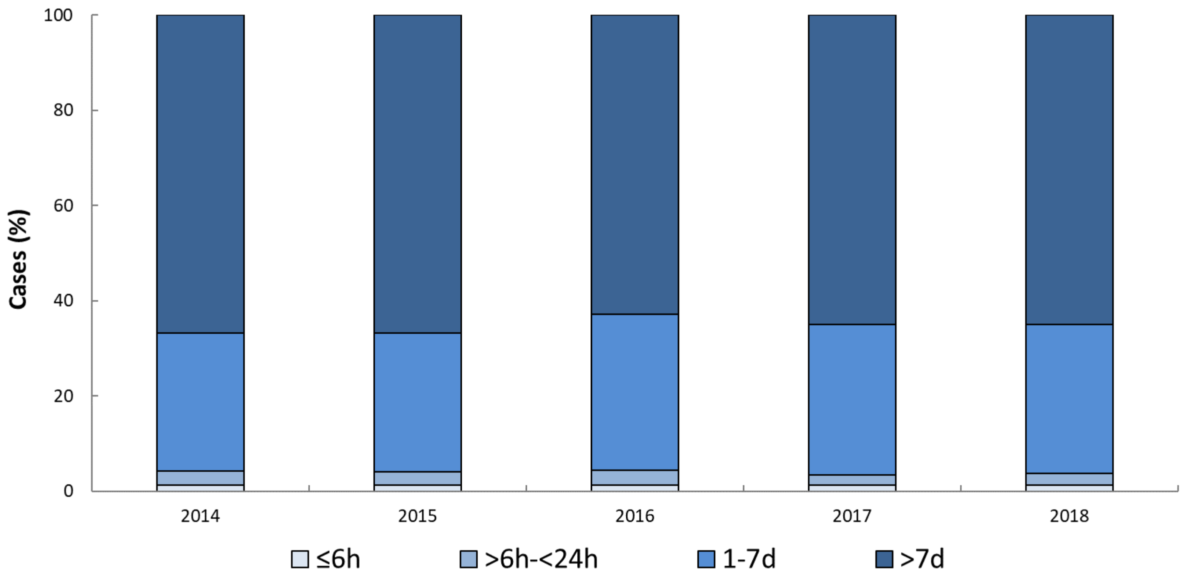
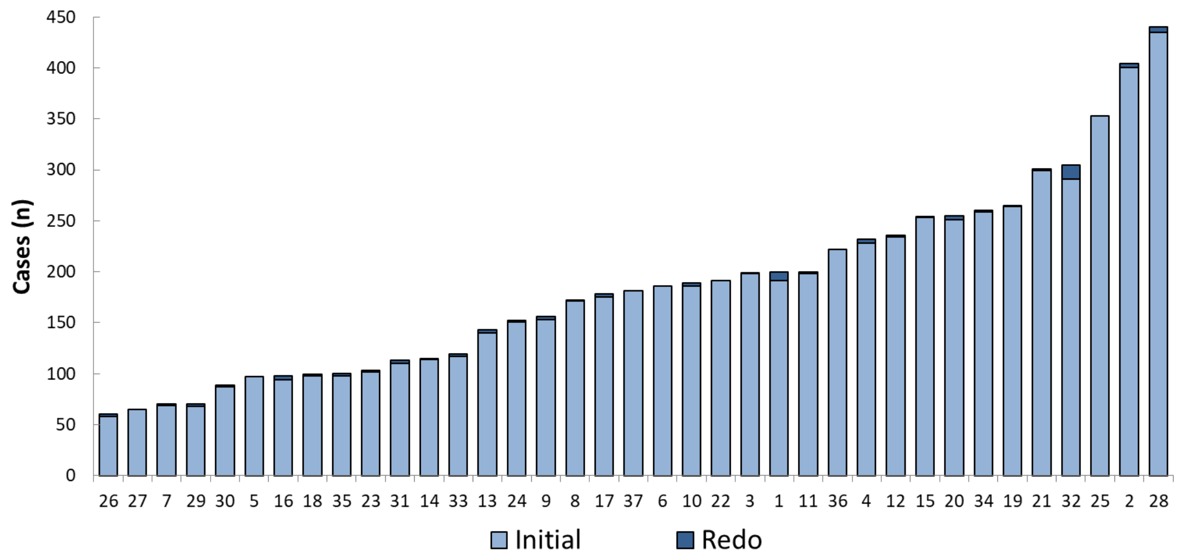


1.2 Previous coronary surgery

Only 1.24% of isolated CABG procedures in 2018 were redo surgery, and this was fairly consistent between units (Figure 11a). There was a steady reduction in the proportion of redo surgeries between 2014 and 2018, however the 2018 rate is double that reported by the SWEDEHEART registry[6] (Figure 11b).

Figure 11. Initial and redo isolated CABG

a. Unit in 2018



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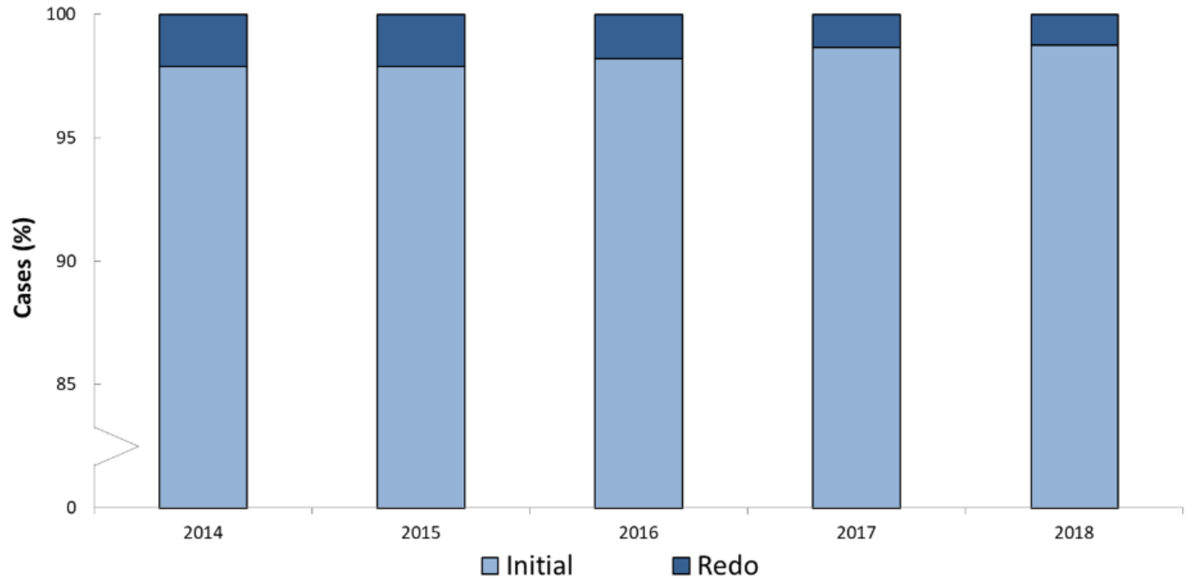
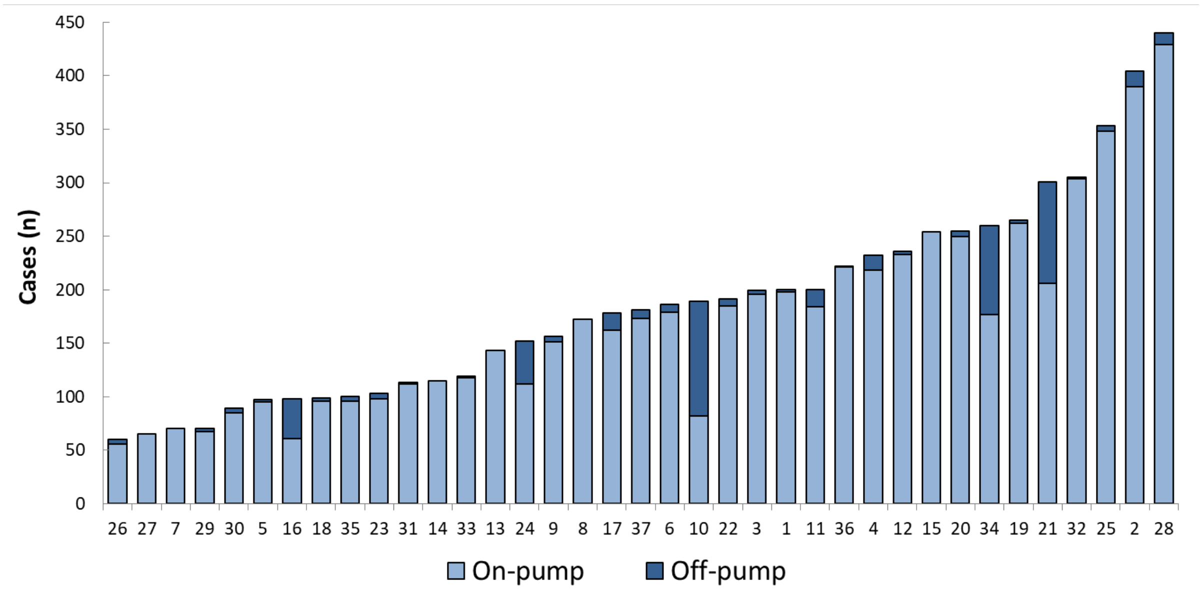


1.3 On-pump and off-pump coronary surgery

Most units perform relatively few off-pump CABGs; however, in 2018 five units did more than one quarter of their cases without cardiopulmonary bypass (CPB; Figure 12a). Overall, the rate of off-pump isolated CABG in 2018 was 7.41% and this has remained consistent since 2015 (Figure 12b).

Figure 12. On-pump and off-pump isolated CABG

a. Unit in 2018



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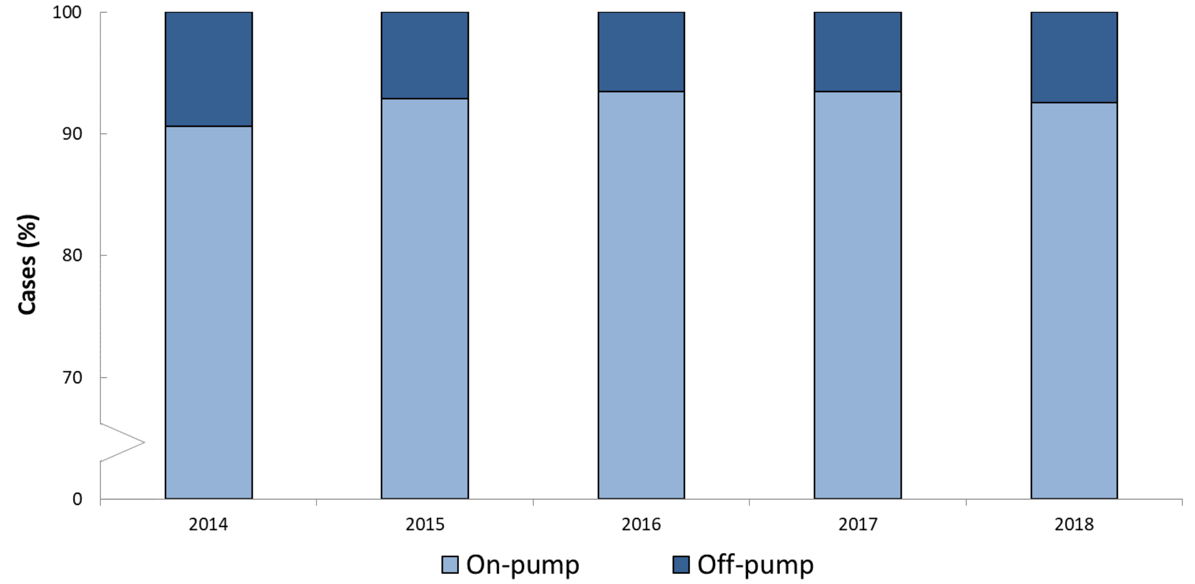


1.4 Conduit selection

1.4.1 Conduits used and distal anastomoses performed

Over the last five years, the all-arterial technique was only used in approximately one fifth of on-pump cases but in more than half of off-pump. Off-pump CABG involved a lower mean number of anastomoses (Table 2a).

In 2018, 94.4 and 96.5% of patients having on- or off-pump isolated CABG, respectively, had left internal thoracic artery (LITA) and/or right internal thoracic artery (RITA) conduits, with or without other arterial or vein conduits (Table 2b). Radial artery (RA) conduits were used in 38.4% of off-pump cases, and 24% of on-pump procedures. Bilateral internal thoracic artery (BITA) conduits and T or Y grafts were uncommon, but used more frequently in off-pump procedures.

Table 2a. Summary of anastomoses and conduits for on-pump and off-pump isolated CABG

		On-pump	Off-pump
n	2018	6363	509
	2014-2017	22910	1790
Mean no. anastomoses	2018	3.1	2.5
	2014-2017	3.2	2.4
Only arterial conduits (%)	2018	22.4	50.5
	2014-2017	21.3	62.6
Arterial with saphenous vein conduits* (%)	2018	77.5	49.5
	2014-2017	78.6	37.2

*Proportion of procedures in which at least one vein conduit was used

Table 2b. Arterial conduits used for on-pump and off-pump isolated CABG (% of cases)

		On-pump	Off-pump
BITA	2018	8.3	18.9
	2014-2017	8.6	25.2
GEPA~	2018	0.0	0.0
	2014-2017	0.2	0.3
LITA or RITA	2018	86.1	77.6
	2014-2017	85.9	72.6
RA (x1 or x2)	2018	38.4	24.0
	2014-2017	37.0	28.9
T or Y grafts*^	2018	9.5	15.9
	2014-2017	9.4	22.2

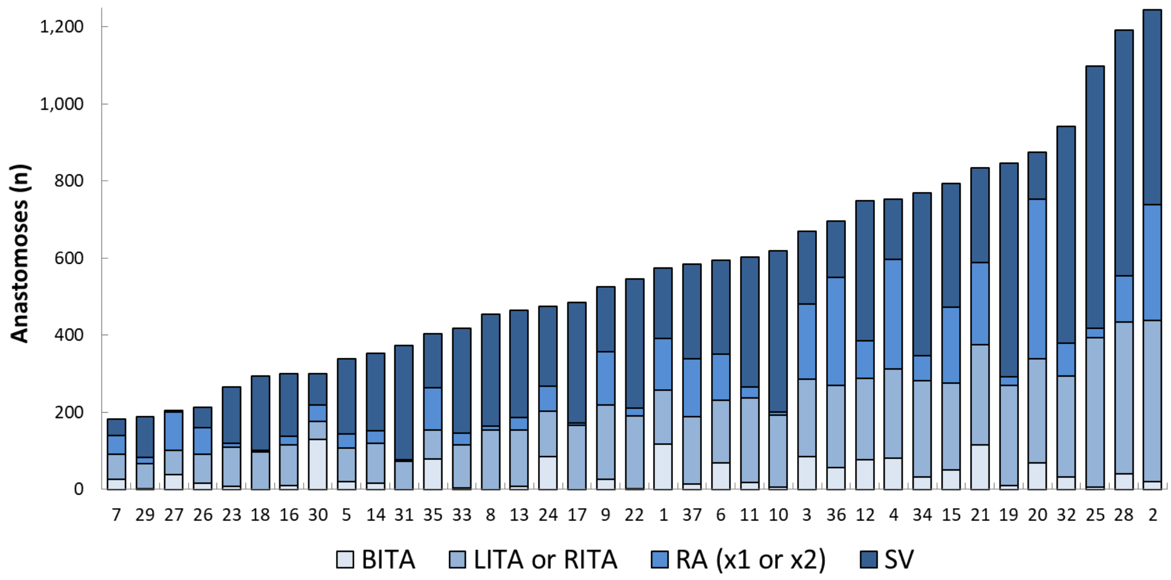
~GEPA = gastroepiploic artery
*Arterial only
^Seven and 14 missing cases in 2018 and 2014-2017, respectively

1.4.2 Conduits used for anastomoses

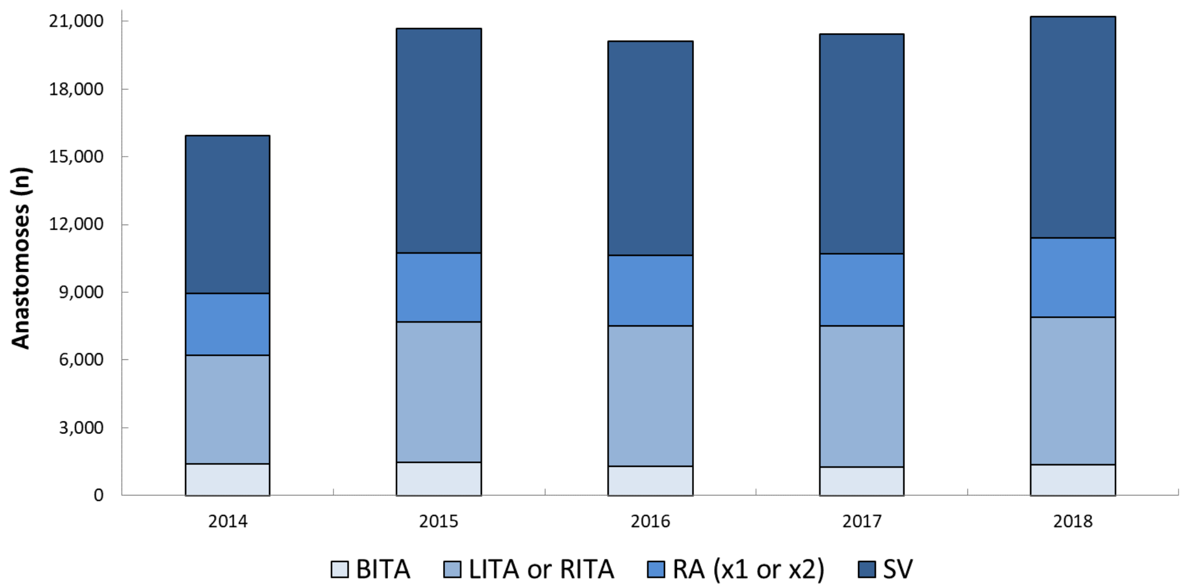
The choice of conduits for isolated CABG differed between units; the greatest variation being in the use of saphenous veins (SV; Figure 13a). The overall number of anastomoses performed using each type of conduit remained consistent between 2015 and 2018, inclusive (Figure 13b). In 2018 SV was used for 46.2% of anastomoses, internal thoracic artery (ITA) for 37.1%, and RA for 16.7%. It should be noted that the number of hospitals contributing these data has changed each year.

Figure 13. Number of arterial and venous anastomoses used in isolated CABG

a. Unit in 2018



b. Year



1.5 Effect of co-morbidities on complications

Post-operative complications considered in this report include permanent stroke, deep sternal wound infection (DSWI), new cardiac arrhythmia (NCA), and re-operation (re-op) for bleeding or tamponade. Data on the incidence of derived new renal insufficiency (DNRI) is presented separately, to allow for the exclusion of patients with pre-operative renal impairment. In the following section, these complications are evaluated in the context of key cardiac surgery patient comorbidities.

1.5.1 Pre-existing diabetes and renal impairment

Thirty-nine percent of patients in the isolated CABG cohort had diabetes, which is substantially higher than the 29.3% reported in New Zealand isolated CABG patients at public hospitals in 2016[7].

This report compares two parameters of renal impairment: patients with a pre-operative creatinine level of ≥200 µmol/L or those with a pre-operative estimated glomerular filtration rate (eGFR) ≤60 mL/min/1.73m^2.

The data demonstrate that the incidence of permanent stroke, DSWI, and re-op for bleeding was higher in patients with diabetes and those with either measure of pre-operative renal impairment (Table 3). The incidence of NCA in 2018 was reasonably consistent between patients with and without diabetes and/or a pre-operative creatinine level of ≥200 µmol/L, but noticeably higher in patients with a pre-op eGFR ≤60.

Table 3. Complications (%) for isolated CABG patients on the basis of pre-operative diabetes and renal function status

		Diabetes*^		Pre-op creatinine		Pre-op eGFR	
		No	Yes	<200 µmol/L	≥200 µmol/L	>60mL /min/1.73m^2	≤60mL /min/1.73m^2
n	2018	4104	2766	6667	205	5467	1405
	2014-2017	15150	9538	24014	686	18984	5716
Permanent stroke#	2018	0.7	1.3	0.9	1.5	0.6	2.0
	2014-2017	0.7	1.0	0.8	2.0	0.7	1.4
DSWI~	2018	0.6	1.8	1.0	3.1	1.0	1.2
	2014-2017	1.0	1.8	1.3	2.9	1.2	1.5
NCA†	2018	27.5	25.5	26.6	28.6	25.5	31.1
	2014-2017	26.2	25.3	25.7	30.8	24.5	30.2
Re-op for bleeding‡	2018	2.4	2.7	2.5	3.4	2.3	3.1
	2014-2017	2.3	2.2	2.2	4.1	2.0	2.9

*Two and 12 cases missing diabetes data in 2018 and 2014-2017, respectively
^Refers to all diabetes, regardless of type of therapy
#Seven and 17 cases missing permanent stroke data in 2018 and 2014-2017, respectively
~82 and 318 cases missing DSWI data in 2018 and 2014-2017, respectively
†Seven and 15 cases missing NCA data in 2018 and 2014-2017, respectively
‡Seven and 17 cases missing Re-op bleeding data in 2018 and 2014-2017, respectively

1.5.2 Age

Advancing age was associated with higher incidence of permanent stroke and NCA, while DSWI and re-op for bleeding appeared to be independent of age (Table 4).

Table 4. Complications (%) for isolated CABG patients on the basis of patient age^

		Age*			
		<50 y	50-69 y	70-79 y	≥80 y
n	2018	443	3712	2199	518
	2014-2017	1575	13635	7557	1930
Permanent stroke	2018	0.2	0.9	1.0	1.2
	2014-2017	0.5	0.7	1.2	1.0
DSWI	2018	0.7	1.1	1.2	0.6
	2014-2017	1.0	1.3	1.5	1.2
NCA	2018	12.9	22.6	32.7	42.0
	2014-2017	10.2	22.2	33.0	36.3
Re-op for bleeding	2018	2.7	2.3	2.6	3.3
	2014-2017	2.7	2.0	2.4	2.7

^Same missing data for complications applies as for Table 3

*Three missing cases from 2014-2017 age group

1.5.3 Surgical history or use of cardiopulmonary bypass

The incidence of post-operative complications was similar between patients who did or did not have redo or off-pump surgery, although in 2018, redo surgery was associated with a relatively high stroke rate. (Table 5).

Table 5. Complications (%) for isolated CABG patients on the basis of redo surgery or use of CPB^

		Surgery		CPB	
		Initial	Redo	On-pump	Off-pump
n	2018	6787	85	6363	509
	2014-2017	24253	447	22910	1790
Permanent stroke	2018	0.9	4.8	0.9	1.0
	2014-2017	0.8	0.7	0.9	0.6
DSWI	2018	1.1	0.0	1.1	1.0
	2014-2017	1.3	1.9	1.3	0.8
NCA	2018	26.7	20.2	26.9	23.6
	2014-2017	25.8	28.2	26.0	23.8
Re-op for bleeding	2018	2.5	2.4	2.5	2.2
	2014-2017	2.2	2.2	2.2	2.6

^Same missing data for complications applies as for Table 3

1.5.4 Effect of comorbidities on derived new renal insufficiency

The incidence of DNRI was markedly higher in patients with diabetes, advancing age, and those having redo or on-pump surgery (Table 6). Unsurprisingly, in 2018, patients with pre-operative creatinine ≥200 µmol/L or eGFR ≤60 mL/min/1.73m^2 had five- and three-fold increases in the incidence of DNRI, respectively. These data exclude patients who had pre-operative dialysis.

Table 6. DNRI (%) for isolated CABG patients on the basis of diabetes, renal impairment, age, surgical history and use of CPB

	2018		2014-2017	
	n	DNRI (%)‡	n	DNRI (%)‡
Diabetes*^				
No	4042	2.1	14433	2.2
Yes	2668	2.9	8911	3.9
Pre-op creatinine				
<200 µmol/L	6614	2.3	23007	2.6
≥200 µmol/L	97	12.4	337	18.1
Pre-op eGFR				
>60mL/min/1.73m^2	5451	1.8	18203	2.2
≤60mL/min/1.73m^2	1260	5.2	5141	5.3
Age†				
<50y	424	1.9	1488	2.4
50-69y	3619	2.1	12861	2.5
70-79y	2158	3.1	7160	3.3
≥80y	510	2.9	1832	4.4
Previous surgery				
Initial	6629	2.4	22929	2.8
Redo	82	3.7	415	4.1
Cardiopulmonary bypass				
On-pump	6216	2.5	21599	2.9
Off-pump	495	2.0	1745	1.8

‡41 and 940 cases missing DNRI data in 2018 and 2014-2017, respectively

Note: the amount of missing data for DNRI in 2014-2017 is largely due to a lack of post-operative creatinine data from one hospital for a portion of this period.

*One case missing for 2018 and 2014-2017

^Refers to all diabetes, regardless of type of therapy

†Three cases missing for 2014-2017

1.6 Influence of patient characteristics on mortality

In 2018, observed mortality (OM) rates increased with more urgent status of surgery, advancing age, worsening LVF, the occurrence of a pre-operative MI, and redo surgery (Table 7). These trends matched those observed in the pooled data for 2014-2017. It should be noted that observed mortality is not risk-adjusted and does not account for differences in patient characteristics.

Table 7. Observed mortality (%) for isolated CABG patients on the basis of patient characteristics

	2018		2014-2017	
	n	OM (%)	n	OM (%)
Clinical status				
Elective	4156	0.7	15794	0.8
Urgent	2525	1.2	8135	1.3
Emergency/salvage	191	6.3	771	6.5
Sex/age				
Male*	5638	0.9	20220	1.1
<50y	365	0.3	1291	0.6
50-69y	3099	0.5	11521	0.7
70-79y	1781	1.5	5966	1.6
≥80y	393	1.3	1439	2.4
Female	1234	1.9	4480	1.4
<50y	78	0.0	284	0.0
50-69y	613	1.1	2114	0.8
70-79y	418	2.9	1591	2.1
≥80y	125	4.0	491	2.4
Left ventricular function^				
Normal LVF	2971	0.7	12280	0.7
Mild LVD	2455	0.9	7756	0.8
Moderate LVD	1071	1.4	3458	2.1
Severe LVD	288	4.9	856	6.2
Previous MI				
No MI	3347	0.7	11850	0.7
NSTEMI	2561	1.3	9288	1.4
STEMI	689	2.0	2945	2.1
Unknown type	275	0.4	617	1.1
Timing of prior MI				
≤6h	42	7.1	160	11.9
>6h-<24h	87	6.9	350	6.3
1-7d	1104	1.8	3950	1.5
>7d	2289	0.9	8387	1.2
Previous surgery				
Initial	6787	1.0	24253	1.1
Redo	85	4.7	447	3.1
Cardiopulmonary bypass				
On-pump	6363	1.0	22910	1.2
Off-pump	509	1.4	1790	0.9

*Three cases missing from 2014-2017 male age group

^16 and 86 cases missing EF data in 2018 and 2014-2017, respectively. 71 and 264 cases had no angiogram performed in 2018 and 2014-2017, respectively

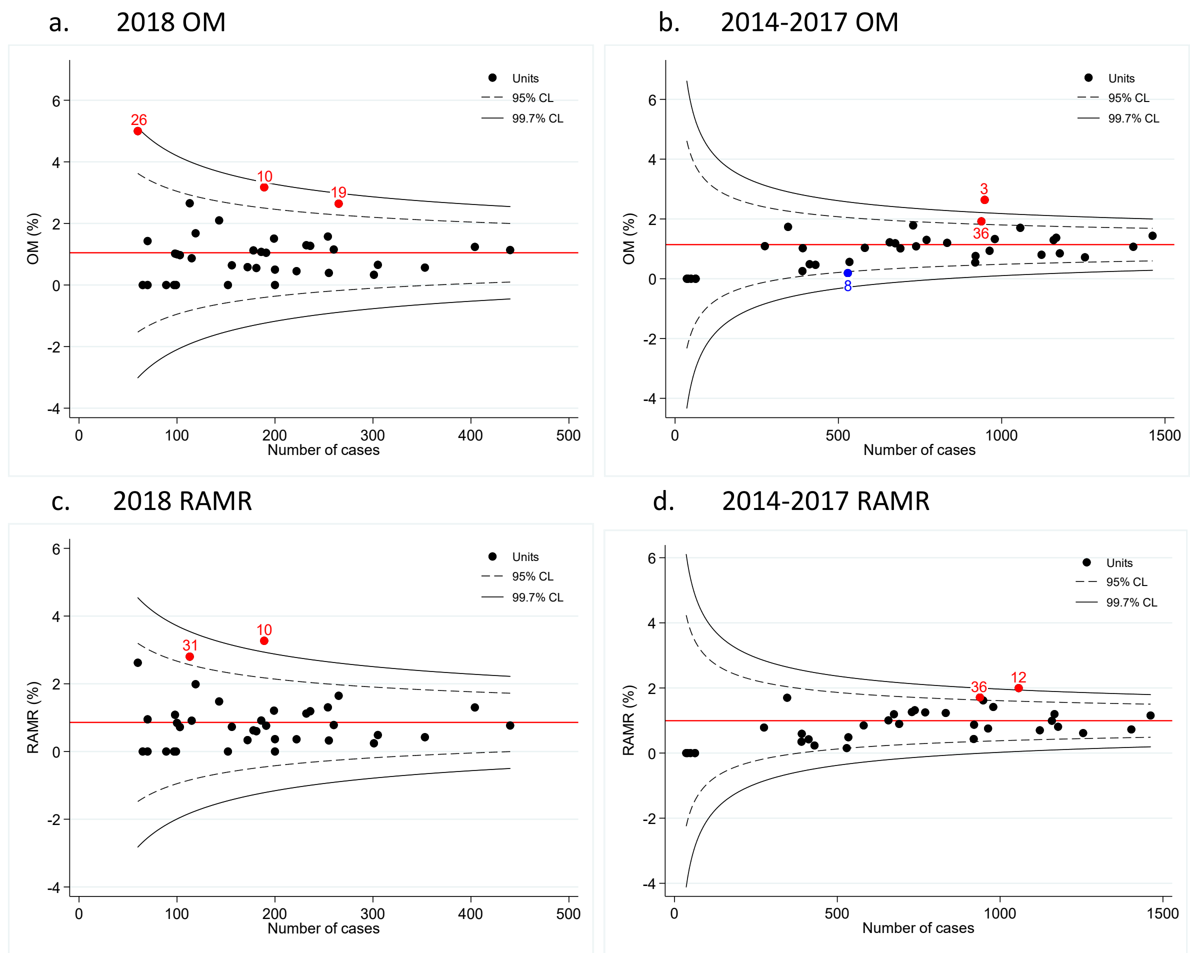
1.7 Unit outcomes – mortality, complications and resource utilisation

Unit outcomes for mortality and complications are presented in funnel plots, which are explained in detail in Appendix D-I. The solid line in each plot represents the average value. Units above the upper 99.7% control limit (CL) are notified and managed as outlined in Appendix A. Note that cases with missing outcome data are excluded from the analyses. The complications explored in this section are permanent stroke, DNRI, DSWI, NCA, readmission, and re-op for bleeding. The resource utilisation variables include duration of ICU stay and ventilation, red blood cell (RBC) and non-RBC transfusion (NRBC), and pre and post-procedural length of stay (PLOS).

1.7.1 Mortality

OM was 1.05% in 2018, and 1.14% in 2014-2017 for all isolated CABG patients in the ANZSCTS Database (Figure 14a and b). This is comparable to New Zealand, which reported 1.54% in-hospital mortality in 2016; the SCTS, which reported 1.05% in first-time isolated CABG patients in 2015; the STS, which published an unadjusted operative mortality of approximately 2.25% for January to September 2018, and the SWEDEHEART registry, which had a 30 day mortality rate of 0.93% for 2018[6–8,10]. The risk-adjusted mortality rate (RAMR) was below 1% in 2018 and the pooled data for the preceding four years (Figure 14c and d). Refer to Appendix E for further information regarding how the Database determines the risk adjusted mortality rate.

Figure 14. Mortality by unit following isolated CABG



1.7.2 Complications

The average rates of post-operative complications in 2018 were similar to the preceding four years (Figures 15-20). The lowest frequency events were permanent stroke (mean of 0.92%) and DSWI (1.06%), followed by re-op for bleeding (2.51%) and DNRI (2.44%). Mean rates of readmission and NCA were 9.58% and 26.7%, respectively. The data for DNRI excludes patients who received pre-operative dialysis (Figure 16).

Figure 15. Permanent stroke by unit following isolated CABG

a. 2018 Permanent stroke

b. 2014-2017 Permanent stroke

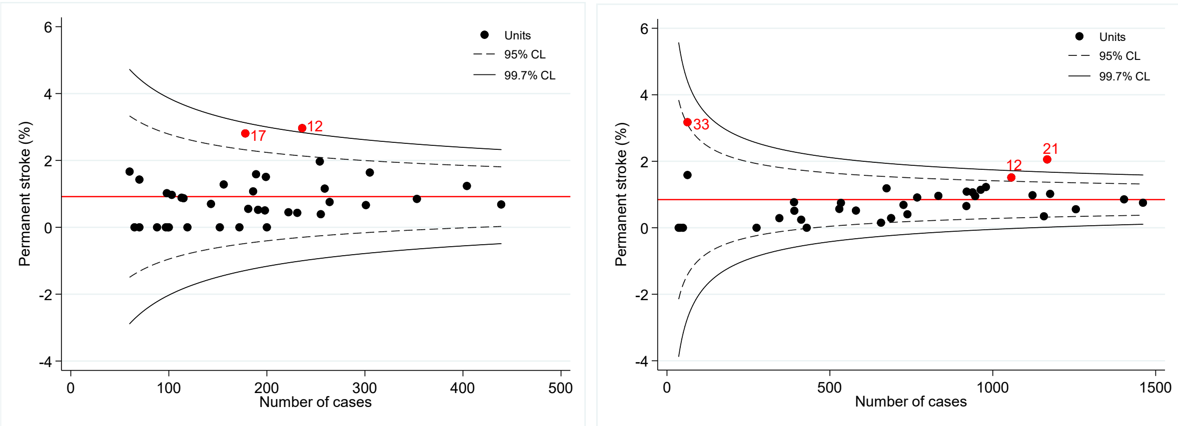


Figure 16. DNRI by unit following isolated CABG

a. 2018 DNRI

b. 2014-2017 DNRI

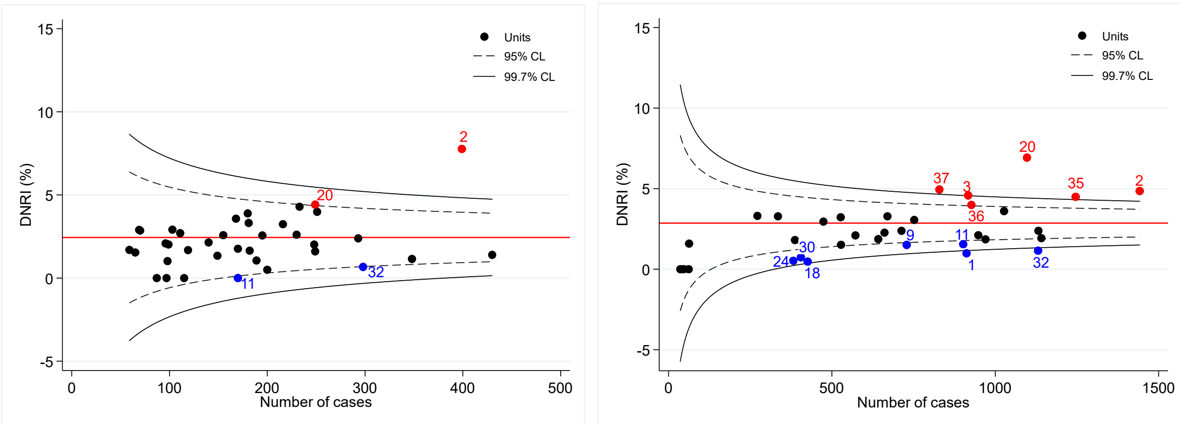


Figure 17. DSWI by unit following isolated CABG

a. 2018 DSWI

b. 2014-2017 DSWI

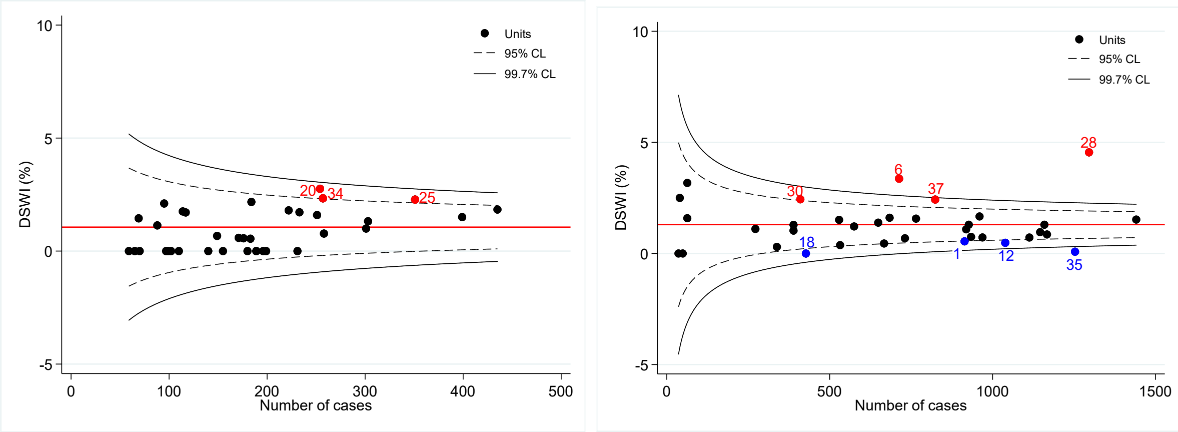


Figure 18. NCA by unit following isolated CABG

a. 2018 NCA

b. 2014-2017 NCA

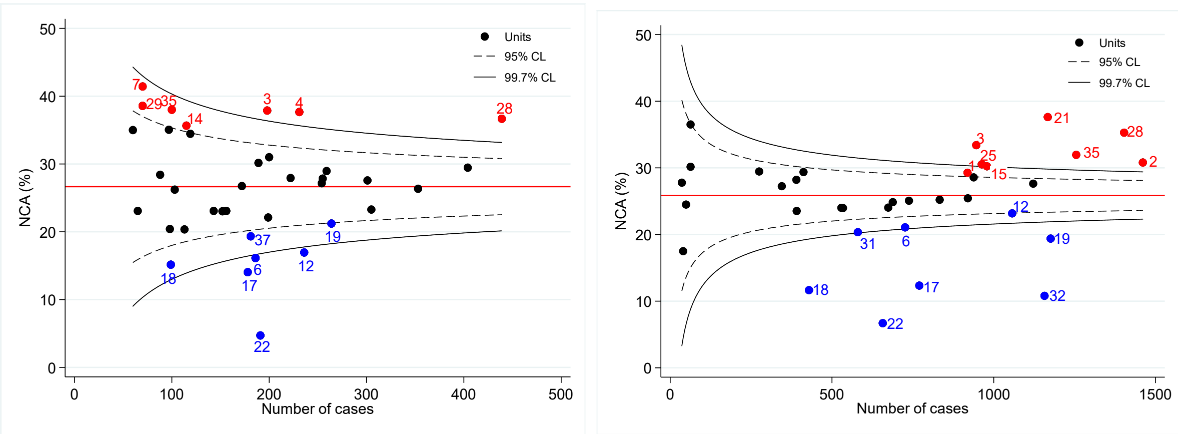


Figure 19. Re-operation for bleeding by unit following isolated CABG

a. 2018 Re-op for bleeding

b. 2014-2017 Re-op for bleeding

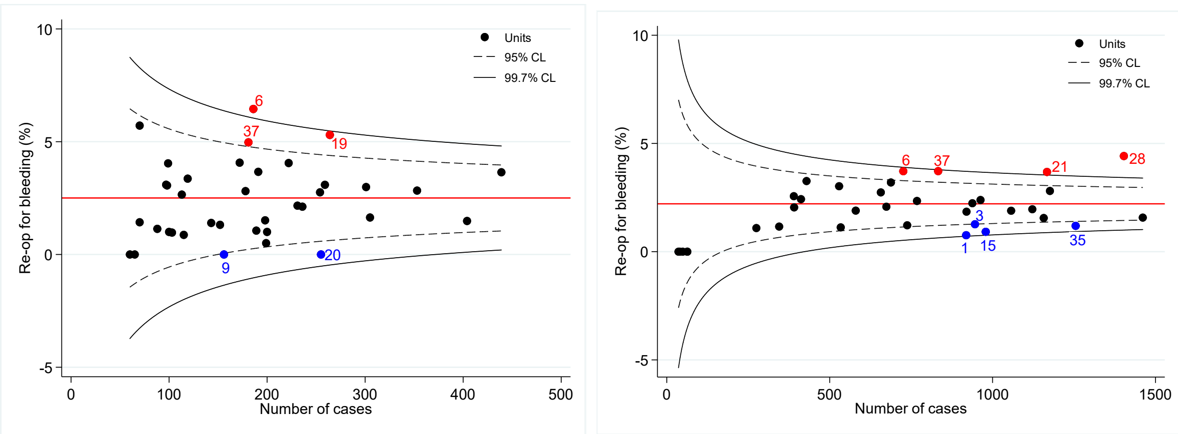
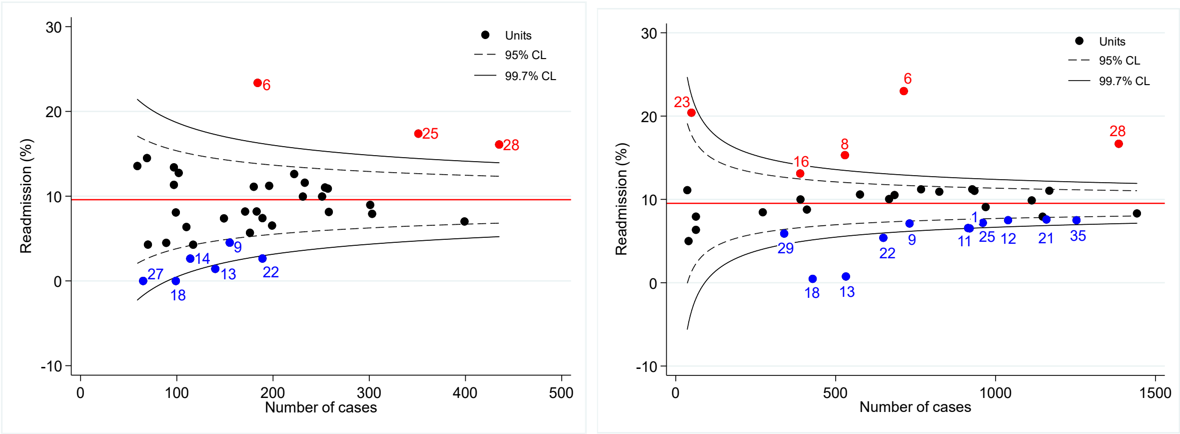


Figure 20. Readmission by unit following isolated CABG

a. 2018 Readmission

b. 2014-2017 Readmission



1.7.3 Resource utilisation

Due to the skewed distribution of the ICU length of stay and ventilation data, the geometric means (GM) are presented. The GM is defined as the nth root of a product of n numbers. It is useful to describe the central tendency of a set of skewed data, as it is less sensitive to outlying values.

In 2018 and the pooled data for the preceding four years, there was marked variation between units in the time patients spent in the ICU, the duration of ventilation, and the percentage of patients who received RBC or NRBC transfusions (Tables 8 and 9).

Table 8. Resource utilisation by unit for isolated CABG patients, 2018

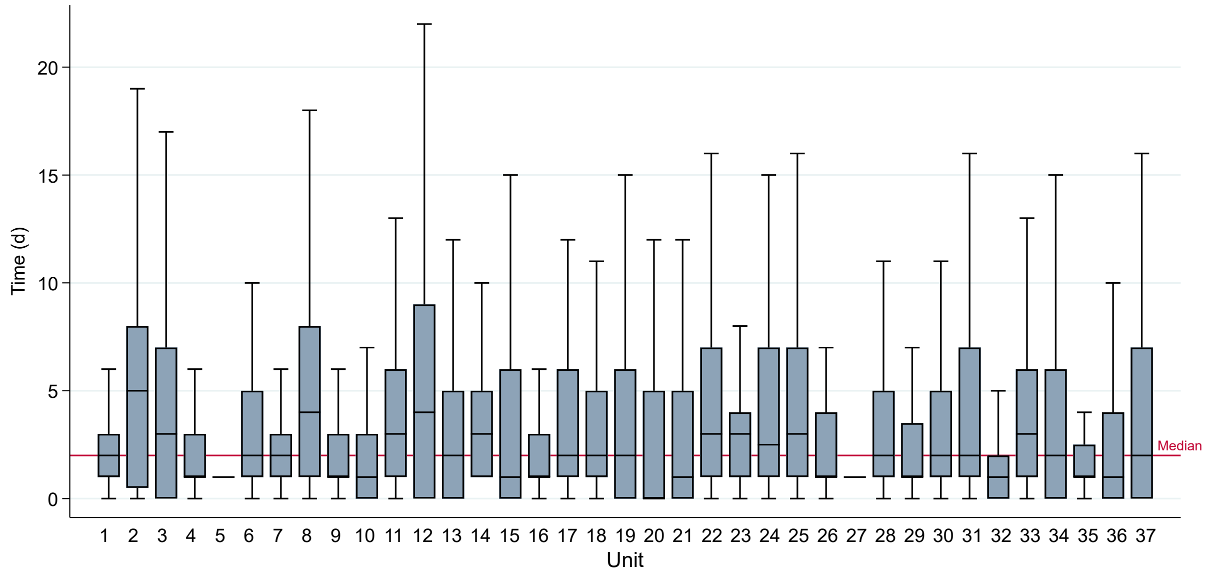
	2018			
Unit	ICU (GM, h)	Ventilation (GM, h)	RBC usage (%)	NRBC usage (%)
1	54.3	10.1	13.5	6.5
2	42.1	8.6	24.8	9.7
3	38.9	9.5	17.6	8.0
4	58.2	9.8	32.8	17.7
5	69.4	7.8	25.8	35.1
6	41.1	12.2	24.2	15.6
7	80.1	7.4	32.9	12.9
8	32.4	9.7	27.9	24.4
9	37.7	5.4	17.9	16.0
10	39.1	7.4	21.7	13.2
11	45.3	12.3	43.2	18.1
12	64.6	12.2	33.5	18.6
13	36.9	7.7	20.3	22.4
14	73.0	14.7	12.2	4.3
15	30.7	11.6	34.3	16.5
16	55.1	7.5	13.3	18.4
17	46.9	12.8	29.8	17.4
18	78.4	14.6	18.2	5.1
19	57.5	10.9	34.7	27.9
20	31.3	9.2	34.9	12.2
21	81.7	8.0	35.9	23.6
22	43.3	11.3	29.8	24.6
23	34.7	6.1	14.6	35.0
24	71.9	11.4	32.5	15.9
25	24.9	8.8	12.2	5.9
26	29.2	7.7	8.3	5.0
27	49.4	7.4	26.2	23.1
28	31.6	8.0	23.6	19.8
29	39.4	8.2	15.7	0.0
30	58.7	12.6	26.4	23.0
31	62.6	14.7	42.5	38.1
32	109.1	11.9	41.3	23.3
33	63.7	15.0	26.1	43.7
34	41.4	8.1	28.1	18.5
35	58.8	8.1	48.0	18.0
36	45.7	9.9	34.7	24.8
37	36.6	10.6	35.4	26.5
Total	46.6	9.7	27.8	18.2

Table 9. Resource utilisation by unit for isolated CABG patients, 2014-2017

	2014-2017			
Unit	ICU (GM, h)	Ventilation (GM, h)	RBC usage (%)	NRBC usage (%)
1	52.7	8.5	11.2	7.4
2	51.6	8.3	29.5	16.0
3	43.0	11.2	16.7	11.5
5	63.5	6.7	22.2	30.6
6	37.3	11.2	29.8	23.8
8	31.8	9.9	21.2	22.7
9	34.4	6.0	18.7	15.4
10	34.8	7.9	26.3	22.0
11	44.8	11.0	43.3	24.0
12	58.1	13.0	28.8	17.3
13	37.7	8.3	25.3	25.3
14	77.2	13.3	9.5	1.6
15	32.0	10.7	33.9	15.8
16	57.0	7.7	20.8	18.7
17	46.9	13.2	33.9	19.5
18	74.3	15.9	21.2	4.7
19	55.2	10.1	28.8	18.3
20	35.5	9.5	25.4	11.3
21	82.6	11.9	35.8	17.8
22	30.7	12.0	36.2	30.4
23	34.3	5.6	26.5	34.7
24	67.9	16.7	18.9	10.7
25	26.2	9.5	15.2	5.6
26	33.1	9.6	16.0	11.3
27	41.4	6.9	17.5	15.0
28	34.2	10.0	28.0	17.8
29	35.3	9.8	27.0	11.3
30	56.6	12.8	29.1	14.6
31	56.9	15.2	47.8	27.9
32	95.6	12.4	37.6	15.2
33	59.8	13.3	39.7	41.3
34	38.4	8.8	19.9	9.3
35	58.1	8.3	37.1	20.5
36	34.9	9.7	35.0	23.2
37	37.9	11.4	31.7	27.0
Total	**45.5**	**10.3**	**28.6**	**17.4**

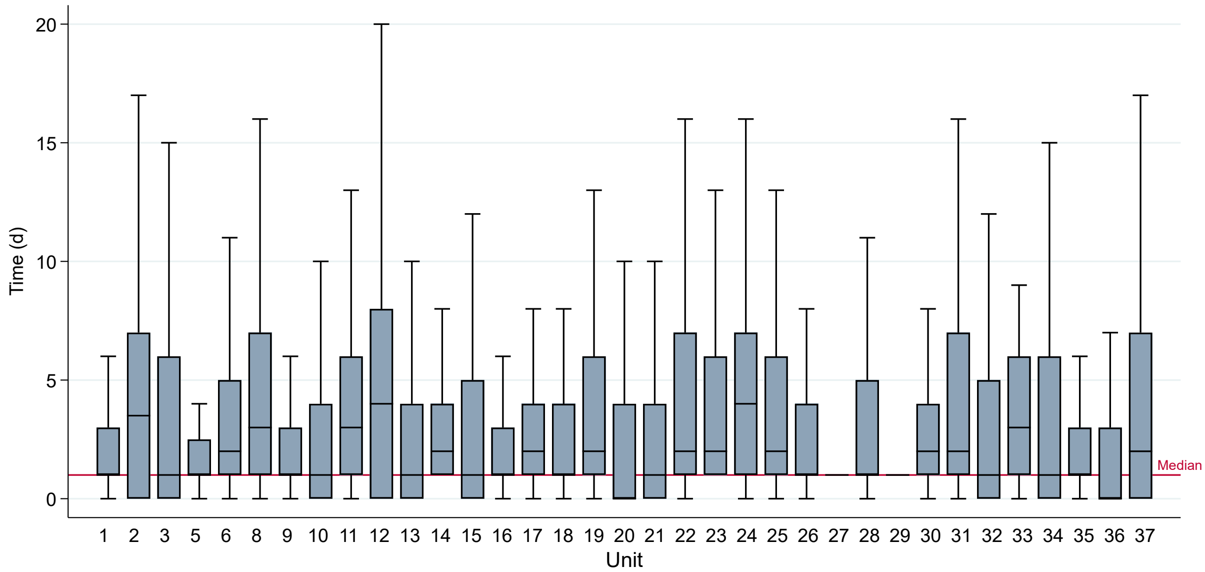
In 2018 and the preceding four years, there was variability between units in the pre- and post-procedural length of stay (PLOS) data (Figures 21-24). In 2018, the medians ranged from zero to five days for pre-PLOS and five to nine days for post-PLOS. Refer to Appendix D-II for an explanation as to how to interpret box plots, including information about the exclusion of outliers.

Figure 21. Pre-procedural length of stay for isolated CABG patients by unit, 2018



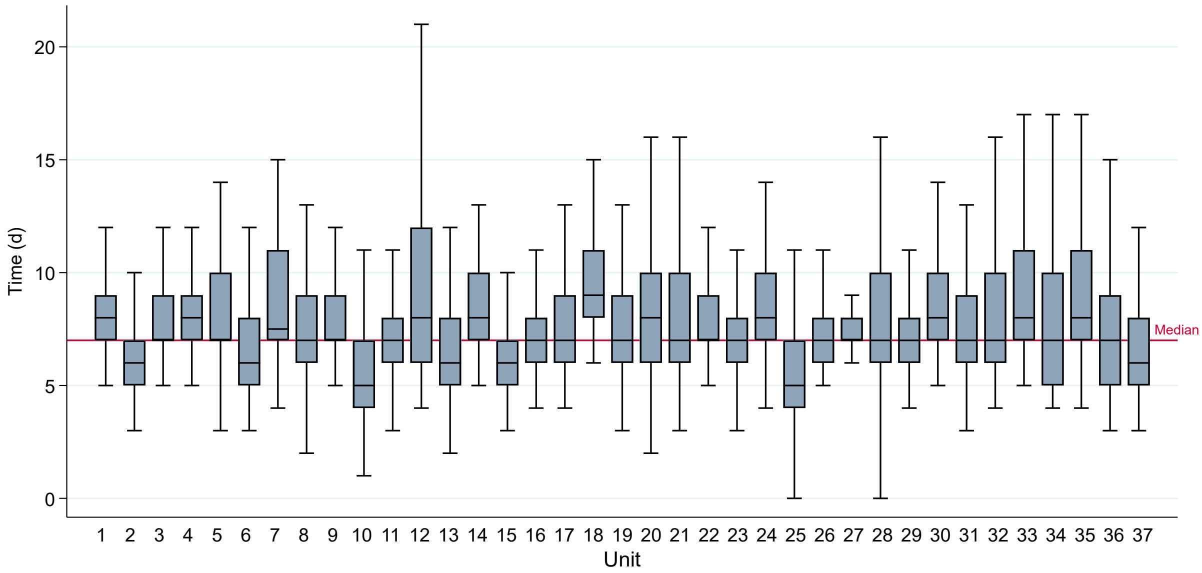
Note: excludes outliers

Figure 22. Pre-procedural length of stay for isolated CABG patients by unit, 2014-2017



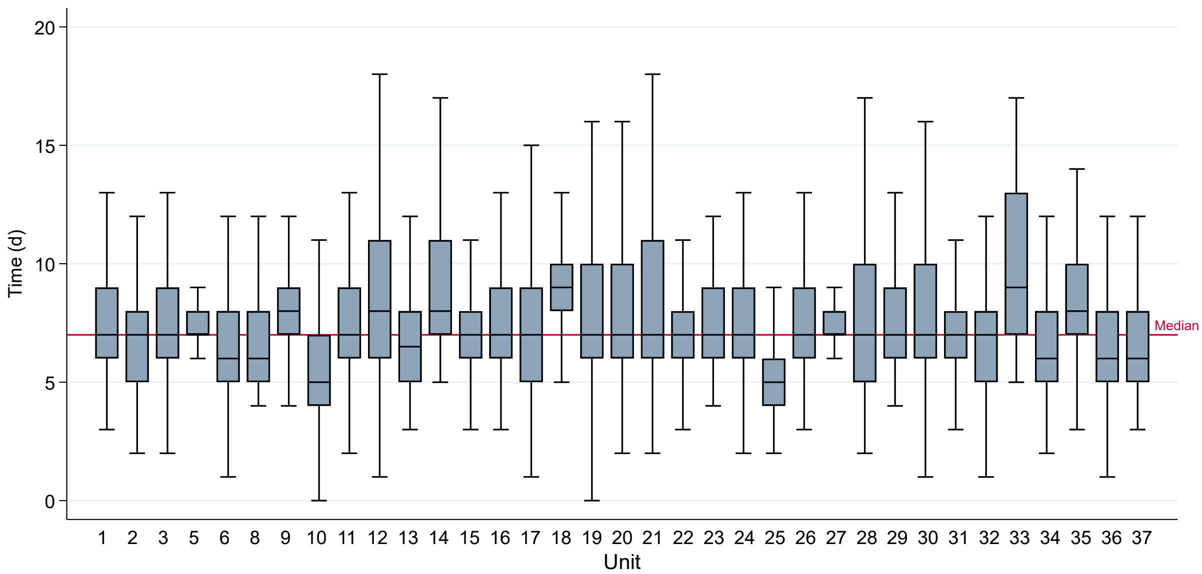
Note: excludes outliers

Figure 23. Post-procedural length of stay for isolated CABG patients by unit, 2018



Note: excludes outliers

Figure 24. Post-procedural length of stay for isolated CABG patients by unit, 2014-2017



Note: excludes outliers

2. Post-operative Renal Insufficiency

2.1 Data analysis

This section explores the data collected by the Database in relation to post-operative renal insufficiency for all types of cardiac surgery. Unit level comparisons cover the most recent three years, 2016-2018, and only include units that have contributed for the entire period. Long-term survival data was formulated using data submitted to the Database between January 2007 and December 2016, and a linkage with the National Death Index performed in September 2017. Other data in this section covers the time period from 2009-2018, inclusive, unless otherwise specified.

The completeness of the variables used to calculate new renal insufficiency (NRI) is summarised in Table 10. Table 11 reports the completeness of variables used to calculate the estimated glomerular filtration rate (eGFR), and blood product data. Where cases were missing one or more variables required to calculate NRI or eGFR, they were excluded from the relevant analyses. When calculating eGFR, cases with a reported weight outside of the ANZSCTS Database data definitions limits (35–200 kg) were also excluded.

Patients on pre-operative dialysis are unable to develop NRI according to the Database data definition, therefore have been excluded from analyses where NRI is involved.

Table 10. Completeness (%) of NRI variables

	Reported NRI	Dialysis	Haemofiltration	Pre-operative creatinine	Post-operative creatinine
Completeness	99.59	99.88	99.35	99.80	96.77

Table 11. Completeness (%) of other relevant variables

	Weight	Age	Sex	Red blood cell transfusion	Red blood cell units
Completeness	99.95	99.98	100.00	99.76	99.59

2.2 Introduction

Acute kidney injury (AKI) is one of the most common major complications of cardiac surgery and is associated with increased post-operative morbidity and mortality[11–14]. Accordingly, one of the key performance indicators reported on and monitored by the ANZSCTS Database is the occurrence of new renal insufficiency following cardiac surgery. While the definition of AKI is not standardised and may be measured against a number of classification systems available in the literature, it has a generally accepted meaning amongst the clinical community. For this reason, the term 'new renal insufficiency' has been deliberately utilised by the Database to distinguish it from other recognised definitions.

In setting a definition for new renal insufficiency (NRI), the ANZSCTS Database Steering Committee aimed to separate only cases where cardiac surgery affected a patient's renal function to the extent that clinical intervention was required. It is well established in the literature that even minimal increases in creatinine levels or reductions in eGFR following cardiac surgery are associated with adverse outcomes, including short and long-term mortality, and increased resource utilisation[15–20]. However, acute kidney injuries are less relevant to the performance monitoring function of the Database. The current Database definition is as follows:

Was there acute post-operative renal insufficiency characterised by one of the following:

a. *Increased serum creatinine to >0.2 mmol/L (>200 µmol/L) AND a doubling or greater increase in creatinine over the baseline pre-operative value AND the patient did not require pre-operative dialysis/haemofiltration*
   OR
b. *A new post-operative requirement for dialysis/haemofiltration (when the patient did not require this pre-operatively).*

Note: Renal insufficiency must not be present pre-operatively. Pre-operative renal transplant does not count as renal insufficiency if the patient did not have impaired kidney function and did not require dialysis/haemofiltration.

The ANZSCTS Database collects data on NRI as it is reported by sites, but for the purposes of peer review and annual reporting, derives this from the data by looking at the difference in pre- and post-operative creatinine levels, and whether the case involved dialysis/haemofiltration pre- or post-operatively. The variable calculated by the Database is referred to as derived new renal insufficiency (DNRI).

Rates of both reported and derived NRI have remained consistent over the last ten years, with derived new renal insufficiency (DNRI) occurring, on average, in approximately 4.68% (n = 843) of cases (Figure 25). DNRI is generally slightly lower than reported levels of NRI in the Database. The incidence of DNRI with post-operative haemofiltration has also remained relatively steady over the last ten years, sitting at 2.18% (n = 2260) in 2018. The levels of reported and derived NRI and haemofiltration vary markedly between sites (Figure 26). No relationship between unit volume and incidence of reported or derived NRI was detected (data not shown).

Most units show a high level of agreement between reported and derived NRI, demonstrating good adherence to the ANZSCTS Database definition. More units over-report NRI, rather than under-report (Figure 26). Where reported and derived NRI differ for a given case, the data is routinely queried by the Database team in an attempt to resolve the difference and verify the data. Where NRI is presented for the rest of this section, DNRI will be used.

Figure 25. Reported and derived NRI, 2009-2018

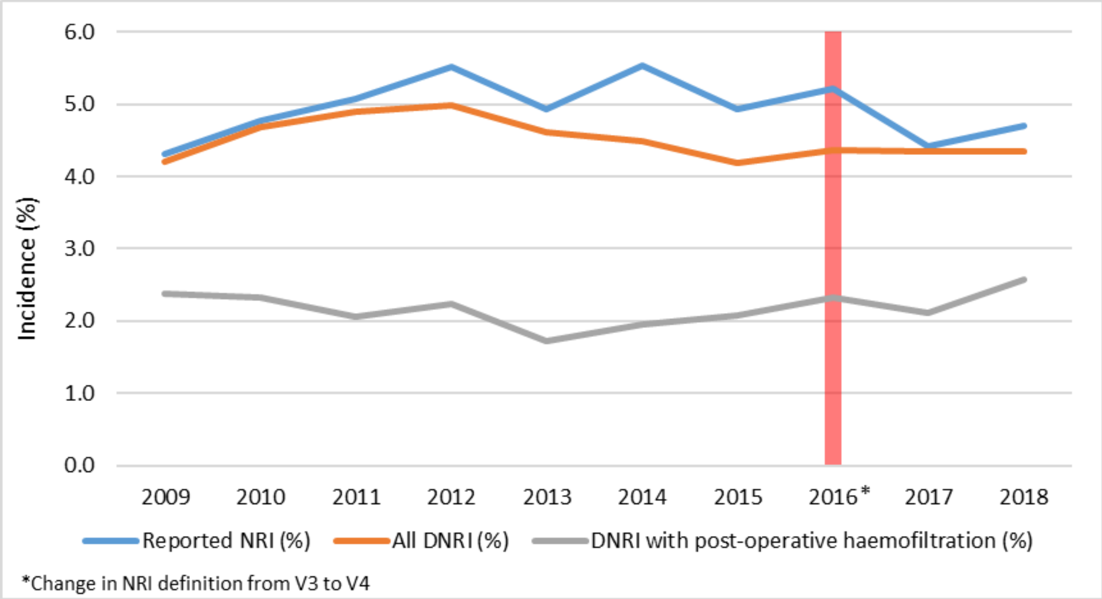
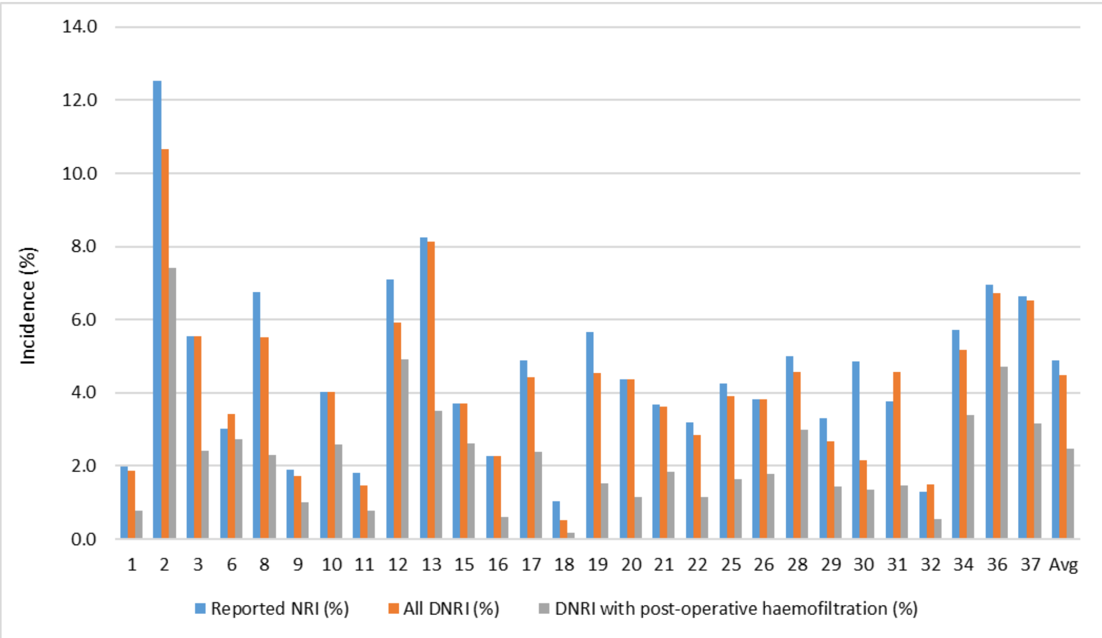
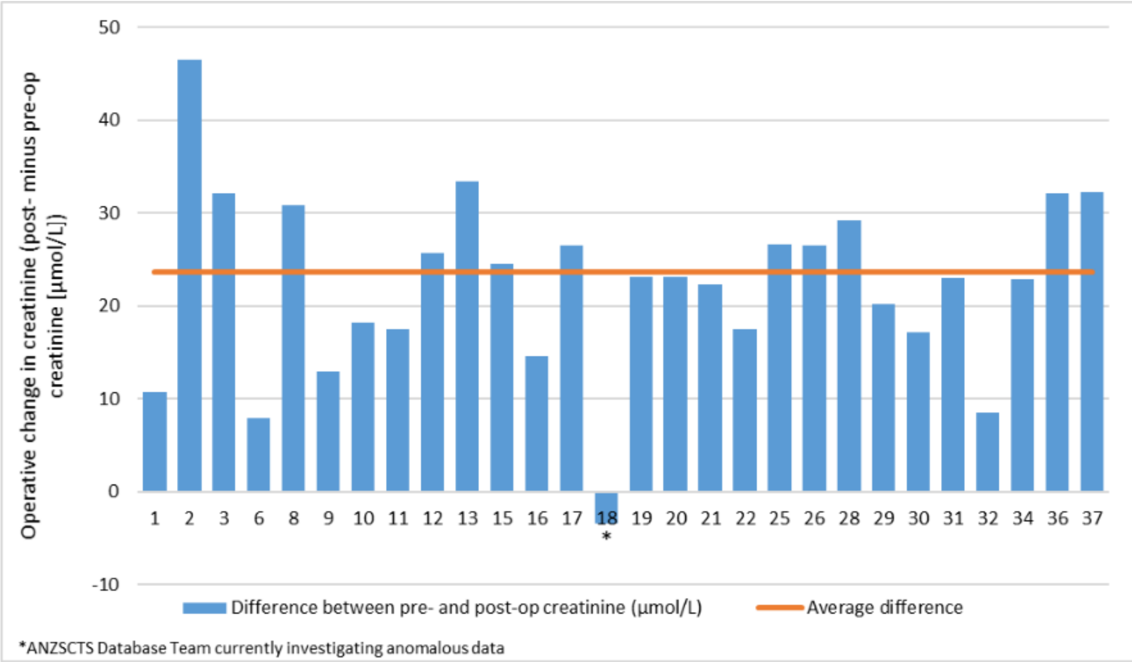


Figure 26. Comparison of reported and derived NRI by site, 2016-2018



On average there is a small increase in creatinine levels after cardiac surgery, as expected. This increase, and the average pre- and post-operative creatinine levels, have remained steady over the last ten years (data not shown). The average difference between pre- and post-operative creatinine levels was 24 µmol/L. The mean change in creatinine levels after surgery is fairly consistent between units (Figure 27).

Figure 27. Difference in pre- and post-operative creatinine levels by unit, 2016-2018



2.3 Risk factors for DNRI

There are a number of variables collected by the Database that the ANZSCTS Database Steering Committee and a previous paper using ANZSCTS Database data have identified as potential risk factors for developing DNRI[21]. These factors are listed in Tables 12 and 13, and their frequency of occurrence compared between cases with and without DNRI, and in those with and without an estimated glomerular filtration rate (eGFR) of greater than or equal to 40.

DNRI cases involved patients that were generally older with a higher prevalence of insulin-dependent diabetes and use of immunosuppressive therapies (Table 12). DNRI was more common in cases involving a range of comorbidities, including an obese body mass index (BMI), cardiogenic shock, cerebrovascular disease, chronic respiratory disease, infective endocarditis, low ejection fraction, and high pre-operative creatinine. Procedural factors such as whether the surgery was a redo, the complexity of the procedure, the use of an intra-aortic balloon pump, duration of bypass, and use of RBC or non-RBC transfusions also varied between the cases that did and did not develop DNRI. Lastly, the use of inotropes for low cardiac output (CO) or low systemic vascular resistance (SVR) was markedly higher in the DNRI cohort. Similar trends were seen among cases with poor pre-operative eGFR (Table 13).

Table 12. ANZSCTS Database DNRI risk assessment, 2009-2018

	No DNRI	DNRI
n	98743	4843
Pre-operative factors (%)		
Sex		
Male	73.3	75.4
Female	26.7	24.6
Age (years, mean)	65.7	67.3
Insulin-dependent diabetes	7.8	12.1
Immunosuppressive therapy	2.5	5.0
BMI		
Underweight	1.3	1.5
Normal	25.1	22.9
Overweight	38.9	34.4
Obese	34.6	41.2
Hypertension	72.4	77.1
Hypercholesterolemia	66.0	64.3
Cardiogenic shock	1.5	7.4
Cerebrovascular disease	9.9	14.8
Chronic respiratory disease	13.3	18.8
Infective Endocarditis	2.5	8.3
Redo	7.5	14.7
Ejection fraction ≤ 45%*	15.6	26.7
Pre-creatinine ≥ 200µmol/L	1.2	6.4
Transplant with normal renal function	0.2	0.3
Peri-operative factors (%)		
Emergency/salvage clinical status	3.6	14.3
Other cardiac surgery	11.5	21.7
Intra-aortic balloon pump		
Pre-operative	2.2	4.9
Intra-operative	1.0	4.5
Post-operative	0.2	2.3
RBC transfusion	34.2	74.2
RBC transfusion (>2 units)	15.3	54.6
NRBC transfusion	25.0	54.6
Cross-clamp time (mean)	77.5	95.6
Perfusion time (mean)	108.6	149.5
Post-operative outcomes (%)		
Peri/post-operative cardiogenic shock	2.4	19.6
Cardiac inotrope use for low CO	19.8	48.2
Cardiac inotrope use for low SVR	24.4	39.7
Acute limb ischemia	0.1	2.0

*moderate to severe LV dysfunction

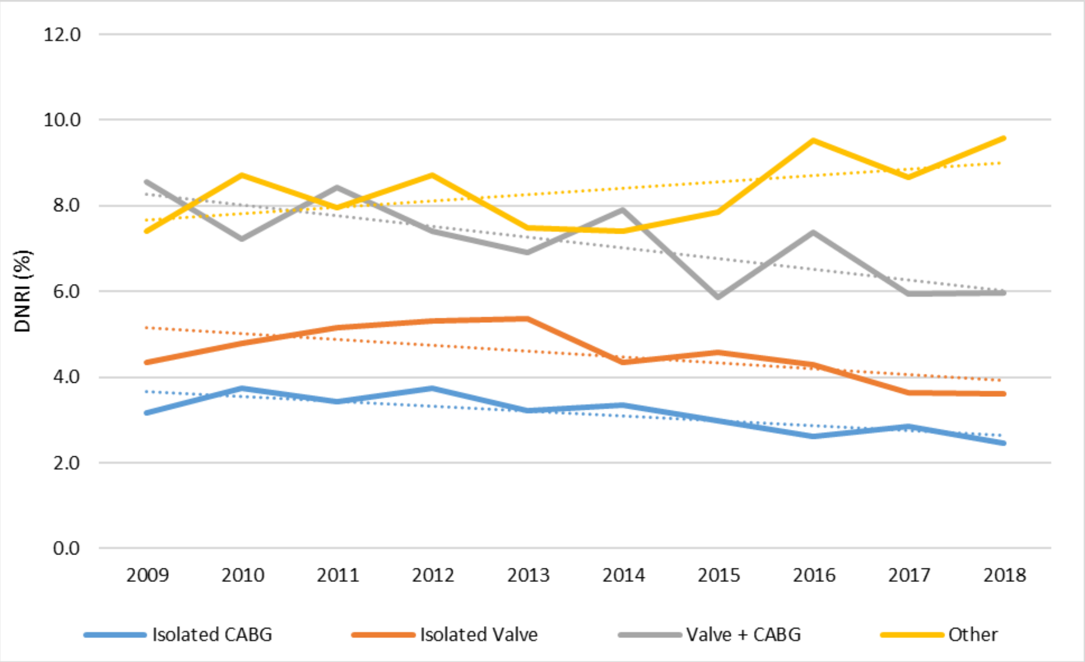
Table 13. ANZSCTS Database pre-operative eGFR risk assessment 2009-2018

	eGFR≥40	eGFR<40
n	98128	10730
Pre-operative factors (%)		
Sex		
Male	75.2	56.2
Female	24.8	43.8
Age (mean)	64.6	75.3
Insulin-dependent diabetes	7.8	14.1
Immunosuppressive therapy	2.6	4.1
BMI		
Underweight	1.1	3.7
Normal	23.0	44.1
Overweight	39.1	34.4
Obese	36.9	17.7
Hypertension	71.5	83.9
Hypercholesterolemia	65.6	69.1
Cardiogenic shock	1.7	4.4
Cerebrovascular disease	9.8	17.1
Chronic respiratory disease	13.4	17.8
Infective Endocarditis	2.9	4.4
Redo	7.6	11.0
Ejection fraction ≤ 45%*	15.5	25.5
Pre-creatinine ≥ 200µmol/L	0.2	26.3
Transplant with normal renal function	0.3	0.0
Peri-operative factors (%)		
Emergency/salvage clinical status	4.2	5.8
Other cardiac surgery	12.1	11.6
Intra-aortic balloon pump		
Pre-operative	2.2	3.6
Intra-operative	1.1	2.2
Post-operative	0.3	0.6
RBC transfusion	33.3	68.9
RBC transfusion (>2 units)	15.3	41.5
NRBC transfusion	25.3	40.1
Cross-clamp time (mean)	77.6	83.0
Perfusion time (mean)	110.0	117.5
Post-operative outcomes (%)		
Peri/post-operative cardiogenic shock	3.0	6.6
Cardiac inotrope use for low CO	19.8	32.4
Cardiac inotrope use for low SVR	24.8	25.8
Acute limb ischemia	0.2	0.4

*moderate to severe LV dysfunction

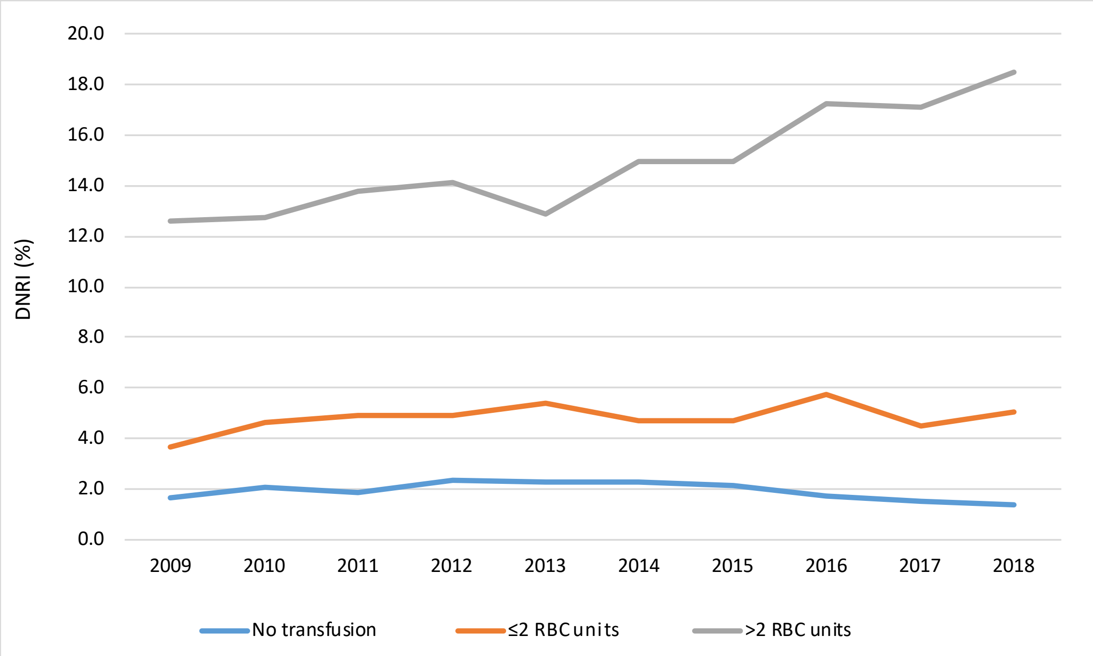
Looking more closely at the effect of procedure type on DNRI, it is clear that there is a higher incidence of DNRI in cases involving more complex procedures (Figure 28). Isolated CABG is associated with the lowest level of DNRI, followed by isolated valves and combined CABG and valve surgery. DNRI incidence for all these types of procedures has shown a decline between 2009 and 2018. In contrast, 'other' types of cardiac surgery are associated with the highest incidence of DNRI, and DNRI among these cases has increased over the last decade. The 'other' cardiac surgery category includes a wide range of procedures from septal defect repairs to aortic replacements and cardiac transplants. Refer to Section 5 for further information regarding the 'other' cardiac surgery category.

Figure 28. DNRI between different procedure groups, 2009-2018



It is well established that peri-operative red blood cell (RBC) transfusion is associated with AKI following cardiac surgery, and it has been suggested that transfusions may be directly involved in the pathological process[22]. This is consistent with the data collected by the Database, which shows a markedly higher incidence of DNRI in cases where patients received greater than two units of RBCs in the peri-operative period (Figure 29).

Figure 29. DNRI according to RBC transfusion levels, 2009-2018



2.4 Comparison of kidney injury classification systems

There are a large number of well-established classification systems for AKI, with the most recognisable being the Risk, Injury, Failure, Loss, End stage kidney disease (RIFLE); Acute Kidney Injury Network (AKIN); and the Kidney Disease: Improving Global Outcomes (KDIGO) criteria. The classification systems are outlined and compared in Table 14.

The RIFLE system was the first evidence based consensus, which was published in 2004[23]. It incorporates three stages of AKI (risk, injury, and failure) and two other stages corresponding to clinical outcomes (loss and end-stage). The stages are determined by criteria relating to changes in serum creatinine levels/GFR over seven days or urine output; whichever leads to the worst possible classification.

In 2007, the AKIN group proposed a new classification system based on RIFLE with some minor modifications[24]. These included adding an option for a reduced threshold in serum creatinine change required to reach stage 1 classification, and the removal of the GFR criteria and outcome stages. Instead, cases where patients initiated renal replacement therapy (RRT) were moved into the stage 3 group. Further, changes in creatinine levels are looked at in a 48-hour window, rather than the one-week period used in RIFLE.

The KDIGO classification system, based on AKIN and RIFLE, was introduced in 2012[25]. One of the key differences with KDIGO occurs with stage 3, where the requirement for an acute rise of greater than or equal to 0.5 mg/dL (44.2 µmol/L) in creatinine levels was removed. In addition, KDIGO looks at changes in both a 48 hour and seven-day period, combining aspects of both AKIN and RIFLE into one classification system.

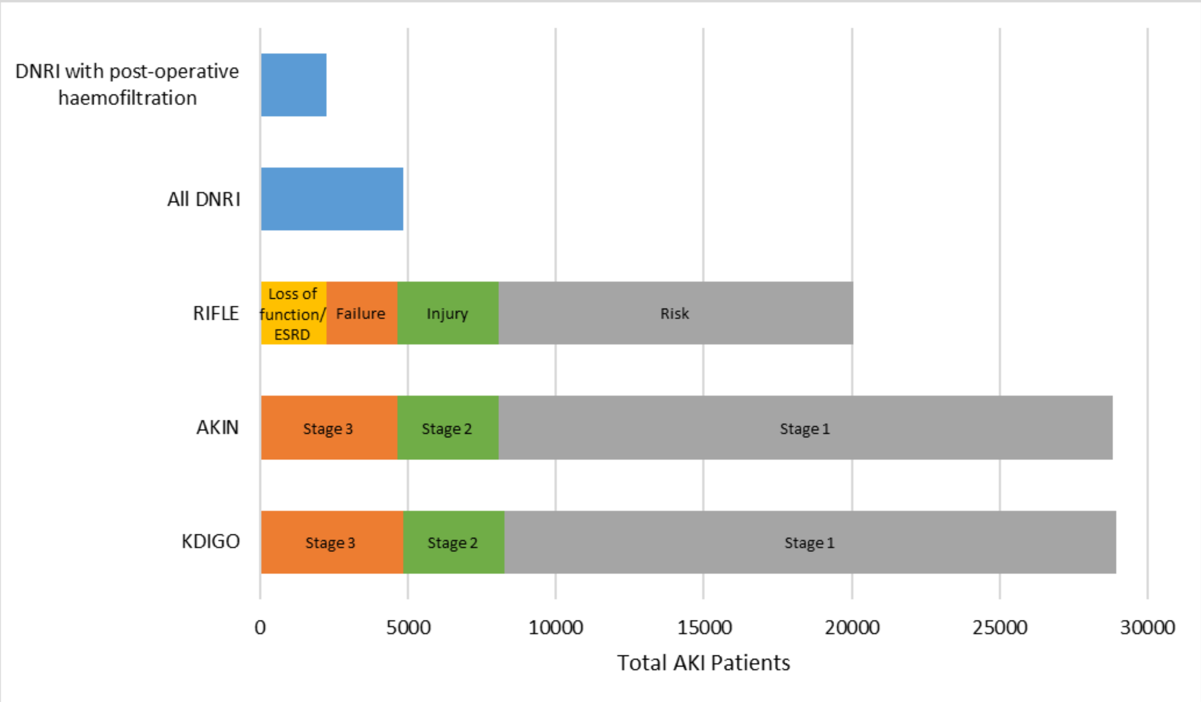
The ANZSCTS Database does not store data on urine output and the highest post-operative inpatient creatinine level is recorded, regardless of how many days this occurs post-operatively. Using Database data, it is possible to do a crude analysis of these variables to examine what proportion of cases meet the criteria for RIFLE, AKIN, and KDIGO classification, and to compare this to the observed incidence of DNRI.

Table 14. Comparison of RIFLE, AKIN and KDIGO Classification Systems

Stage	RIFLE	AKIN	KDIGO
Risk / 1	Increased serum creatinine x 1.5 or eGFR decrease > 25% UO < 0.5 mL/kg/h for 6 hrs	Increased serum creatinine x 1.5-2 or ≥ 0.3 mg/dL (26.5 µmol/L) increase UO < 0.5 mL/kg/h for > 6 hrs	Increase serum creatinine x 1.5-1.9 or ≥ 0.3 mg/dL (26.5 µmol/L) increase UO < 0.5 mL/kg/h for > 6 hrs
Injury / 2	Increased serum creatinine x 2 or eGFR decrease > 50% UO < 0.5 mL/kg/h for 12 hrs	Increased serum creatinine x 2-3 UO < 0.5 mL/kg/h for > 12 hrs	Increased serum creatinine x 2.0-2.9 UO < 0.5 mL/kg/h for ≥ 12 hrs
Failure / 3	Increased serum creatinine x 3 or ≥ 4 (353.6 µmol/L) mg/dL (acute rise ≥ 0.5 mg/dL (44.2 µmol/L)) or eGFR decrease 75% UO < 0.3 mL/kg/h in 24 hrs (oliguria) or anuria 12 hrs	Increased serum creatinine > x 3 or = to 4 mg/dL (353.6 µmol/L) (acute rise ≥ 0.5 mg/dL (44.2 µmol/L)) UO < 0.3 mL/kg/hr for 24 hrs or anuria for 12 hrs Initiation of RRT	Increased serum creatinine x 3 or ≥ 4 mg/dL (353.6 µmol/L) UO < 0.3 mL/kg/hr for 24 hrs or anuria for ≥ 12 hrs Initiation of RRT Decrease in eGFR to < 35 mL/min per 1.73 m^2
Loss or End-stage kidney disease	Initiation of RRT for > 4 weeks or > 3 months	-	-

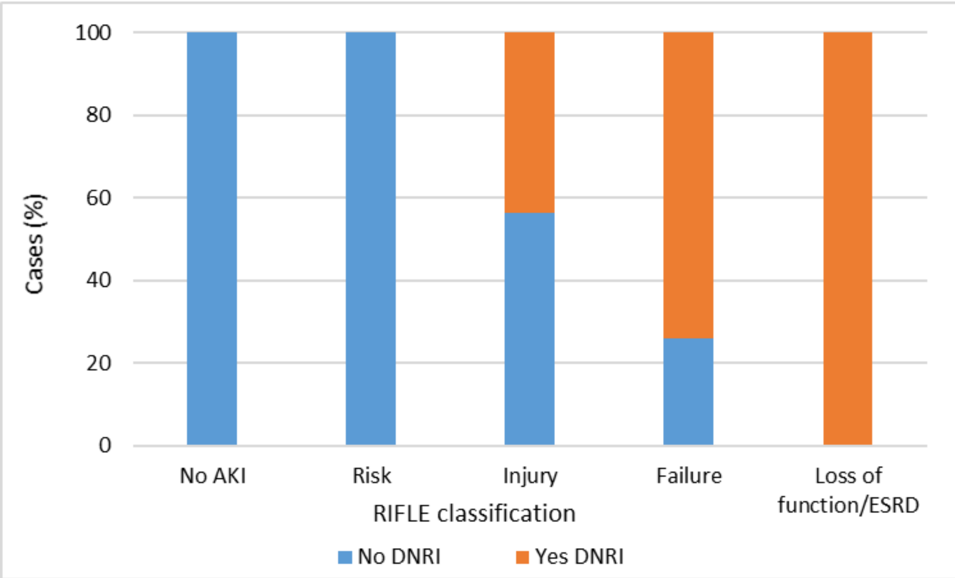
Between 2009 and 2018, 4,843 (4.68%) cases in the ANZSCTS Database had DNRI, according to the ANZSCTS Database definition. A substantially higher number of cases were identified as involving some level of AKI according to the RIFLE (n = 20,054, 19.0%), AKIN (n = 28,808, 27.3%) and KDIGO (n = 28,938, 27.4%) classification systems (Figure 30). For RIFLE, this incidence sits mid-way through the wide range of rates (6.5-31%) reported in the literature applying RIFLE in large studies with cardiac surgery patients[26–31]. The RIFLE criteria was the most similar to DNRI, with 8,063 injury, failure and loss of function/ESRD cases, which are the categories that most strongly correlate to the data definition for DNRI.

Figure 30. Total cases classified as having some level of AKI, 2009-2018



Approximately 43.7% (n = 1479) and 74.0% (n = 1155) of the cases classified with RIFLE-defined injury or failure, respectively, were also classified as having DNRI by the Database (Figure 31). There were no cases classified as having DNRI by the Database that were not picked up by the RIFLE system. None of the cases having a RIFLE stage of risk were classified as having DNRI, which is consistent with the aim of the Database Steering Committee to have DNRI represent only the more serious stages of AKI. All of the cases where patients received RRT were captured under the loss of function/end stage renal failure classification. These two stages could not be distinguished as the Database does not collect information on the duration of RRT.

Figure 31. RIFLE classification compared to DNRI, 2009-2018



During 2009-2018:

- 4.68% of cases were classified as having DNRI by the ANZSCTS Database.
- 19.0% of cases were classified by RIFLE as having some form of AKI.
  - Risk – 11.4%
  - Injury – 3.25%
  - Failure – 2.26%
  - Loss of function/End stage renal disease – 2.14%
- 27.3% of cases were classified by AKIN as having some form of AKI.
  - AKIN stage I – 19.7%
  - AKIN stage II – 3.25%
  - AKIN stage III – 4.41%
- 27.4% of cases were classified by KDIGO as having some form of AKI.
  - KDIGO stage I – 19.6%
  - KDIGO stage II – 3.24%
  - KDIGO stage III – 4.58%
- 26.6% of cases were classified by at least one criterion.
- 18.2% of cases were classified by all three criteria.

2.5 Outcomes for cases involving DNRI or AKI

The ANZSCTS Database monitors a number of key performance indicators in addition to DNRI, which are defined in Appendix B. These include observed mortality, return to theatre, deep sternal wound infection (DSWI) within 30 days of procedure, and permanent stroke.

Cases involving DNRI consistently experienced a higher incidence of peri-operative complications, with DNRI cases requiring post-operative haemofiltration showing the worst outcomes (Figure 32). In particular, observed mortality rates for cases with DNRI, and in those needing haemofiltration were 14 and 23 times higher, respectively, than for cases with no DNRI. Cases where patients were on pre-operative dialysis also had poorer outcomes, compared to cases with no DNRI, indicating that any important degree of pre-operative renal impairment is a predictor of risk.

For all cases, regardless of DNRI or pre-operative renal impairment status, a return to theatre was most commonly due to issues with bleeding (Table 15). Unsurprisingly, all reasons for returning to theatre were more common in cases with DNRI, particularly those requiring haemofiltration, but the largest difference was seen in cases with DSWI. Cases where patients have DNRI, and in those needing haemofiltration, were nine and 11 times more likely, respectively, to return to theatre due to DSWI within 30 days of procedure, compared to cases without DNRI.

It is difficult to comment on the cause and effect relationship between DNRI, haemofiltration, and outcomes. With respect to the high rate of return to theatre for cases with DNRI and haemofiltration, re-operation was previously identified as a risk factor for AKI [20]. Information regarding the time of diagnosis of DNRI or initiation of haemofiltration is not collected for the Database.

There was also a consistent, progressive increase in the proportion of cases returned to theatre with worsening RIFLE classification (Table 16).

Figure 32. Case outcomes by pre-operative dialysis and DNRI status, 2009-2018

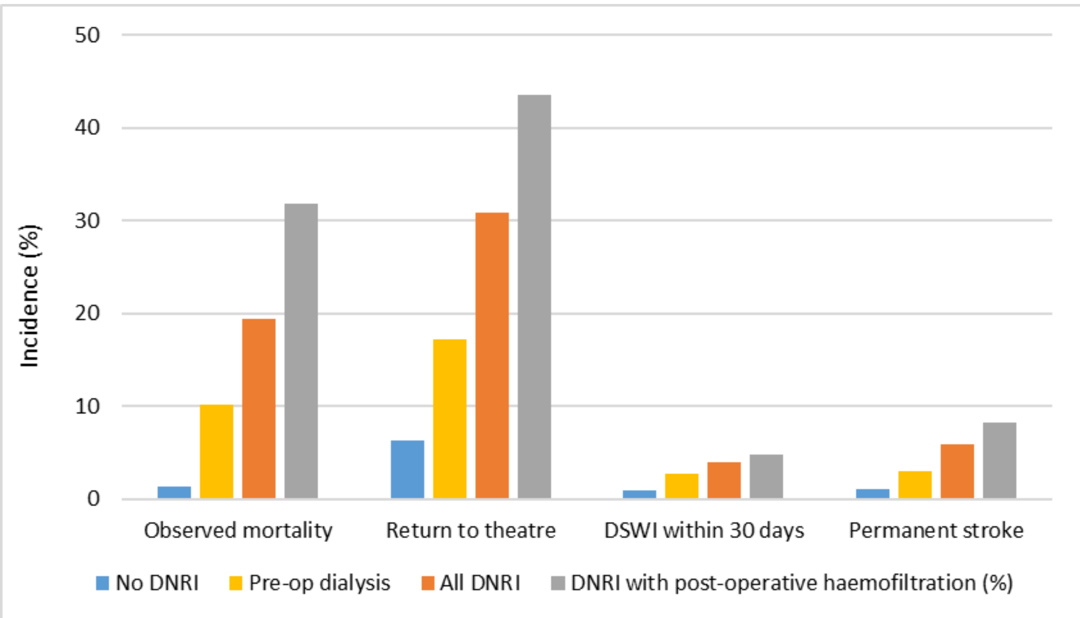


Table 15. Return to theatre reasons by pre-operative dialysis and DNRI status, 2009-2018

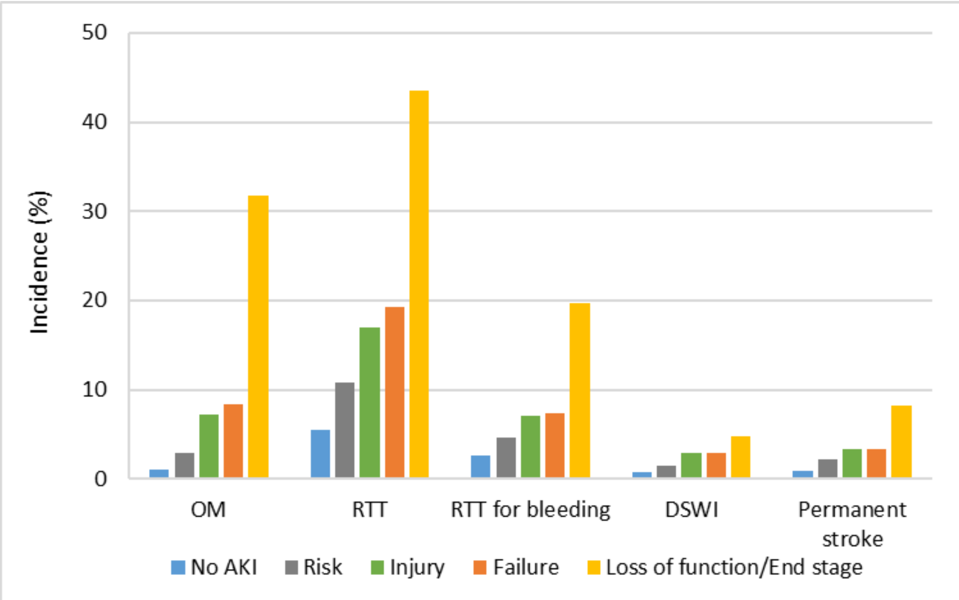
	No DNRI	Pre-op dialysis	All DNRI	DNRI with post-operative haemofiltration
n	98743	1805	4843	2260
Return to theatre (%)	6.3	17.2	30.8	43.5
Return to theatre reason (%)				
Valve dysfunction	0.1	0.2	0.6	1.2
Bleeding	2.9	6.9	13.7	19.6
Graft occlusion	0.1	0.0	0.5	0.9
DSWI	0.3	1.2	2.7	3.4
Deep thoracotomy wound infection	0.0	0.2	0.2	0.1
Insertion of pacemaker/AICD	0.6	0.8	1.0	1.4
Other cardiac	1.6	4.6	9.3	14.1
Other non-cardiac	1.3	6.9	12.0	18.4

Table 16. Return to theatre reasons by RIFLE classification, 2009-2018

	No AKI	Risk	Injury	Failure	Loss of function/End stage
n	85316	11990	3419	2382	2260
Return to theatre (%)	5.5	10.9	17.0	19.2	43.5
Return to theatre reason (%)					
Valve dysfunction	0.1	0.2	0.2	0.1	1.2
Bleeding	2.6	4.6	7.1	7.4	19.6
Graft occlusion	0.1	0.1	0.1	0.0	0.9
DSWI	0.3	0.7	1.6	1.8	3.4
Deep thoracotomy wound infection	0.0	0.0	0.2	0.0	0.1
Insertion of pacemaker/AICD	0.5	1.0	1.0	0.5	1.4
Other cardiac	1.4	2.7	4.8	4.6	14.1
Other non-cardiac	1.0	3.0	5.0	7.7	18.4

When examining the incidence of post-operative mortality and complications in cases with AKI according to the RIFLE criteria, it is not surprising that cases in the 'risk' category are associated with better outcomes, while cases with loss of function/end stage renal disease fare the worst (Figure 33). Interestingly, the levels of post-operative complications are similar between the injury and failure groups, suggesting poor AKI discrimination between these categories for RIFLE.

Figure 33. Outcomes by RIFLE classification, 2009-2018



In line with the higher levels of post-operative complications, the mean duration of stay in the intensive care unit (ICU) and duration of ventilation was longer for DNRI cases, particularly those requiring haemofiltration (Table 17). The number of units of RBCs transfused was also higher in all patients with DNRI, with or without haemofiltration, compared to cases that did not meet the definition for DNRI. There was also a progressive increase in resource utilisation for worsening RIFLE classification (Table 18). It should be noted that cases where patients require haemofiltration and therefore have longer ICU stays are likely to experience prolonged fluid shifting, which may affect the decision to transfuse. The ANZSCTS Database does not store data on the timing of transfusion.

Table 17. Mean resource utilisation by pre-operative dialysis and DNRI status, 2009-2018

	No DNRI	Pre-op dialysis	All DNRI	DNRI with post-operative haemofiltration (%)
n	98743	1805	4843	2260
Resource utilisation (mean)				
Time in ICU (h)	65.3	159.4	232.9	339.9
Time on ventilation (h)	18.7	60.7	99.9	164.3
RBCs transfused (units)	3.4	6.44	8.6	11.3

Table 18. Mean resource utilisation by RIFLE classification, 2009-2018

	No AKI	Risk	Injury	Failure	Loss of function/End stage
n	85316	11990	3419	2382	2260
Resource utilisation (mean)					
Time in ICU (h)	61.5	88.9	127.2	150.0	339.9
Time on ventilation (h)	17.2	28.1	43.8	51.1	164.3
RBCs transfused (units)	3.3	4.1	5.2	5.7	11.5

Long-term survival for cases with patients who have DNRI or who have pre-operative dialysis is markedly reduced (Figure 34). In DNRI cases, there is a significant early effect on survival and also a continuing progressive smaller long-term effect. In comparison to cases for cardiac surgery patients who did not have DNRI, cases for patients with DNRI have a survival rate that is 19.6% lower one-year post-procedure, and 26.0% lower after seven years (Table 20).

In cases with patients on pre-operative dialysis, the initial reduction in survival compared to cases without DNRI is smaller than for cases with DNRI, but the gap widens over time. At seven years, survival is 33.6% lower, although it should be noted that case numbers for this category is low (Tables 19 and 20).

Figure 34. Long-term survival by pre-operative dialysis and DNRI status, 2007-2016

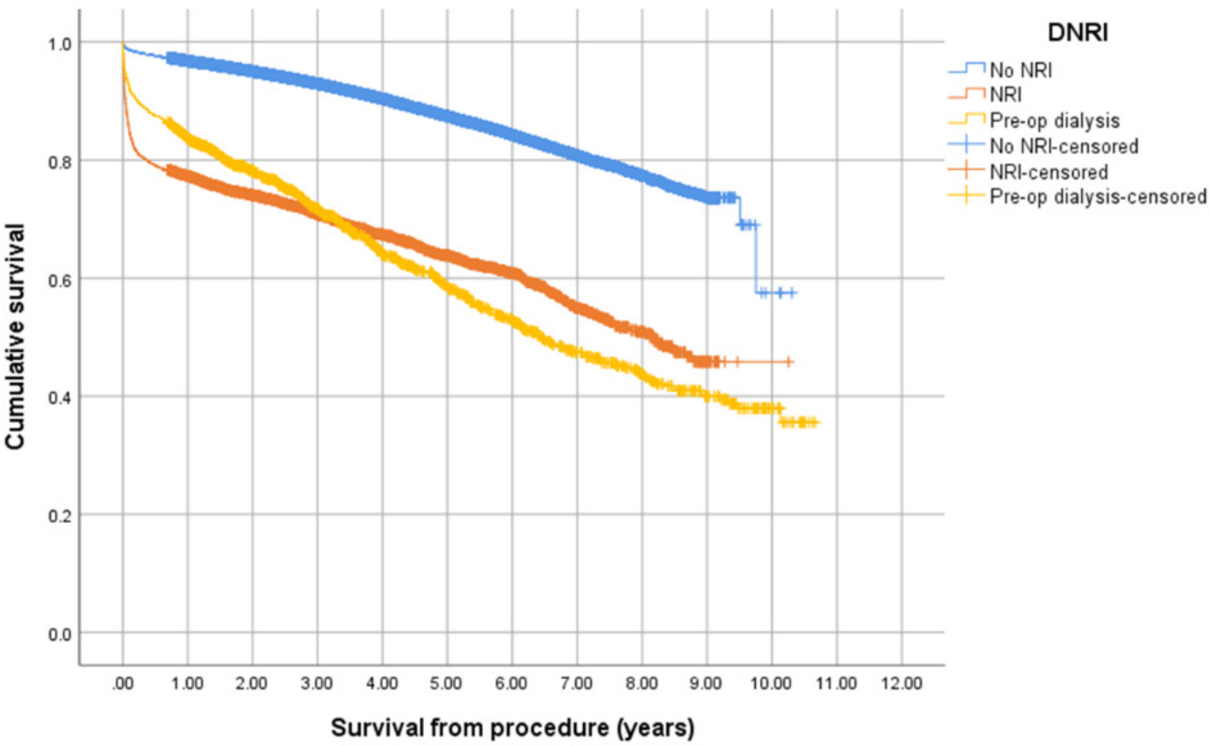


Table 19. Cases remaining by pre-operative dialysis and DNRI status at 1, 3, 5 and 7 years post-procedure

	Cases remaining			
Time since surgery	1 year	3 year	5 year	7 year
No DNRI	69236	46423	26581	11032
DNRI	2829	1857	1035	377
Pre-op dialysis	1222	758	426	203

Table 20. Long-term survival (%) by pre-operative dialysis and DNRI status, at 1, 3, 5 and 7 years post-procedure

	Survival			
Time since surgery	1 year	3 year	5 year	7 year
No DNRI	96.8	92.9	87.4	80.7
DNRI	77.2	70.7	63.8	54.7
Pre-op dialysis	83.6	71.7	58.5	47.1

There is a decrease in survival with each worsening RIFLE classification (Figure 35). Cases with loss of function or end-stage renal disease have a dramatic short-term reduction in survival, whereas there is a smaller short-term effect for the risk, injury and failure categories. The impact on survival is long-term, with the survival rates for all RIFLE categories continuing to diverge from the no AKI group up to seven years (Table 22).

Figure 35. Long-term survival by RIFLE classification, 2007-2016

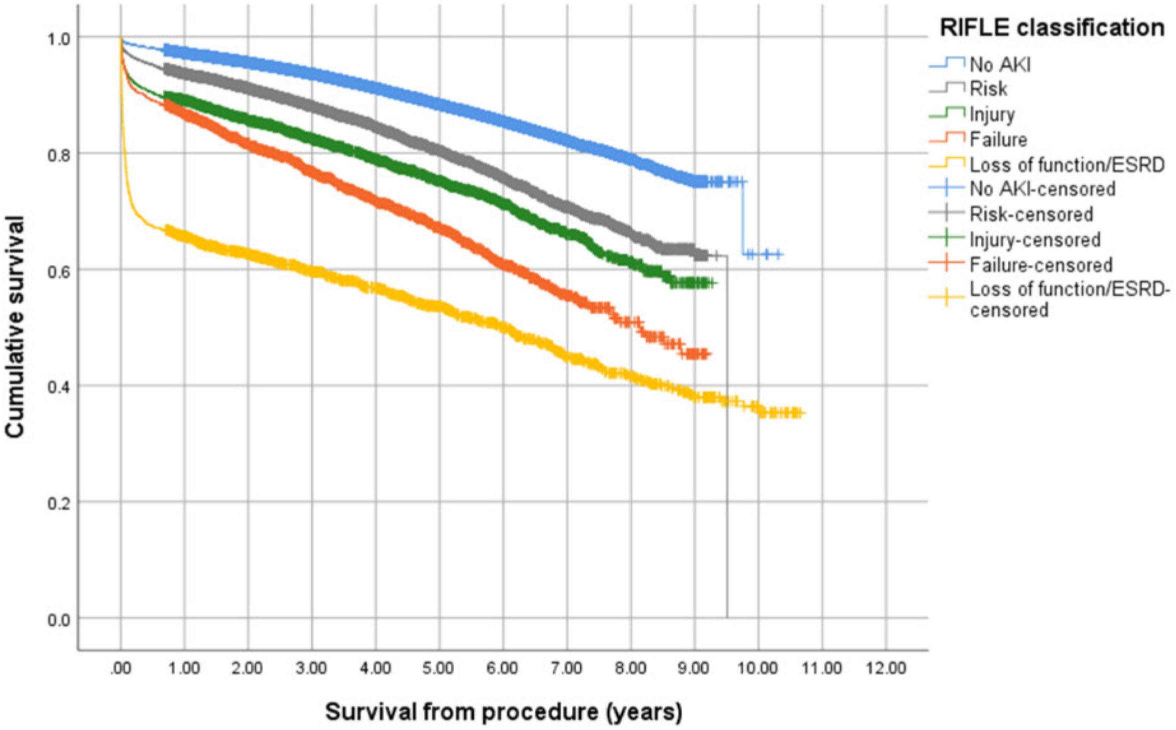


Table 21. Cases remaining by RIFLE classification, at 1, 3, 5 and 7 years post-procedure

	Cases remaining			
Time since surgery	1 year	3 year	5 year	7 year
No AKI	60525	40827	23481	9841
Risk	7665	4835	2629	1018
Injury	2306	1586	895	330
Failure	1557	983	532	161
Loss of function/ESRD	1204	785	494	245

Table 22. Long-term survival (%) by RIFLE classification, at 1, 3, 5 and 7 years post-procedure

	Survival			
Time since surgery	1 year	3 year	5 year	7 year
No AKI	97.2	93.6	88.3	82.1
Risk	93.7	88.0	80.4	70.7
Injury	89.0	82.4	75.1	65.9
Failure	86.7	76.6	67.0	55.1
Loss of function/ESRD	65.7	59.5	53.5	44.7

2.6 Summary and conclusions

- Participating sites show good adherence to the data definition for NRI.
- DNRI is more common in cases involving older patients, insulin-dependent diabetes and other key comorbidities, and in patients undergoing redo and more complex procedures.
- DNRI is also more common in cases that receive RBC products, particularly where more than two units of product are involved.
- The RIFLE, AKIN, and KDIGO classification systems identified four to six times as many cases with some level of AKI, compared to DNRI.
- Levels of post-operative complications and mean resource utilisation are markedly higher in cases that involve pre-operative dialysis or DNRI, particularly in those requiring haemofiltration.
- Seven-year survival is 33.6% lower in cases that involve pre-operative dialysis and 26.0% lower in cases with DNRI.
- Seven-year survival is 37.4% lower in cases assigned to the highest RIFLE classification compared to the no AKI group.

In line with the Steering Committee's aim, NRI captures only the more significant cases of AKI or renal failure, which correspond to the later stages of the RIFLE, AKIN and KDIGO classification systems. The strong correlation between reported and derived NRI demonstrates the high quality of the data submitted to the ANZSCTS Database.

The high incidence of post-operative complications and poor long-term survival in the DNRI cohort indicate the importance of DNRI as a KPI for the Database. During the quarterly peer review, units that sit above the 99.7% control limit for DNRI in the six and/or 36 month rolling periods are managed in accordance with our outlier management process, which seeks to assist units with identifying sources of issues and finding opportunities to improve performance (Appendix A), but this analysis highlights the importance for all units to continually strive to reduce their level of DNRI to optimise patient outcomes. In particular, there is a need to target the increased DNRI in cases involving more complex types of surgery.

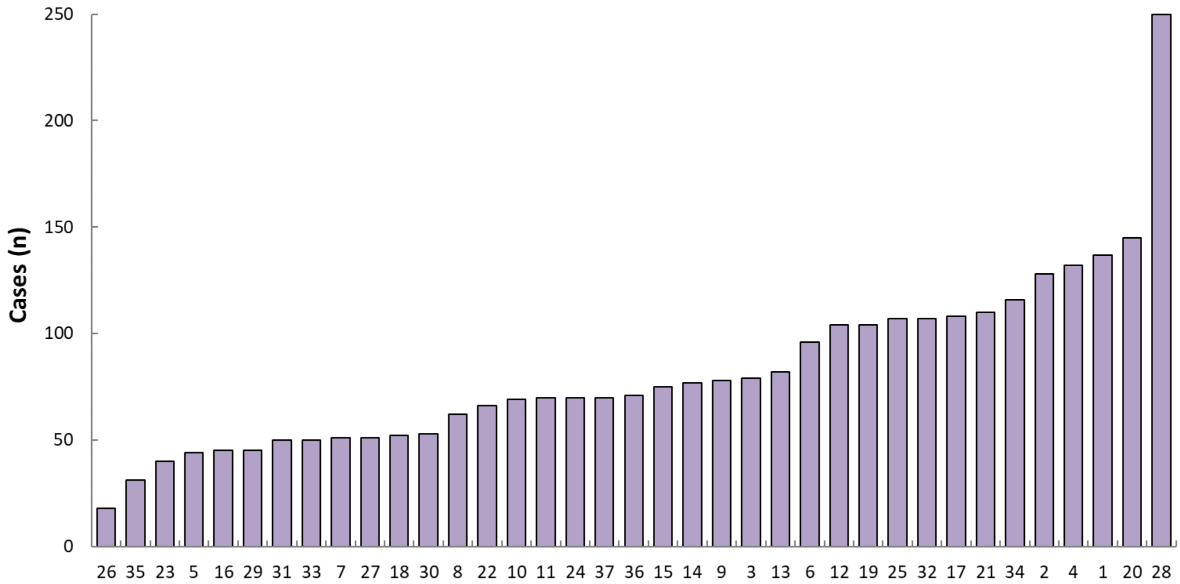
The Database is pleased to report there are a number of units that continually excel with respect to favourable DNRI outcomes (have rates sitting below the 99.7% control limit on the quarterly review). The Steering Committee are currently developing a survey to determine the between-unit differences in how cases are managed with respect to DNRI risk factors and treatment, and will examine trends among units that under and over-perform. This information will be reported back to units in a de-identified manner to facilitate quality improvement initiatives.

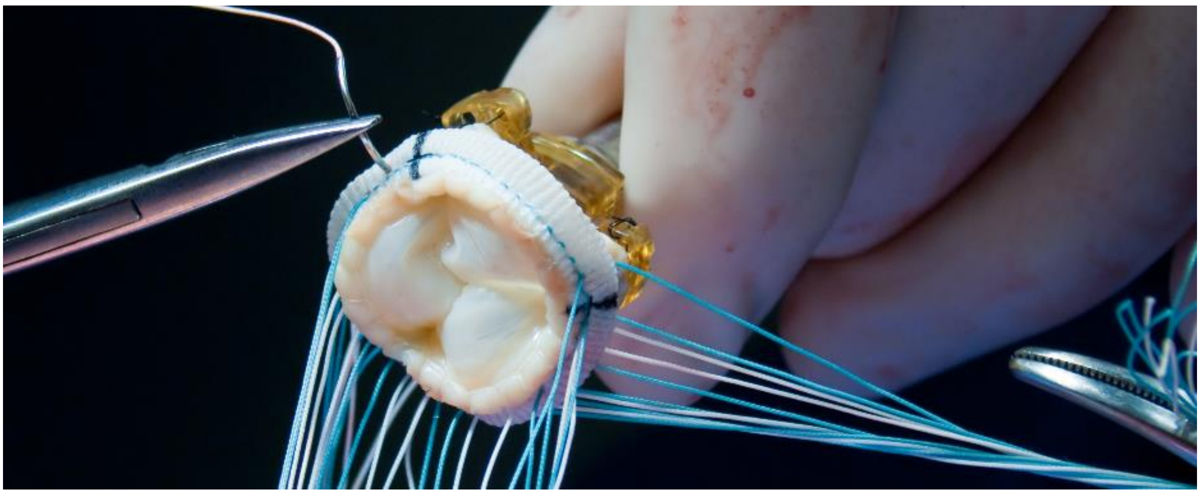
3. Isolated Valve

This section explores the patient population and outcomes for isolated surgical valve procedures. Transcatheter aortic or mitral valve replacements (TAVR and TMVR) are not included in the following grouped analyses.

In 2018, there was a wide range in the total number of isolated valve procedures performed in each unit that contributed to the ANZSCTS Database (Figure 36). The lowest volume unit submitted 18 cases, while the highest contributed 250.

Figure 36. Isolated valve procedures performed by unit, 2018





3.1 Patient characteristics

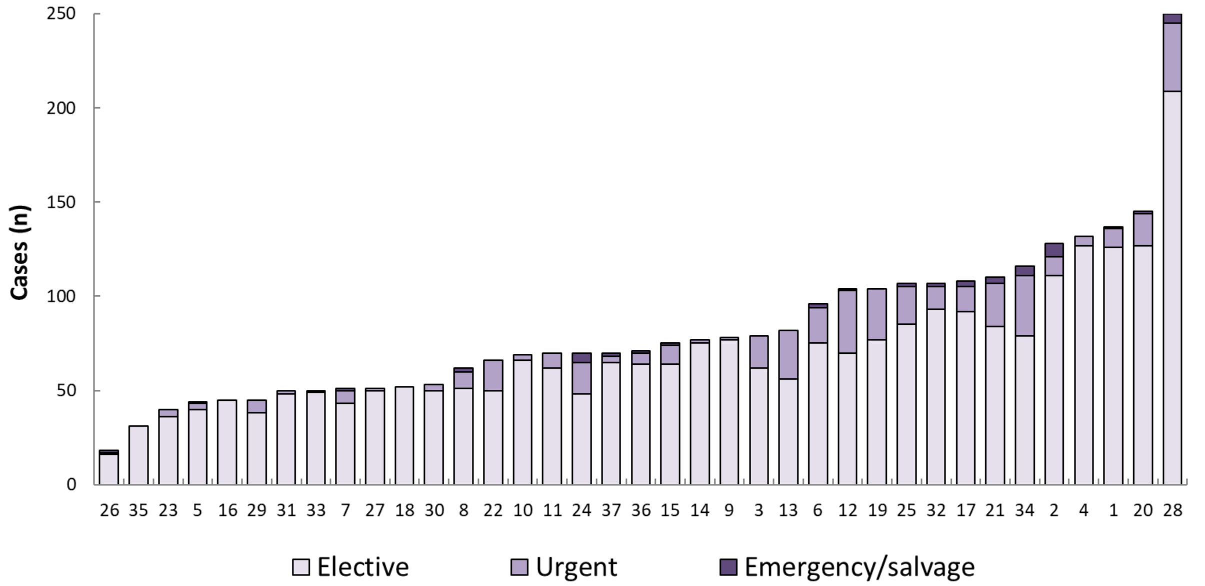
Key patient characteristics that influence the outcomes of surgery include clinical status, sex, age and comorbidities. The distributions of these factors in the Australian isolated valve surgery patient population are explored in the following sections.

3.1.1 Clinical status

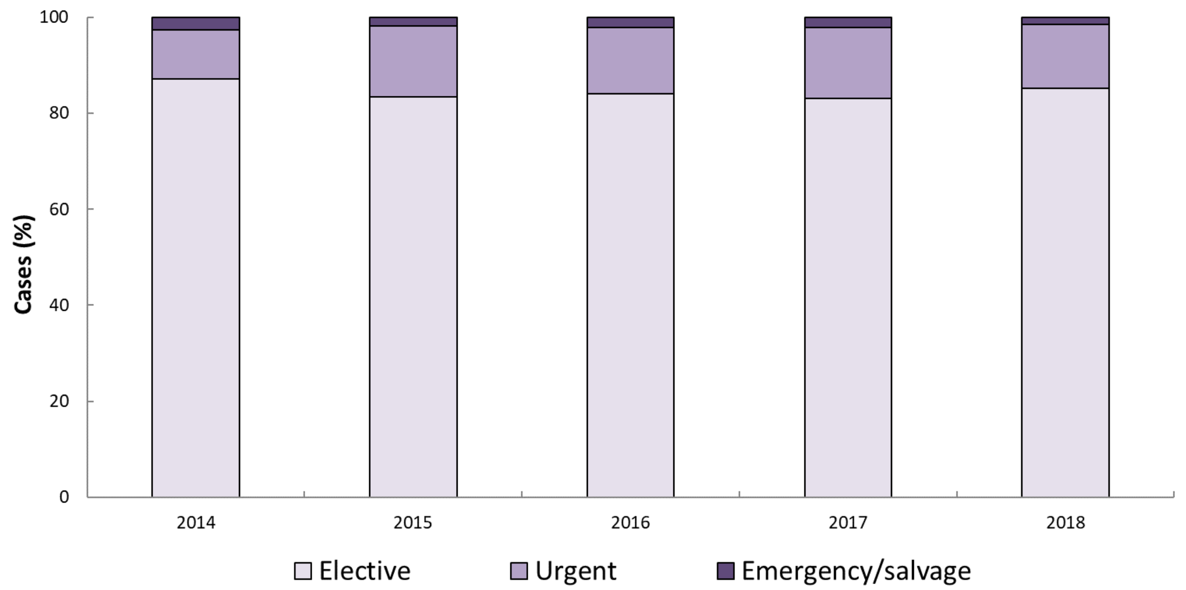
The proportion of urgent and emergency/salvage cases in 2018 varied between units; however, the average rates were consistent over the past five years with 84.4% of cases classified as elective, 13.6% as urgent, and 2.01% as emergency/salvage (Figures 37a and b).

Figure 37. Clinical status of isolated valve procedure patients

a. Unit in 2018



b. Year

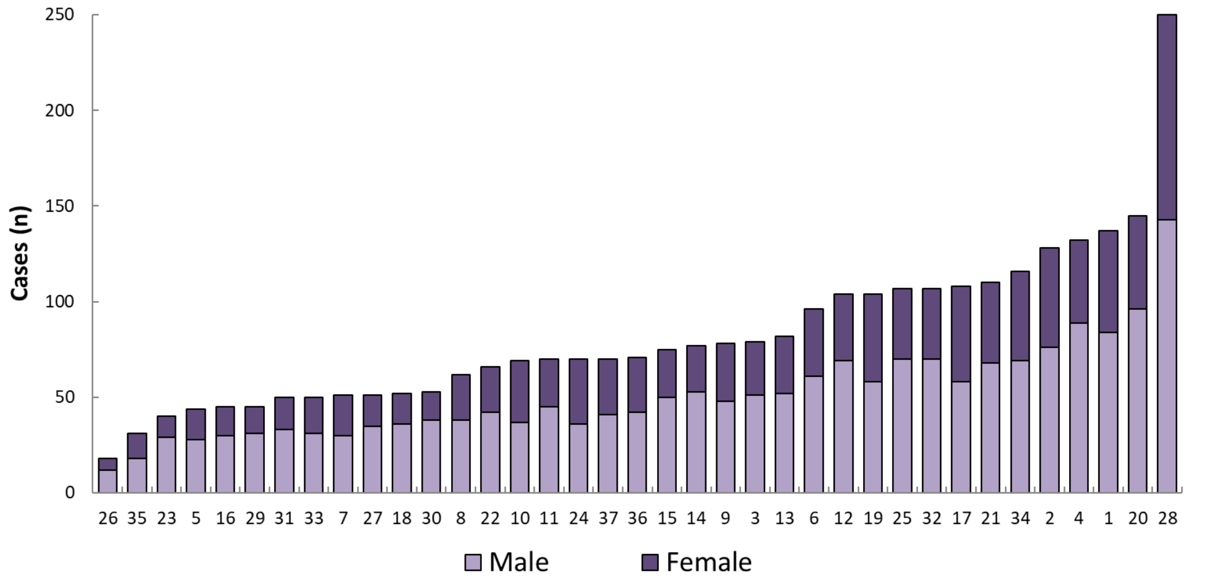


3.1.2 Sex and age

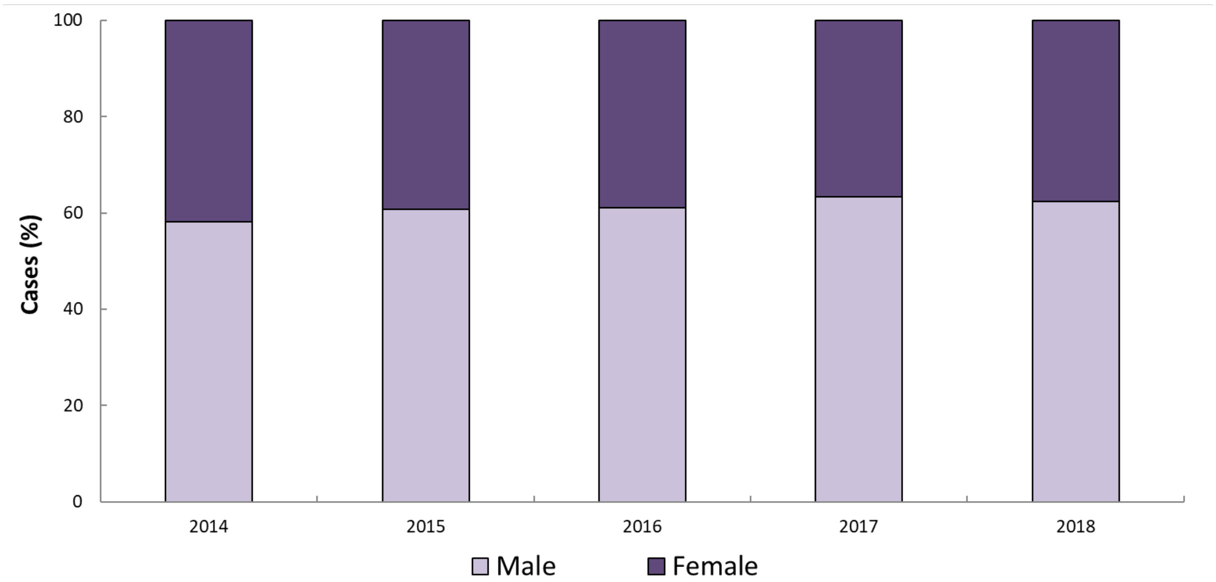
The ratio of male to female patients was consistent between units in 2018 (Figure 38a). There was a slight increase in the proportion of male patients presenting for isolated valve surgery over the last five years, progressing from 58.2% in 2014 to 62.3% in 2018 (Figure 38b).

Figure 38. Sex of isolated valve procedure patients

a. Unit in 2018

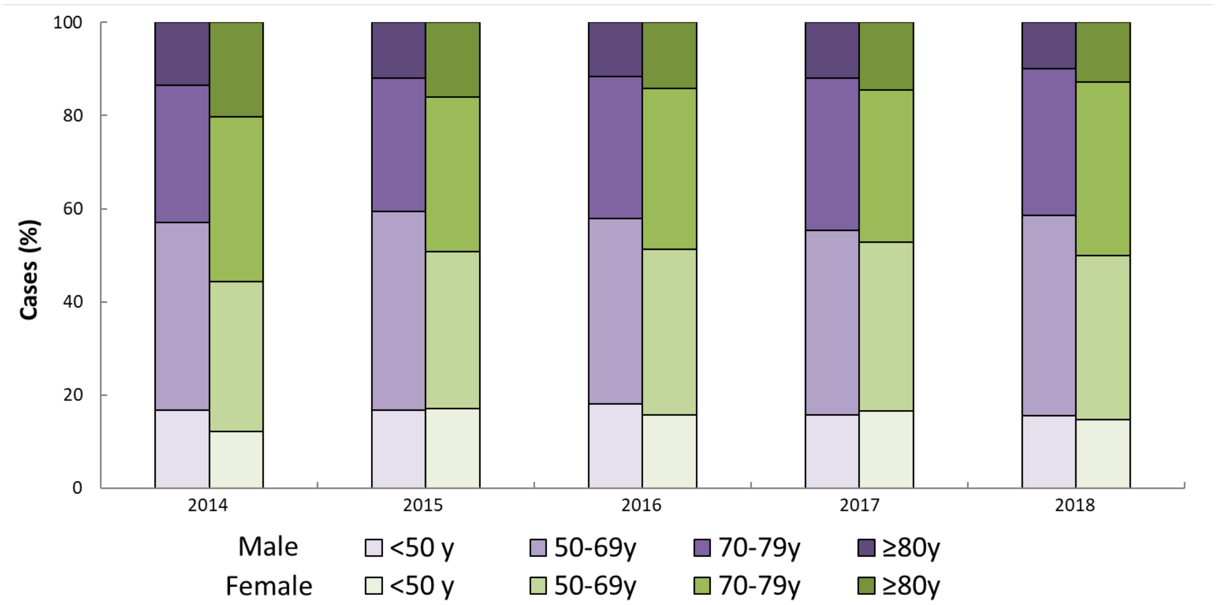


b. Year



As was the case with isolated CABG procedures, a higher proportion of women undergoing isolated valve procedures over the last five years were aged 70 years and over, compared to their male counterparts (Figure 39).

Figure 39. Age groupings for male and female isolated valve procedure patients, 2014-2018

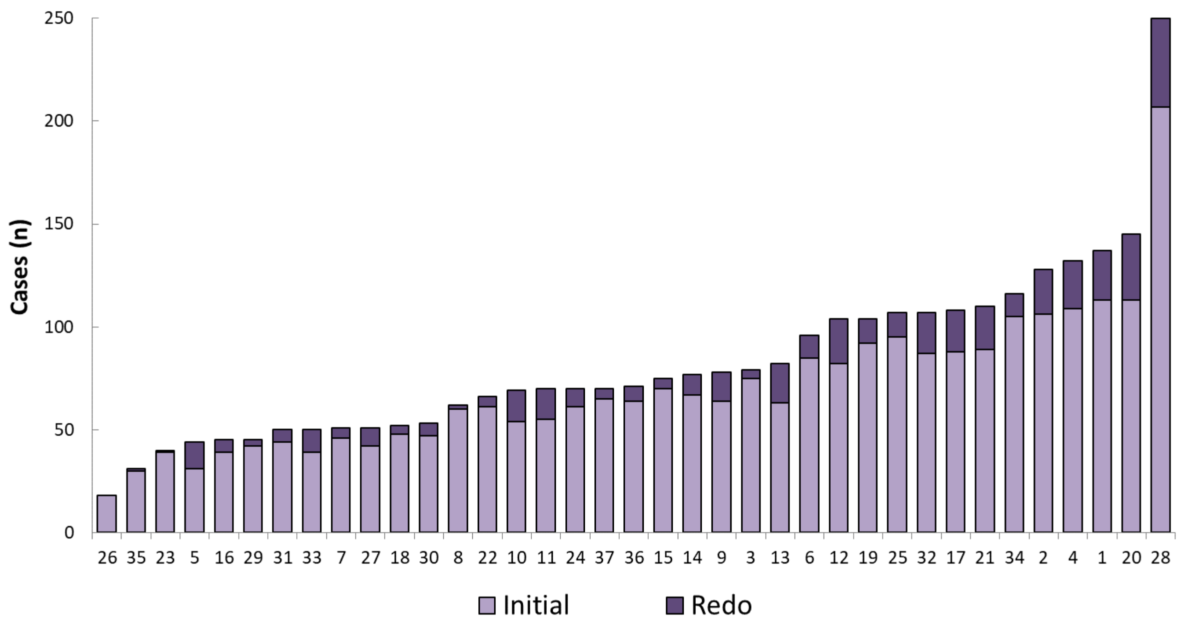


3.2 Previous surgery

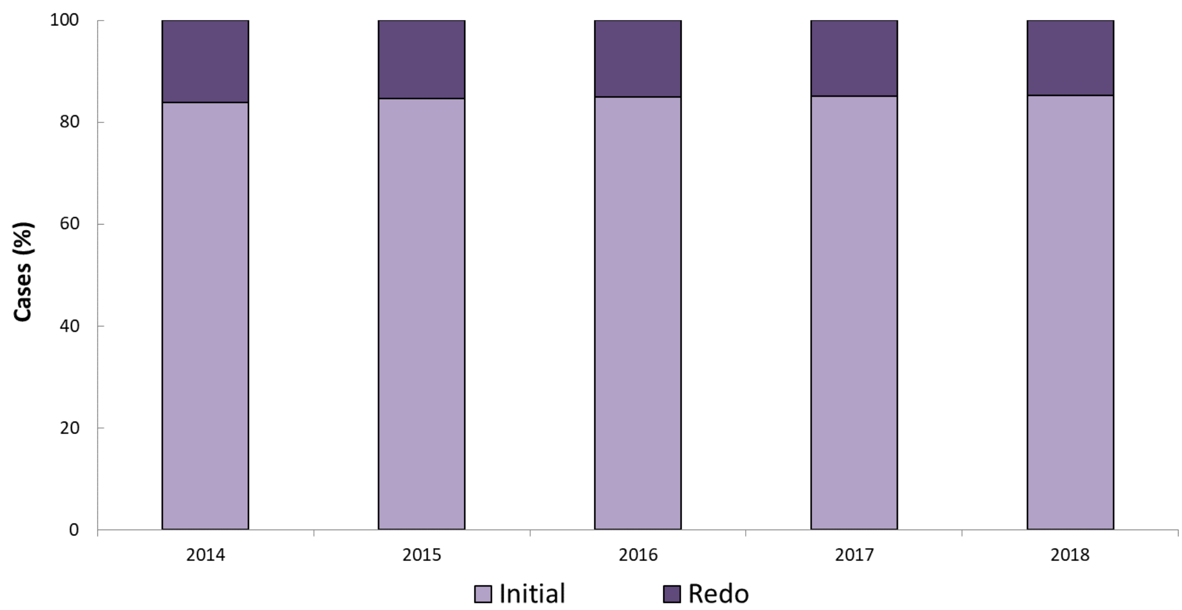
A procedure is considered a redo if the patient had any prior cardiac surgery. In 2018, the proportion of isolated valve surgery patients who had previous cardiac surgery varied between units from 0 to 29.5% (Figure 40a). There was a 9.21% reduction in the total proportion of redo cases between 2014 and 2018, changing from 16.2% to 14.7% of all procedures. (Figure 40b).

Figure 40. Initial and redo isolated valve procedures

a. Unit in 2018



b. Year



3.3 Overview of all valve procedures

Case numbers and OM for single and multi-valve procedures are detailed in Table 23. Where these procedures were performed with CABG, they are presented separately, in Section 4 (Table 27). A full list of valve operations is available in the ANZSCTS Database Data Definitions Manual.

TAVR cases are reported in Table 24. The ANZSCTS Database released a specific TAVR module in September of 2016 and, as a result, has seen a significant increase in the number of TAVR cases reported.

The most common isolated valve operations performed in 2018 and in the preceding four years were single aortic, which predominantly involve aortic valve replacements (AVR), followed by single mitral (Table 23).

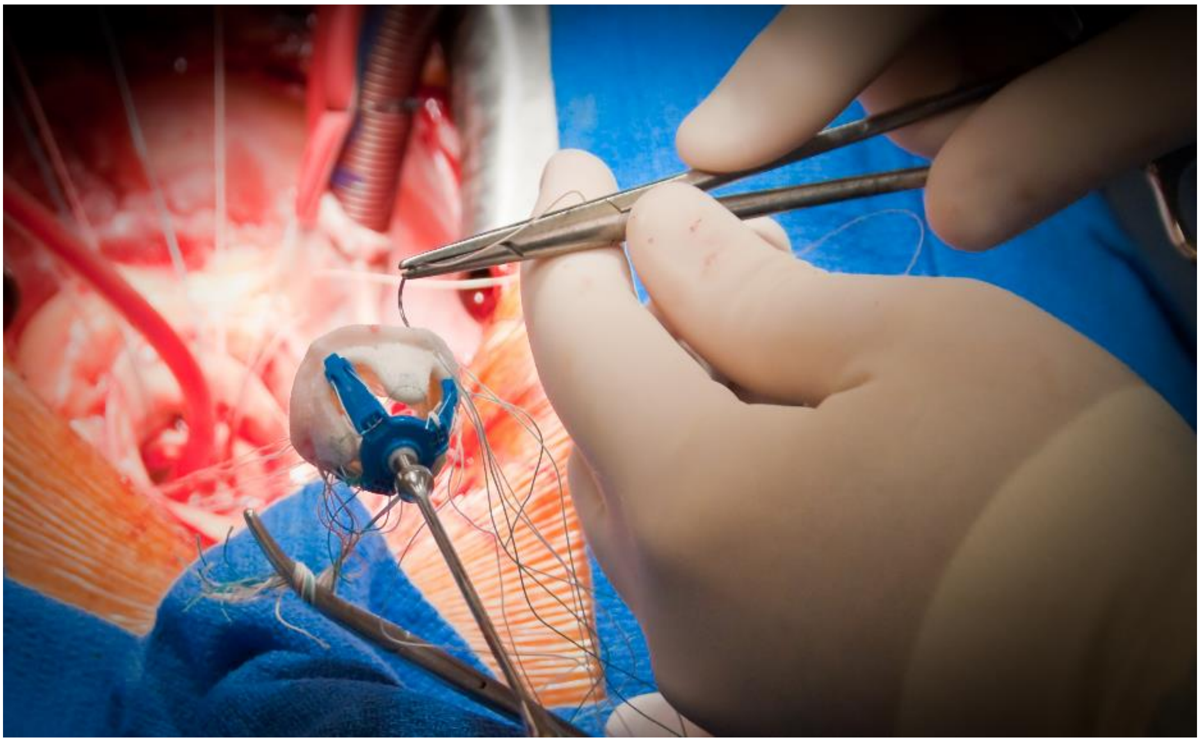


Table 23. Observed mortality (%) for valve procedures, 2018 and 2014-2017

Valve Procedure	Year	n	OM (%)
Single aortic#	2018	1632	1.2
	2014-2017	5514	1.9
AVR	2018	1557	1.2
	2014-2017	5269	1.8
Other aortic	2018	75	0.0
	2014-2017	244	2.9
Single mitral*	2018	883	1.9
	2014-2017	2850	1.6
Replacement	2018	387	4.1
	2014-2017	1238	3.0
Repair	2018	482	0.2
	2014-2017	1582	0.4
Single tricuspid	2018	70	1.4
	2014-2017	209	7.2
Single pulmonary	2018	41	0.0
	2014-2017	139	1.4
Aortic and mitral	2018	170	4.7
	2014-2017	640	5.3
Aortic and tricuspid	2018	16	12.5
	2014-2017	70	2.9
Mitral and tricuspid	2018	159	3.1
	2014-2017	553	4.5
Other double	2018	13	7.7
	2014-2017	46	2.2
Triple	2018	59	3.4
	2014-2017	172	9.3
Quadruple	2018	0	-
	2014-2017	2	0.0
Total valve procedures	2018	3043	1.8
	2014-2017	10195	2.4

#Aortic valve procedures exclude TAVR
*Mitral valve procedures exclude TMVR
Three cases excluded from table due to missing procedural data

Table 24. Observed mortality (%) for TAVRs, 2018 and 2014-2017

Valve Procedure	Year	n	OM (%)
TAVR	**2018**	372	1.6
	2014-2017	700	2.0
Transapical	**2018**	6	0.0
Transfemoral	**2018**	277	1.4
Transaortic	**2018**	7	0.0
Transsubclavian	**2018**	5	0.0
Unknown access route^	**2018**	77	2.6
Total other valve procedures	**2018**	**447**	**1.3**
	2014-2017	**943**	**2.0**

^77 cases had missing access route data

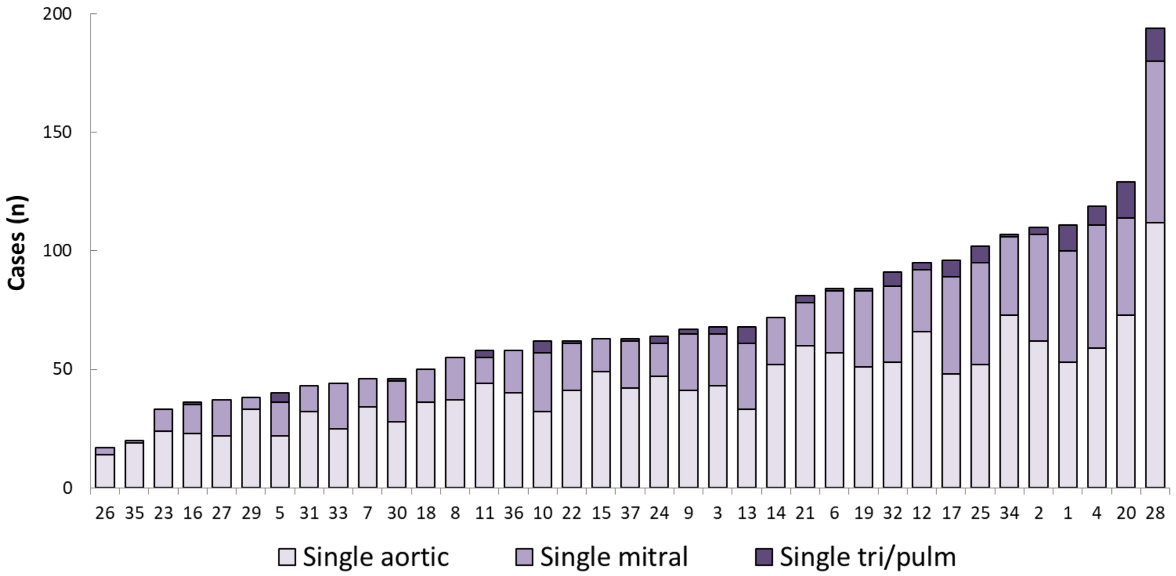
3.4 Single valve procedures

3.4.1 Type of procedure

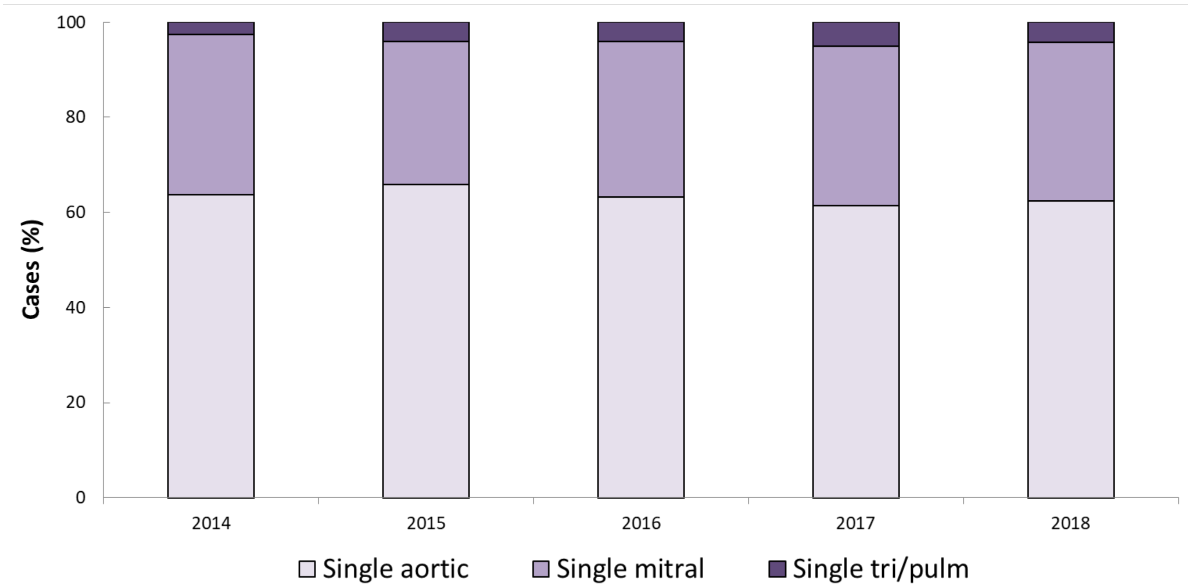
The proportions of the types of single valve surgery performed were consistent over the last five years, and between units in 2018 (Figure 41a and b). Approximately 62.5% of isolated single valve procedures performed in 2018 involved the aortic valve, 33.3% the mitral, and 4.25% were tricuspid or pulmonary (tri/pulm; Figure 41b).

Figure 41. Type of isolated single valve procedures performed

a. Unit in 2018



b. Year



3.4.2 Influence of patient characteristics on mortality

Generally, observed mortality was higher for patients having urgent or redo procedures (Table 25). The relationship between mortality and age, LVF, and previous MI was less consistent which, particularly with respect to mitral valve replacement (MVR) and mitral valve (MV) repair, may be related to lower case numbers. It should be noted that OM is not risk-adjusted and therefore does not account for differences in patient characteristics.

The table below refers to surgical valve replacements. Non-invasive percutaneous valve replacements such as TAVR and TMVR have been excluded.

Table 25. Observed mortality (%) on the basis of patient characteristics for the three most common isolated single valve procedures, 2014-2018

	AVR		MVR		MV repair	
	n	OM (%)	n	OM (%)	n	OM (%)
Clinical status						
Elective	5890	1.2	1265	2.3	1870	0.3
Urgent	835	3.7	285	4.9	178	0.6
Emergency/salvage	101	13.9	75	13.3	16	0.0
Sex/age						
Male~	4414	1.5	796	2.6	1425	0.1
<50y	458	0.2	149	4.0	285	0.0
50-69y	1734	1.3	329	1.8	767	0.1
70-79y	1610	1.6	233	2.1	292	0.3
≥80y	610	2.8	85	4.7	81	0.0
Female*	2412	2.1	829	3.9	639	0.8
<50y	136	3.7	181	2.8	121	0.0
50-69y	805	0.6	300	4.3	300	1.0
70-79y	994	2.0	246	4.9	161	0.6
≥80y	476	4.2	101	2.0	57	1.8
Left ventricular function^						
Normal LVF	4100	1.2	940	3.1	1291	0.3
Mild LVD	1829	2.0	454	4.6	608	0.5
Moderate LVD	574	2.6	168	1.2	135	0.0
Severe LVD	199	5.5	35	2.9	12	0.0
Previous MI						
No MI	6315	1.6	1477	3.2	2010	0.3
NSTEMI	354	3.1	76	5.3	31	3.2
STEMI	77	1.3	54	1.9	12	0.0
Unknown type	80	5.0	18	0.0	11	0.0
Previous surgery						
Initial	6058	1.4	1229	2.8	1984	0.4
Redo	768	4.0	396	4.8	80	0.0

~Two cases missing for AVR male age group

*One case missing for both the AVR and MVR female age group

^One case missing for each of AVR and MV repair. 121, 28 and 17 cases had no angiogram performed or have an unknown EF entered for AVR, MVR and MV repair, respectively.

3.5 Aortic valve replacement

The number of surgical AVRs performed by each unit in 2018 ranged from 12 to 110 (Figure 42), which is comparable to the 2017 case numbers[32]. Since 2014, 8.37% of isolated AVRs have been limited access procedures (Figure 43).

Figure 42. AVR procedures performed by unit, 2018

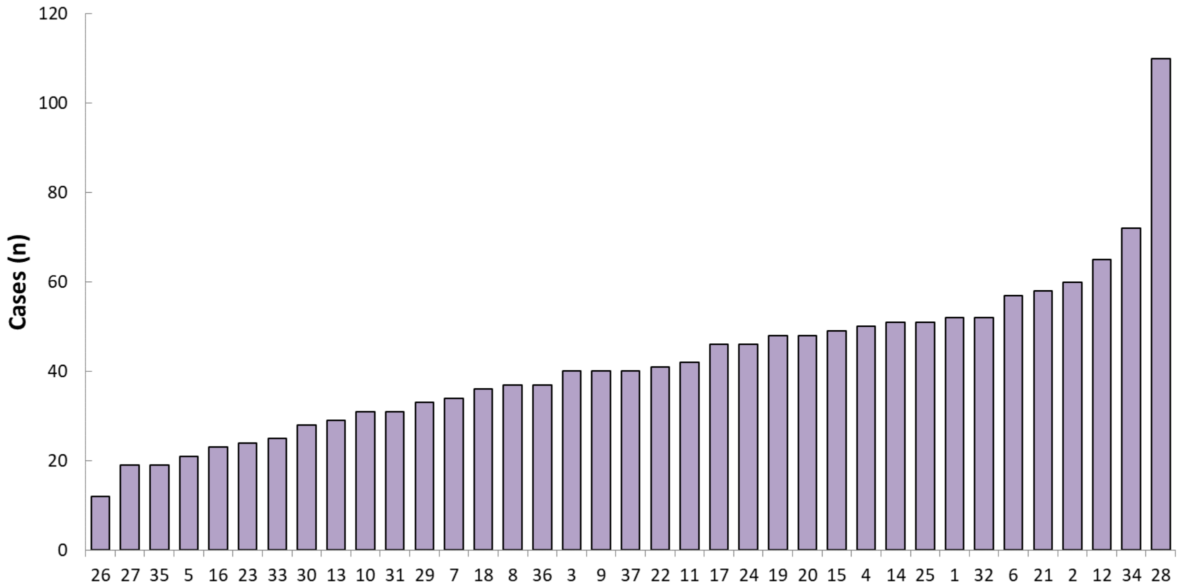
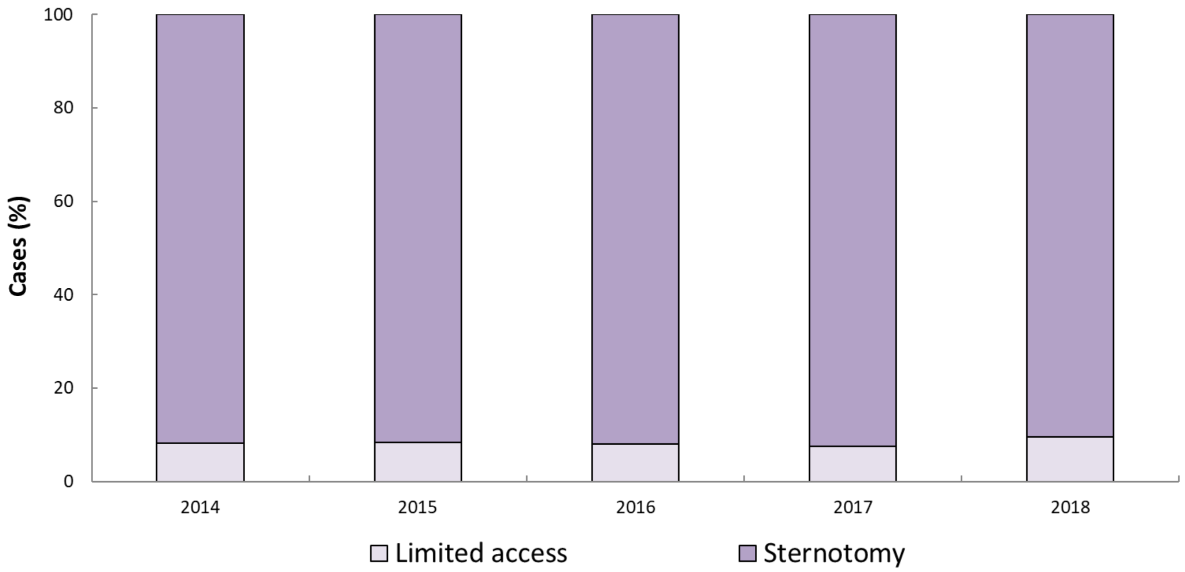


Figure 43. Surgical access for isolated AVR procedures by year



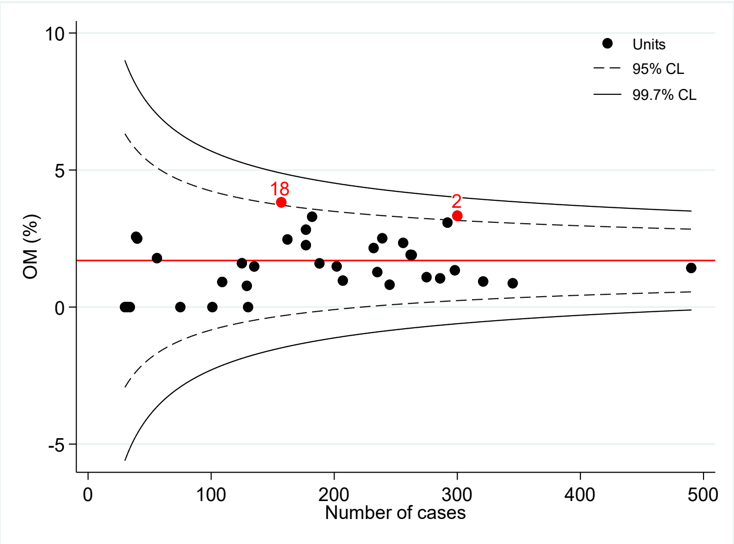
3.5.1 Unit outcomes – mortality, complications and resource utilisation

Unit outcomes are reported for isolated AVR procedures only, because these are the most commonly performed valve procedures. Due to low procedure numbers, the unit outcome data for AVRs is presented for the pooled 2014-2018 period.

3.5.1.1 Mortality

Between 2014 and 2018, the average observed mortality for all isolated surgical AVR cases submitted to the Database was 1.70% (Figure 44). This is comparable to 30 day mortality reported by the SWEDEHEART registry in 2018 (2.04%), the SCTS 2015 figure for first-time isolated AVR (1.55%), the STS operative mortality of approximately 1.9% from January to September 2018, and is above that of New Zealand in 2016 (0.83%)[6–8,10]. All units were within the upper 99.7% CL.

Figure 44. Observed mortality by unit following AVR, 2014-2018

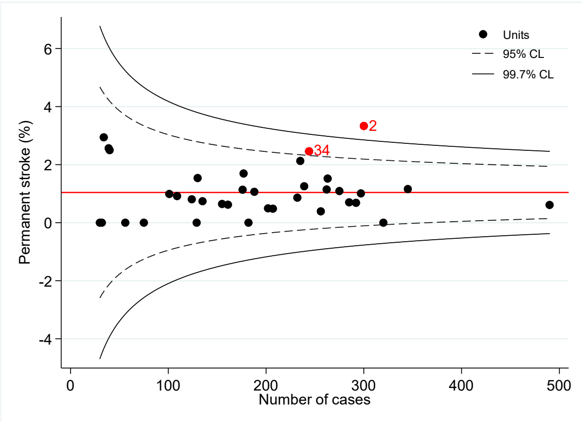


3.5.1.2 Complications

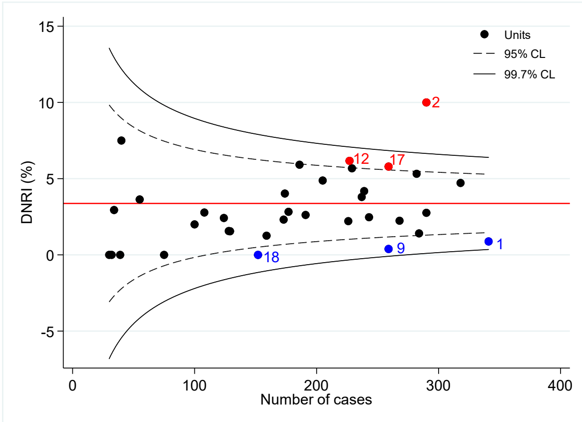
While the incidences of permanent stroke (mean of 1.04%) and DSWI (0.83%) were similar for most units, there was notable variation with DNRI (3.37%), NCA (32.4%), re-op for bleeding (3.68%), and readmission (10.2%; Figure 45). The data for incidence of DNRI excludes patients who received pre-operative dialysis (Figure 45b).

Figure 45. Complications by unit following AVR, 2014-2018

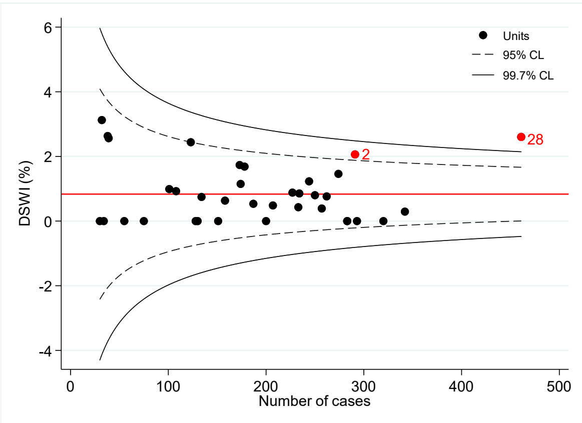
a. Permanent stroke



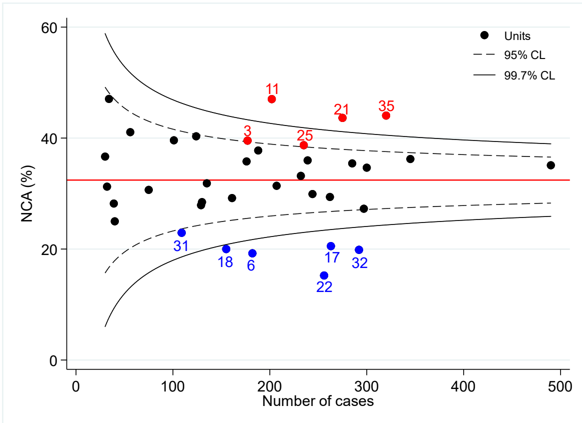
b. DNRI



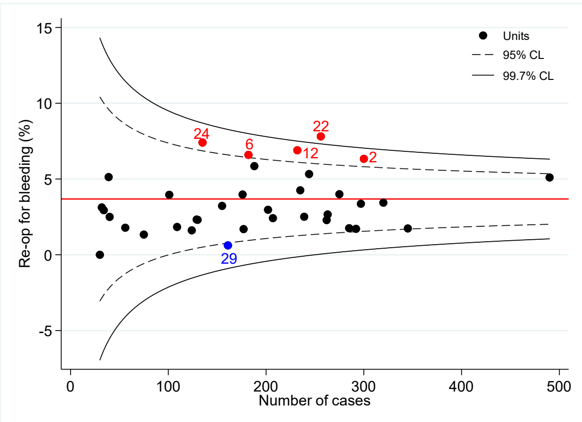
c. DSWI



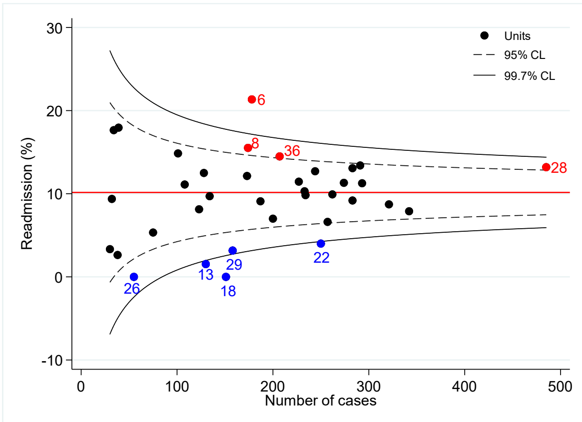
d. NCA



e. Re-op for bleeding



f. Readmission



3.5.1.3 Resource utilisation

Due to the skewed distribution of the ICU length of stay and ventilation data, the GMs are presented. The GM is defined as the nth root of a product of n numbers. It is useful to describe the central tendency of a set of skewed data, as it is less sensitive to outlying values.

The pooled data shows marked variation between units for the time patients spent in the ICU, the duration of ventilation, and the percentage of patients who received RBC or NRBC transfusions (Table 26). The ICU length of stay and ventilation times were similar to those for isolated CABG cases, as were the proportion of cases involving transfusions.

Table 26. Resource utilisation by unit for isolated AVR patients, 2014-2018

	2014-2018			
Unit	ICU (GM, h)	Ventilation (GM, h)	RBC usage (%)	NRBC usage (%)
1	53.3	8.6	10.4	5.8
2	57.8	9.7	35.0	28.7
3	38.2	9.1	17.5	10.7
5	58.0	7.0	6.7	26.7
6	39.1	11.0	27.5	25.3
7	75.8	8.0	20.6	5.9
8	32.9	10.3	27.7	26.6
9	36.9	6.2	25.6	22.9
10	35.0	7.8	22.5	22.5
11	43.2	12.0	38.8	24.9
12	70.6	13.9	35.3	25.0
13	35.0	7.6	17.7	25.4
14	77.1	15.8	5.3	1.3
15	31.8	10.1	29.3	15.5
16	57.3	8.4	25.7	32.7
17	48.9	14.3	28.9	16.3
18	78.5	15.6	19.7	6.4
19	60.9	10.5	27.6	19.5
20	31.4	9.1	23.4	12.2
21	81.5	9.6	30.9	19.3
22	38.2	14.3	40.6	41.8
23	34.6	6.4	10.0	40.0
24	66.6	15.4	17.9	15.7
25	25.1	8.8	17.4	6.4
26	34.5	10.2	17.9	12.5
27	61.8	8.2	50.0	28.1
28	31.6	9.1	25.9	20.2
29	33.3	8.9	15.5	10.6
30	60.5	12.4	31.2	13.6
31	65.7	14.3	48.6	45.0
32	102.1	11.8	34.6	19.5
33	54.9	13.9	28.2	51.3
34	41.2	8.0	27.3	15.9
35	53.6	8.4	37.4	19.9
36	36.2	8.6	36.2	25.1
37	35.1	10.4	30.9	29.3
Total	**46.2**	**10.0**	**27.5**	**20.1**

In 2014-2018, there was variability between units in the pre- and post-PLOS data for isolated AVR cases (Figures 46 and 47). The medians ranged from zero to one days for pre-PLOS and five to ten days for post-PLOS.

Figure 46. Pre-procedural length of stay for isolated AVR patients by unit, 2014-2018

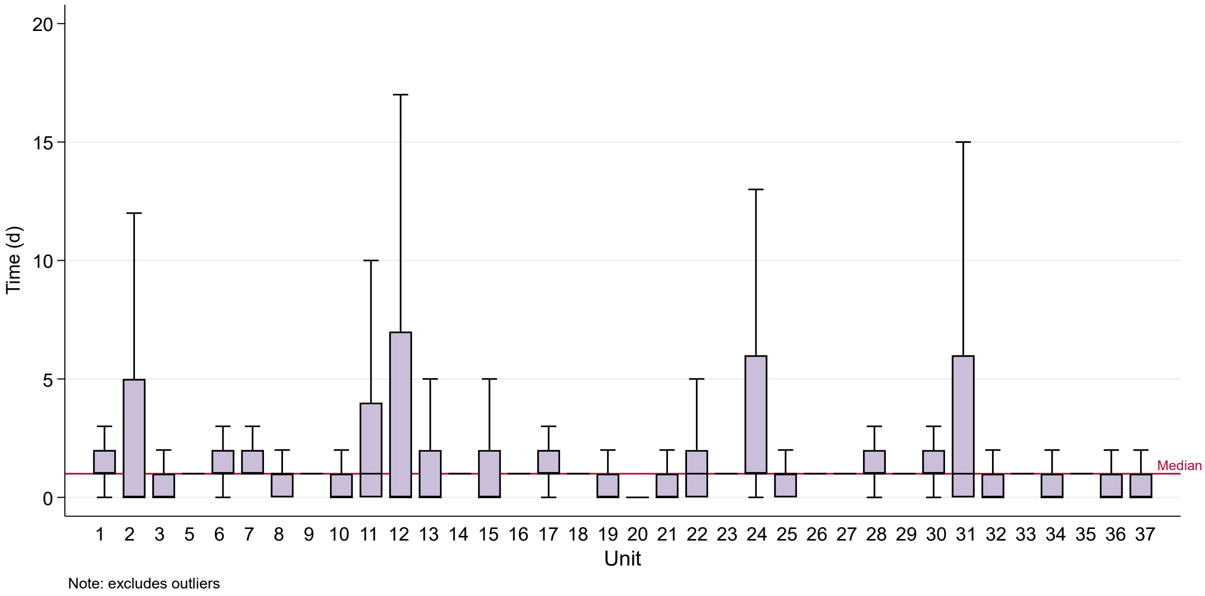
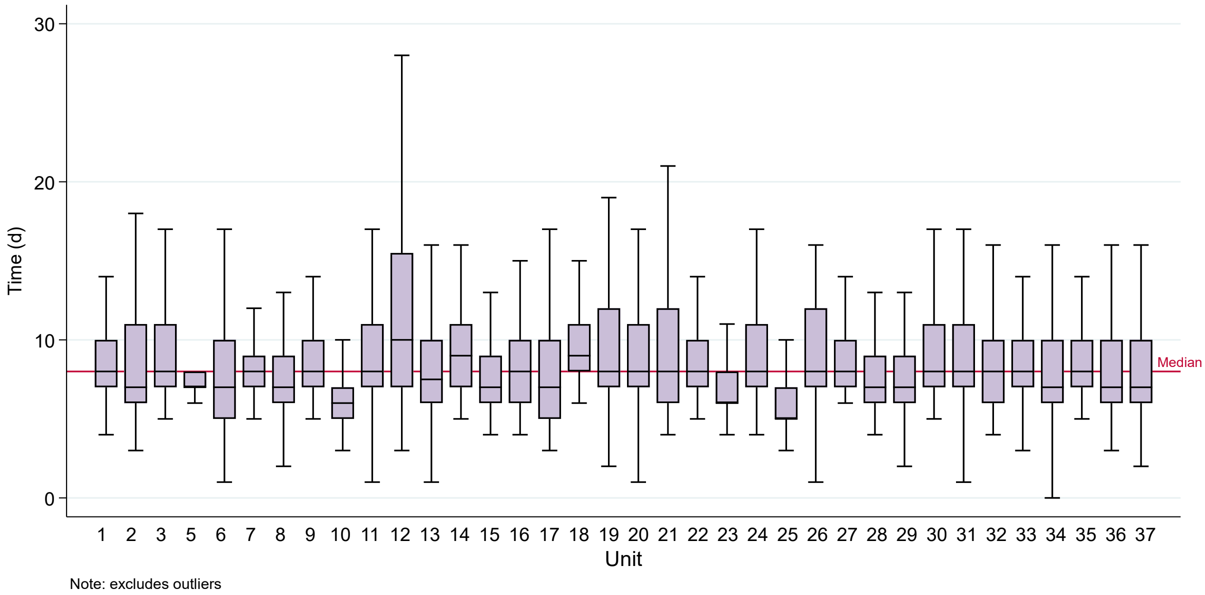


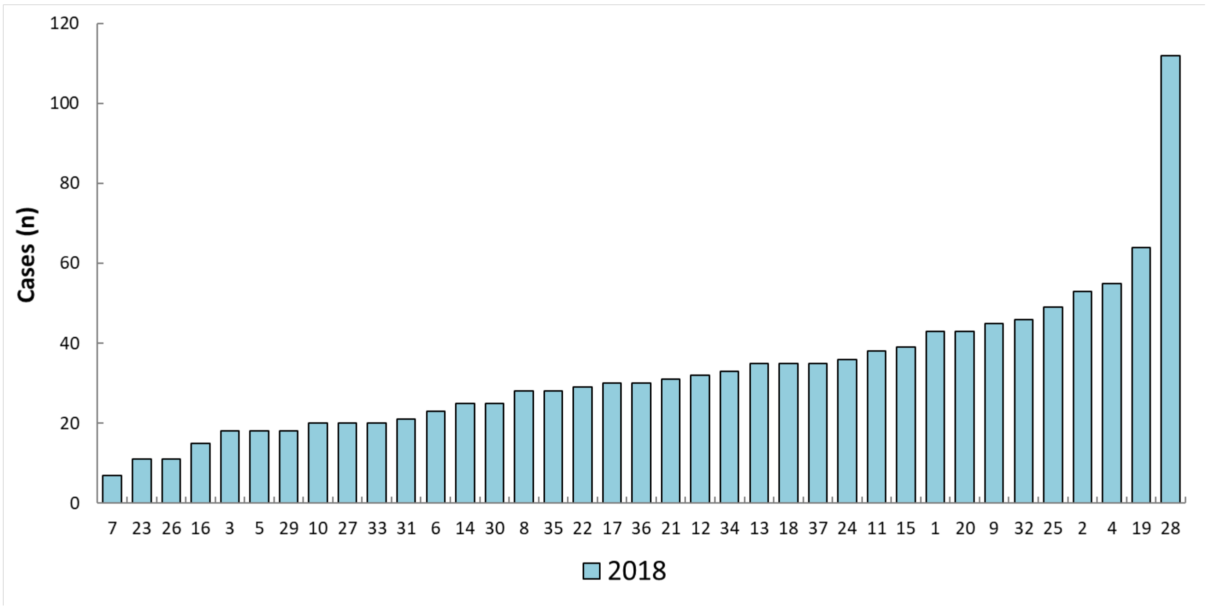
Figure 47. Post-procedural length of stay for isolated AVR patients by unit, 2014-2018



4. Valve with CABG

A total of 1221 valve with CABG procedures were submitted to the Database in 2018. The lowest volume unit performed 7 of these procedures, while the highest accounted for 112 (Figure 48).

Figure 48. Valve with CABG procedures performed by unit, 2018



4.1 Patient characteristics

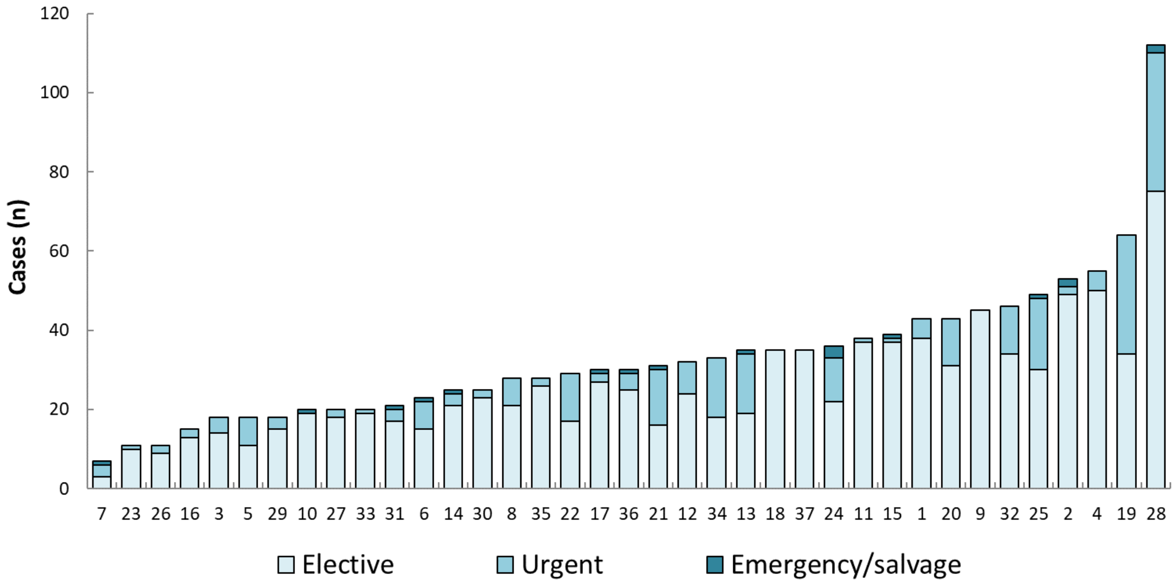
Key patient characteristics that influence the outcomes of surgery include clinical status, sex, age and comorbidities. The distributions of these factors in the Australian cardiac surgery patient population are explored in the following sections.

4.1.1 Clinical status

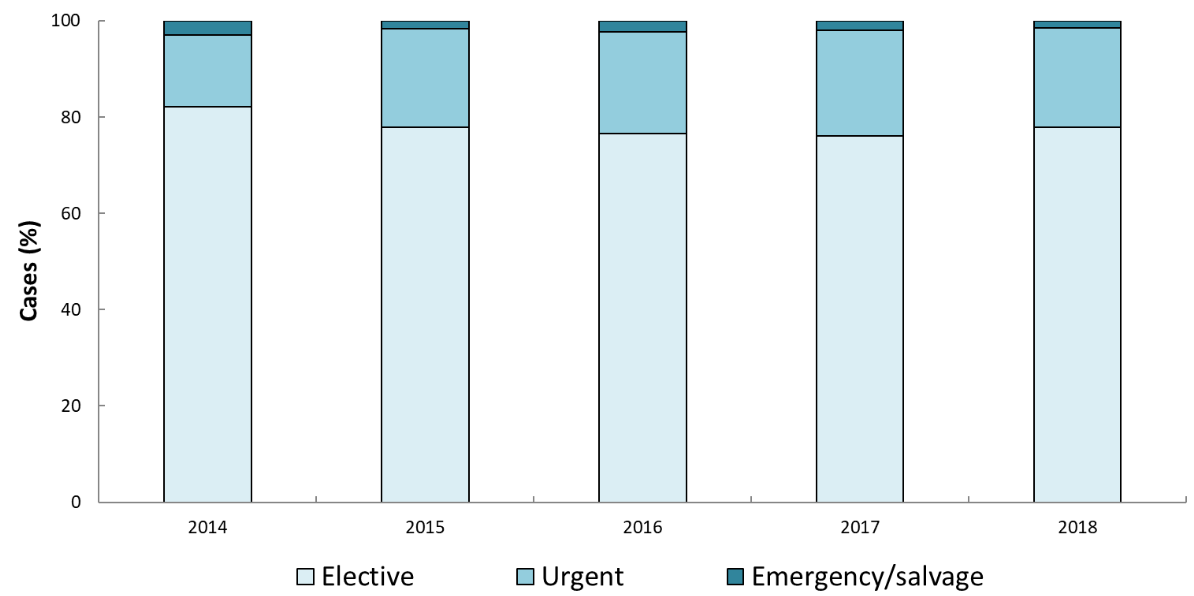
As with isolated CABG and isolated valve procedures, the proportion of elective and urgent surgery varied between units (Figure 49a). The distribution of clinical status remained fairly consistent over the last four years, with 77.2% of valve with CABG cases being elective, 21.0% urgent, and 1.79% emergency or salvage (Figure 49b). A much smaller proportion of valve with CABG cases are urgent or emergency/salvage, compared to isolated CABG procedures.

Figure 49. Clinical status of valve with CABG patients

a. Unit in 2018



b. Year

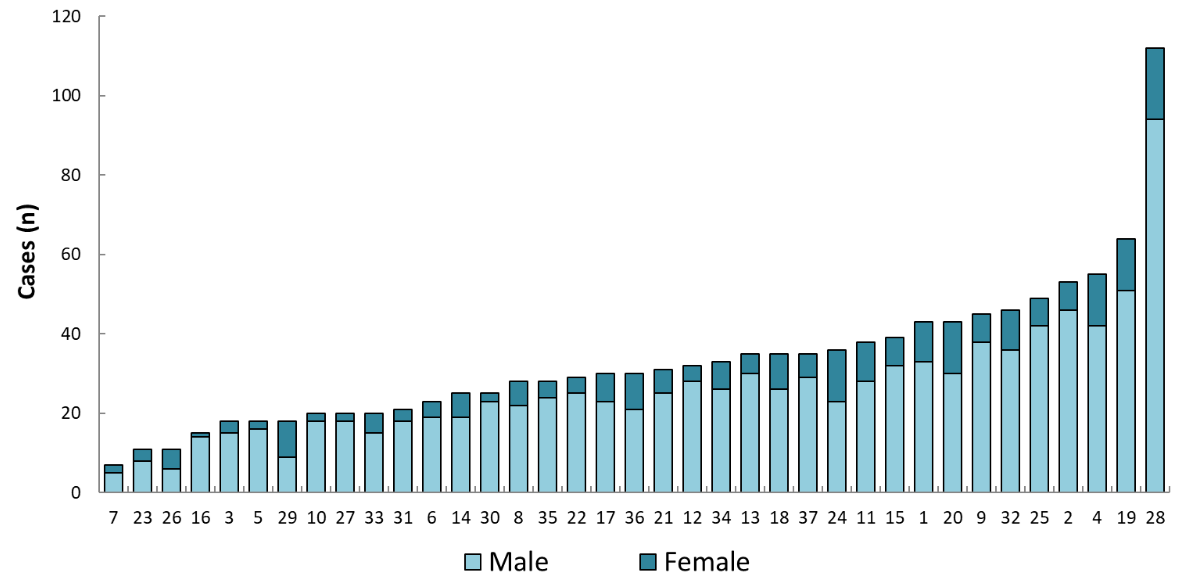


4.1.2 Sex and age

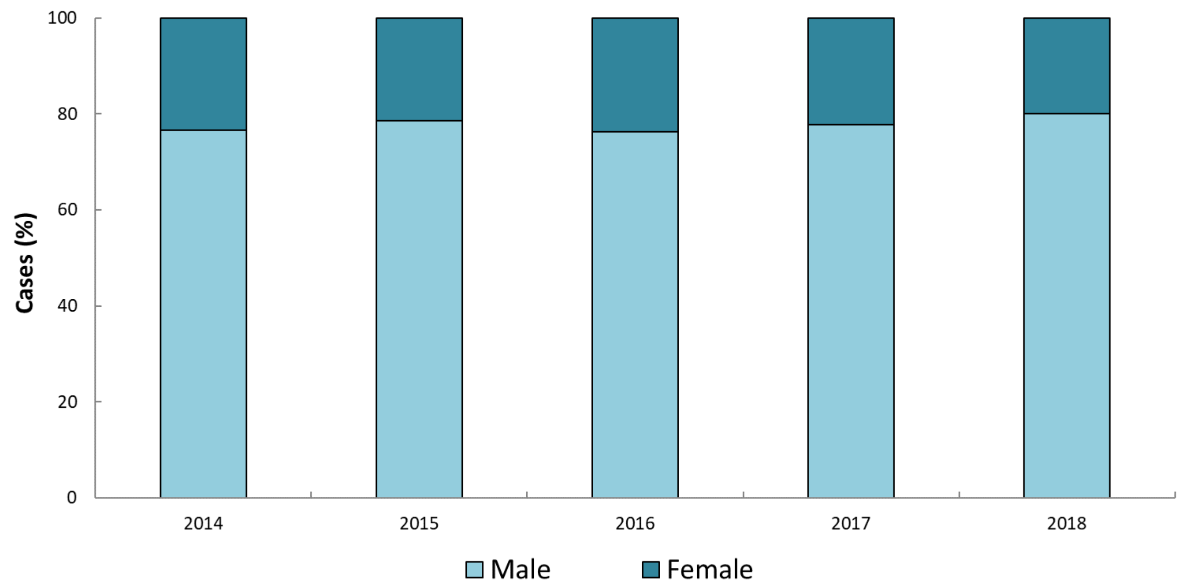
The ratio of male to female valve with CABG patients was reasonably similar between units in 2018 (Figure 50a). Of note, there was a slightly higher proportion of male patients in 2018, compared to the previous four years (Figure 50b).

Figure 50. Sex of valve with CABG patients

a. Unit in 2018

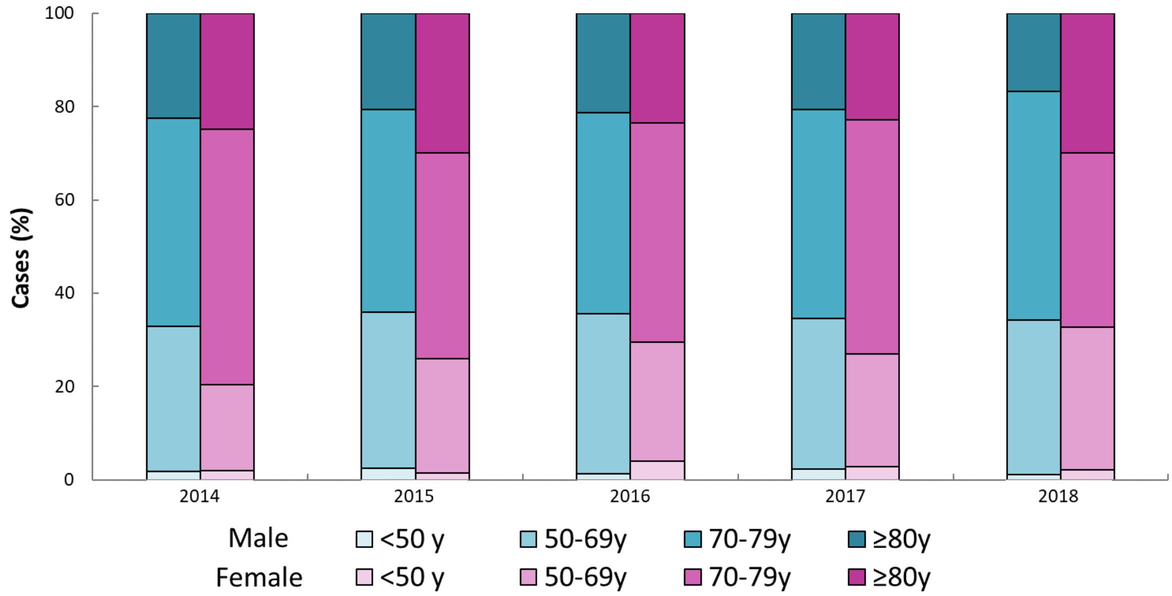


b. Unit in 2018



Between 2014 and 2017 there was a higher proportion of female patients aged 70 years and over having valve with CABG procedures, compared to male patients; however, this was less clear in 2018 (Figure 51). In contrast, there was a much higher proportion of female patients aged 80 years and over, compared to males (29.9% vs 16.8%).

Figure 51. Age groupings for male and female valve with CABG patients 2014-2018

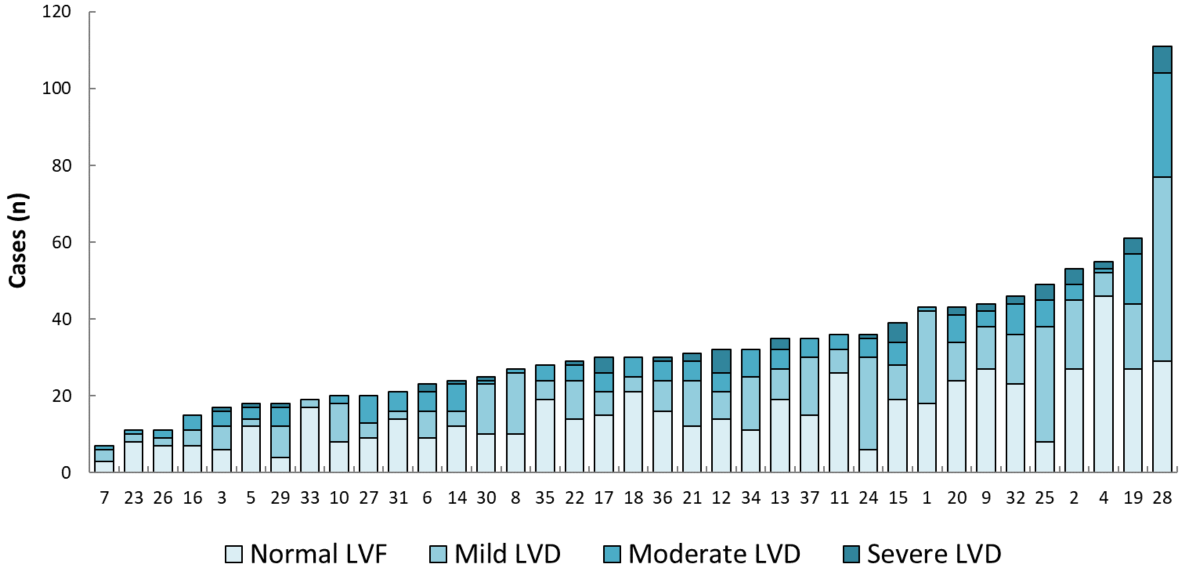


4.1.3 Left ventricular function

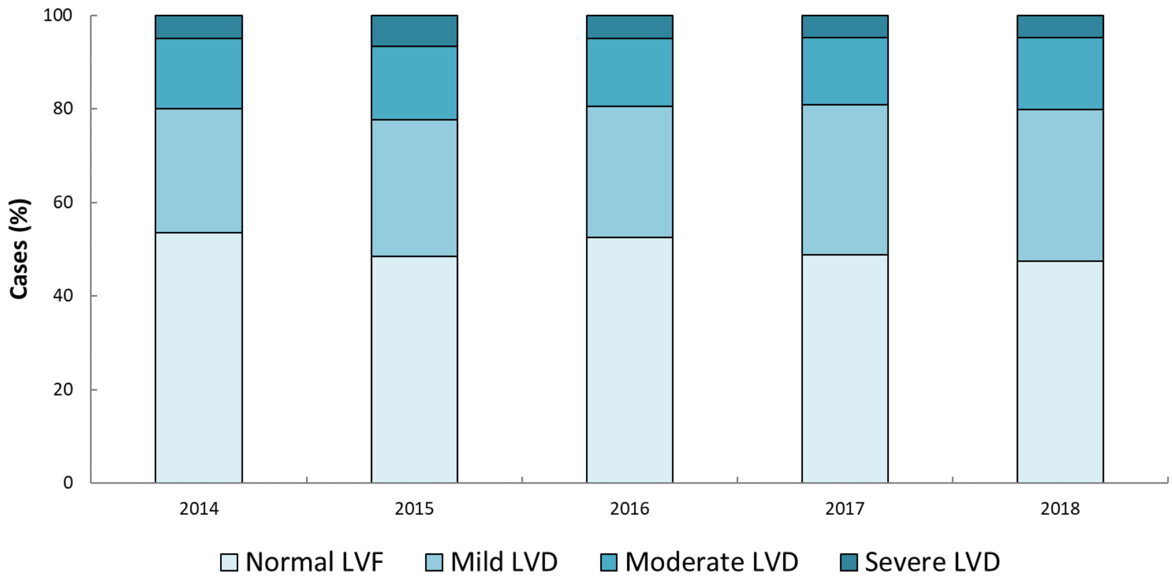
Slightly less than half of the patients undergoing valve with CABG procedures in 2018 had normal LVF (Figure 52a and b). There was variation between units, with some showing a higher proportion of patients with mild LVD (Figure 52a). Patients with moderate LVD and severe LVD accounted for 15.4% and 4.73% of cases, respectively (Figure 52b).

Figure 52. Valve with CABG: pre-procedure LV function

a. Unit in 2018



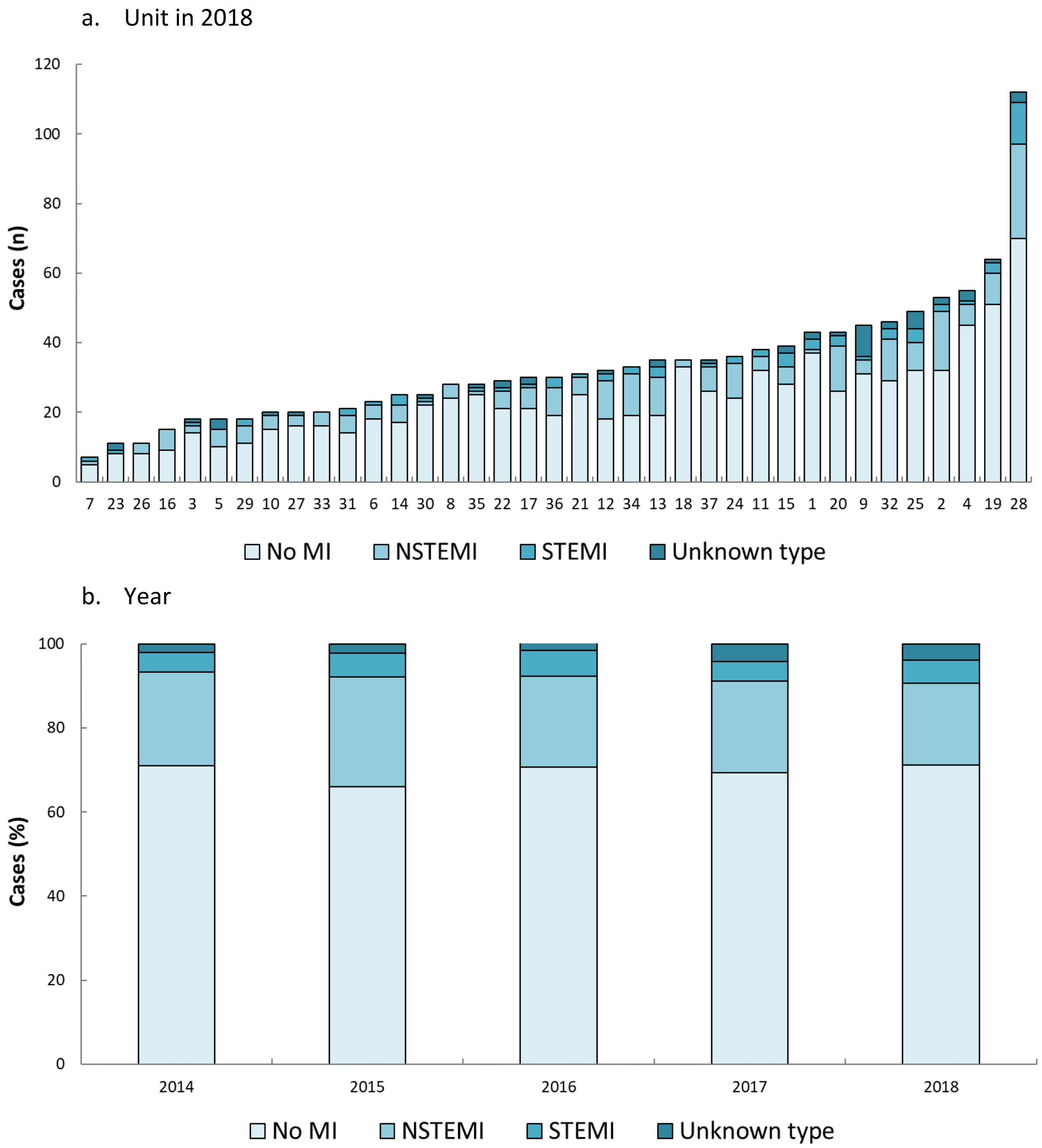
b. Year



4.1.4 Previous myocardial infarction

In 2018, 71.3% of valve with CABG patients did not have a MI prior to surgery, and this was fairly consistent between units (Figure 53). Of those who did have a MI, 67.2% were a NSTEMI, 19.1% a STEMI, and 13.7% were classified as unknown.

Figure 53. Valve with CABG: prior MI

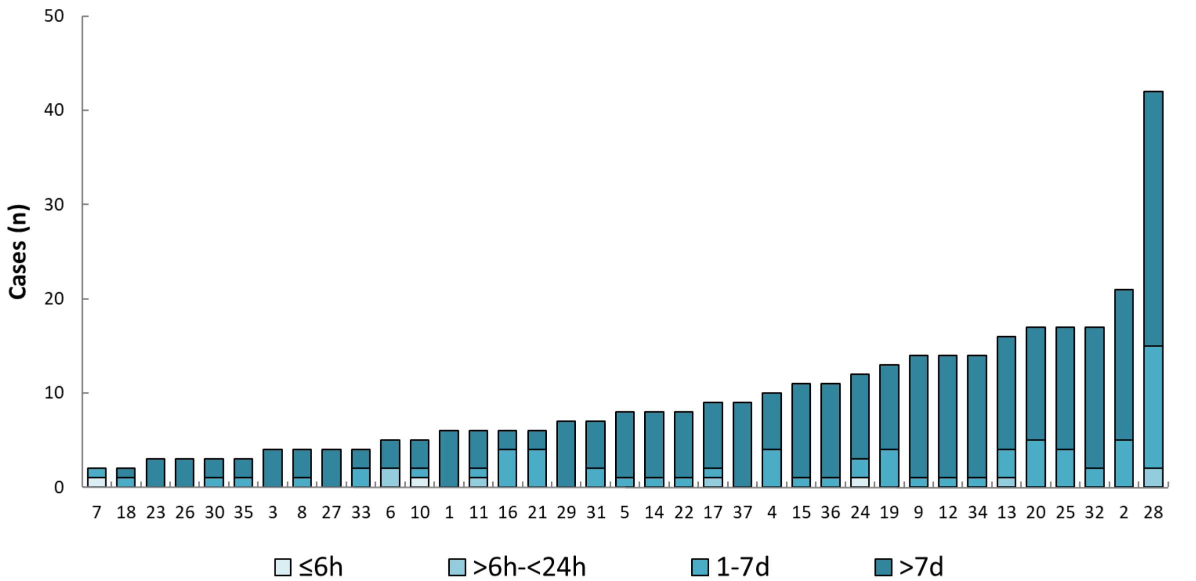


4.1.5 Timing of prior myocardial infarction

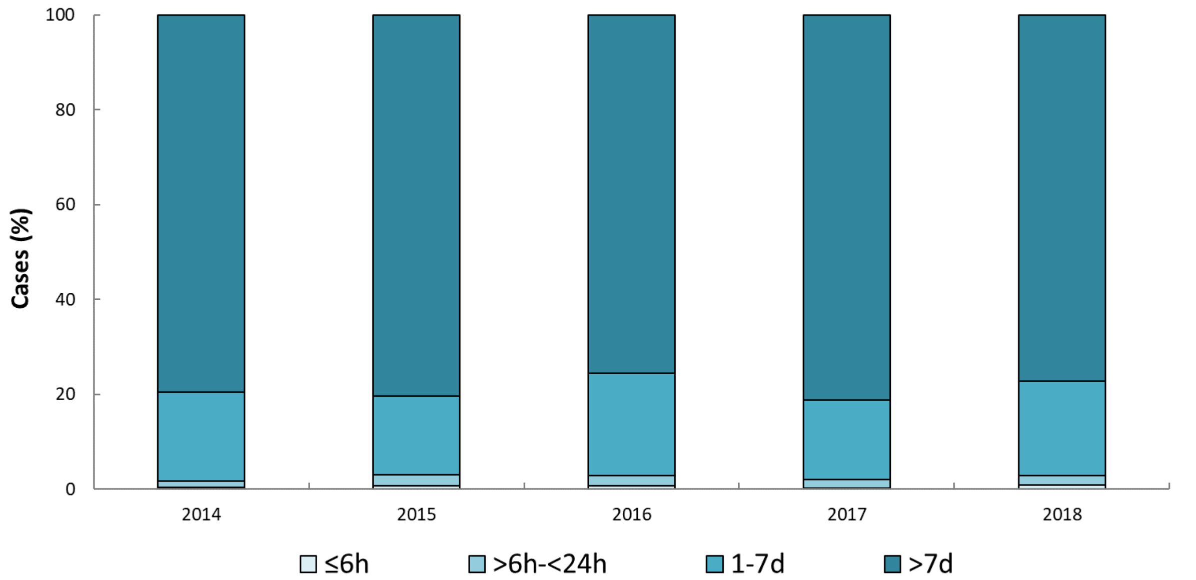
In all units, the majority of patients with a prior MI reported the incident as having occurred more than seven days before valve with CABG surgery (Figure 54a). This is consistent with the pooled data over the last five years (Figure 54b). In 2018, 2.85% of MIs occurred within 24 hours of surgery.

Figure 54. Valve with CABG: timing of pre-procedure MI

a. Unit in 2018



b. Year

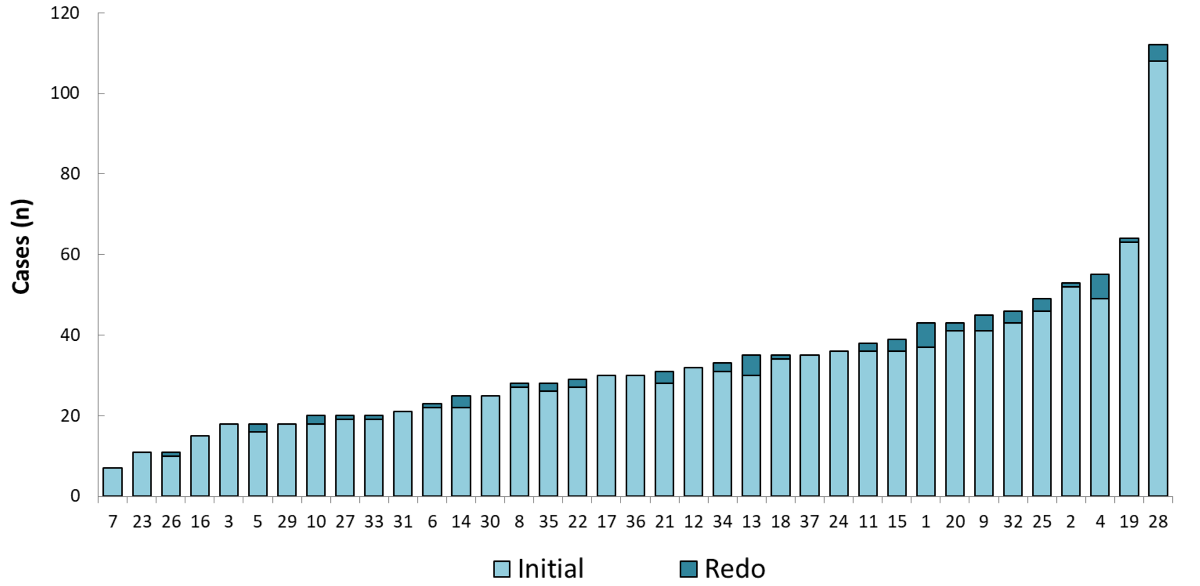


4.2 Previous surgery

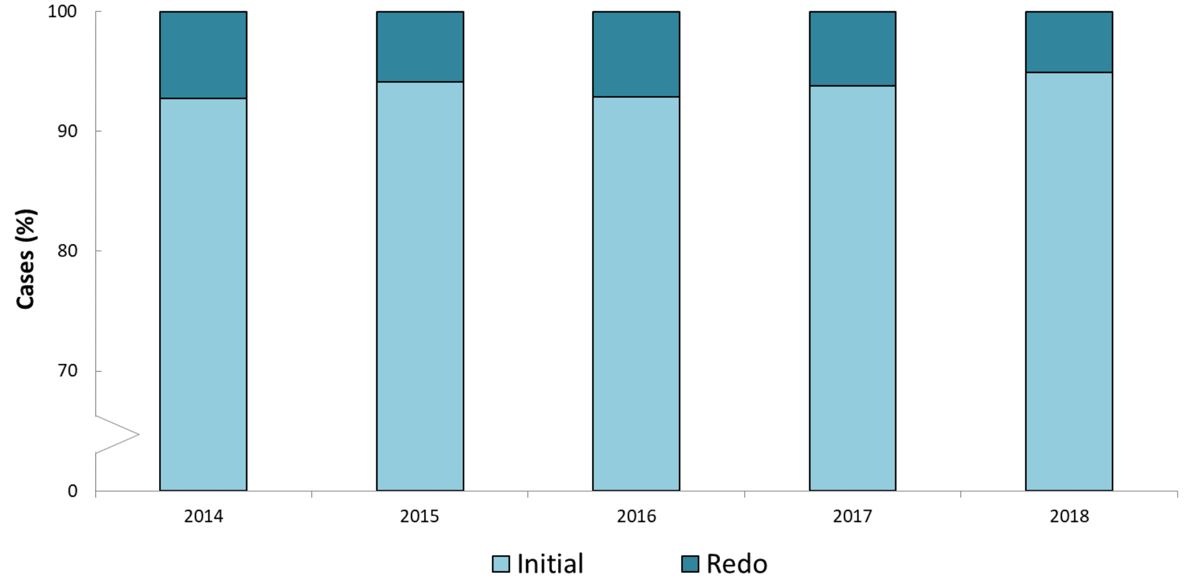
A total of 5.1% of valve with CABG operations performed in 2018 were redo procedures, and there was a similar distribution of redo cases between units (Figure 55). A procedure is considered a redo if the patient has had any prior cardiac surgery. As was the case with isolated CABG or valve procedures, the proportion of redo cases for valve with CABG patients marginally decreased in recent years.

Figure 55. Initial and redo valve with CABG

a. Unit in 2018



b. Year

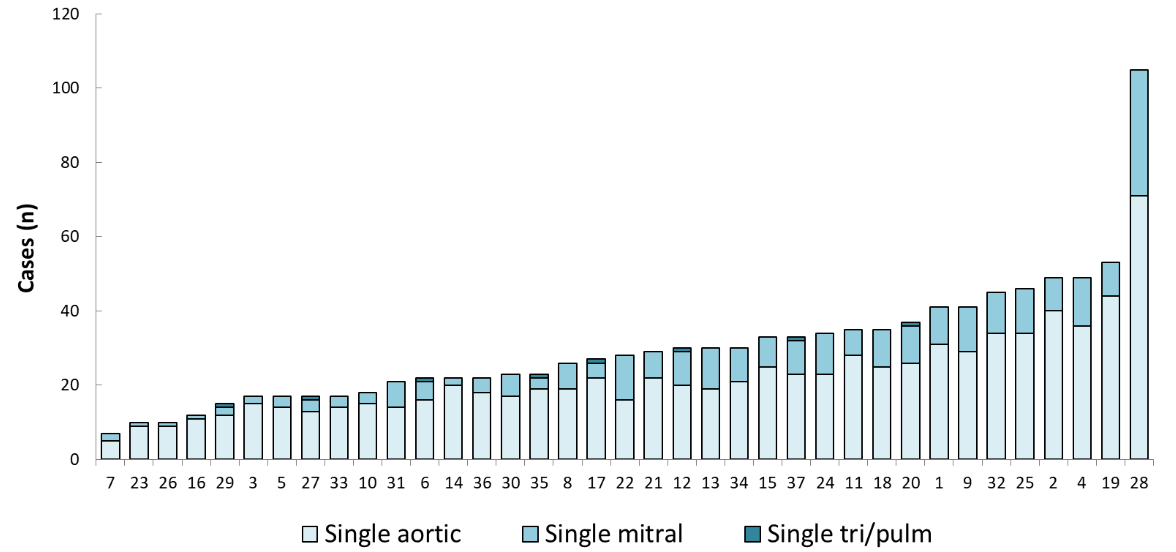


4.3 Valve procedure types with CABG

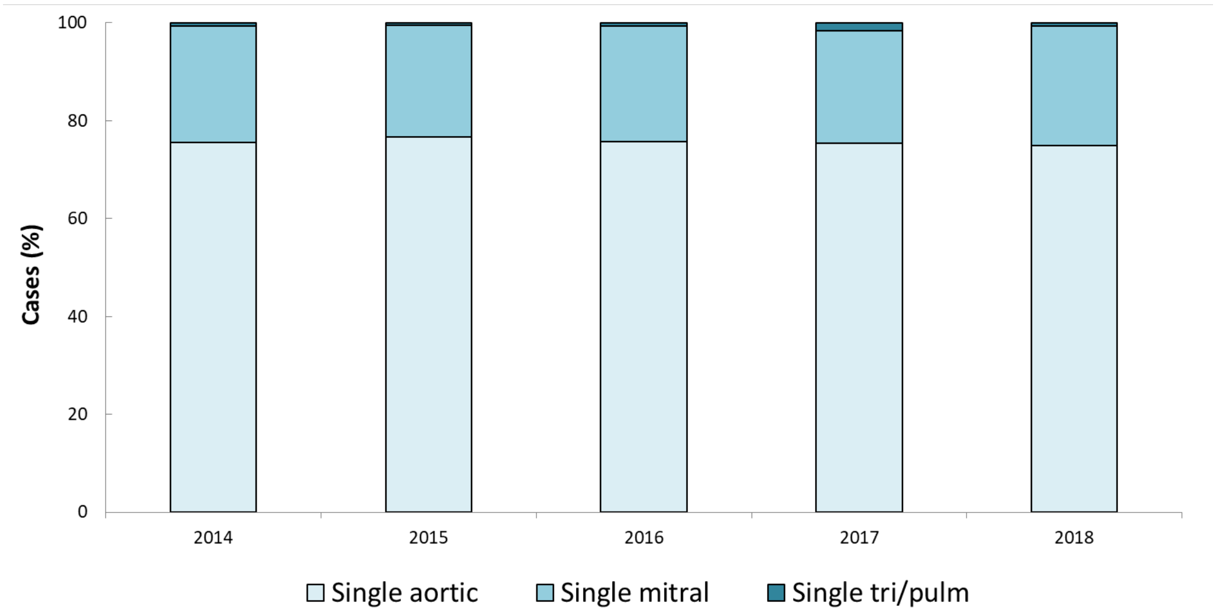
The most commonly performed single valve with CABG procedure involves the aortic valve. This was consistent between units and over the last five years (Figure 56). Single aortic valve with CABG surgery accounted for 74.9% of single valve with CABG procedures in 2018, while single mitral and tricuspid or pulmonary (tri/pulm) with CABG accounted for 24.4% and 0.72%, respectively.

Figure 56. Type of valve procedures performed with CABG

a. Unit in 2018



b. Year



In 2018 and the preceding four-year period, single aortic with CABG procedures had the lowest OM of all the valve with CABG procedures, not taking into consideration the three single pulmonary valve procedures (Table 27). The OM rates increased for single mitral repairs with CABG, single mitral replacements with CABG, and double or triple valve with CABG procedures. The average OM for all valve with CABG procedures was 3.19% in 2018, down from 3.99% in 2014-2017.

Table 27. Observed mortality (%) for valve with CABG procedures, 2018 and 2014-2017

Valve Procedure	Year	n	OM (%)
Single aortic	**2018**	829	2.4
	2014-2017	3354	2.8
AVR	**2018**	817	2.4
	2014-2017	3295	2.8
Other aortic	**2018**	12	0.0
	2014-2017	59	5.1
Single mitral	**2018**	272	4.4
	2014-2017	1036	5.6
Replacement	**2018**	142	7.0
	2014-2017	462	8.2
Repair	**2018**	128	1.6
	2014-2017	567	3.4
Single tricuspid	**2018**	7	0.0
	2014-2017	37	8.1
Single pulmonary	**2018**	1	0.0
	2014-2017	2	0.0
Aortic and mitral	**2018**	63	3.2
	2014-2017	221	8.1
Aortic and tricuspid	**2018**	7	28.6
	2014-2017	23	13.0
Mitral and tricuspid	**2018**	31	3.2
	2014-2017	127	9.4
Other double	**2018**	0	-
	2014-2017	3	0.0
Triple	**2018**	10	20.0
	2014-2017	35	14.3
Quadruple	**2018**	1	0.0
	2014-2017	0	-
Total valve procedures	**2018**	**1221**	**3.2**
	2014-2017	**4838**	**4.0**

4.4 Influence of patient characteristics on mortality

Generally, OM for all valve with CABG procedures increased with urgency of the procedure, advancing age, severity of LVD and the incidence of a previous MI or redo surgery (Table 28).

Table 28. Observed mortality (%) on the basis of patient characteristics for AVR with CABG and all other valve with CABG, 2014-2018

	AVR with CABG		All other valve with CABG	
	n	OM (%)	n	OM (%)
Clinical status				
Elective	3299	2.1	1432	4.0
Urgent	761	4.7	450	10.2
Emergency/salvage	52	11.5	69	26.1
Sex/age				
Male~	3263	2.5	1456	5.6
<50y	33	0.0	52	1.9
50-69y	937	1.5	614	5.4
70-79y	1563	2.2	560	5.5
≥80y	729	4.5	230	7.4
Female	849	3.5	495	7.9
<50y	11	0.0	23	8.7
50-69y	166	3.0	165	6.1
70-79y	421	3.6	207	7.7
≥80y	251	4.0	100	11.0
Left ventricular function^				
Normal LVF	2238	1.9	759	4.7
Mild LVD	1197	3.1	587	5.1
Moderate LVD	477	4.2	421	8.1
Severe LVD	149	7.4	165	10.9
Previous MI				
No MI	2942	2.0	1263	4.7
NSTEMI	893	4.3	452	7.3
STEMI	154	8.4	170	14.7
Unknown type	123	1.6	66	6.1
Timing of prior MI*				
≤6h	6	0.0	5	40.0
>6h-<24h	15	6.7	21	9.5
1-7d	198	5.6	148	13.5
>7d	951	4.3	513	7.2
Previous surgery				
Initial	3902	2.6	1780	5.7
Redo	210	4.8	171	11.7

~One case missing from AVR with CABG male age group

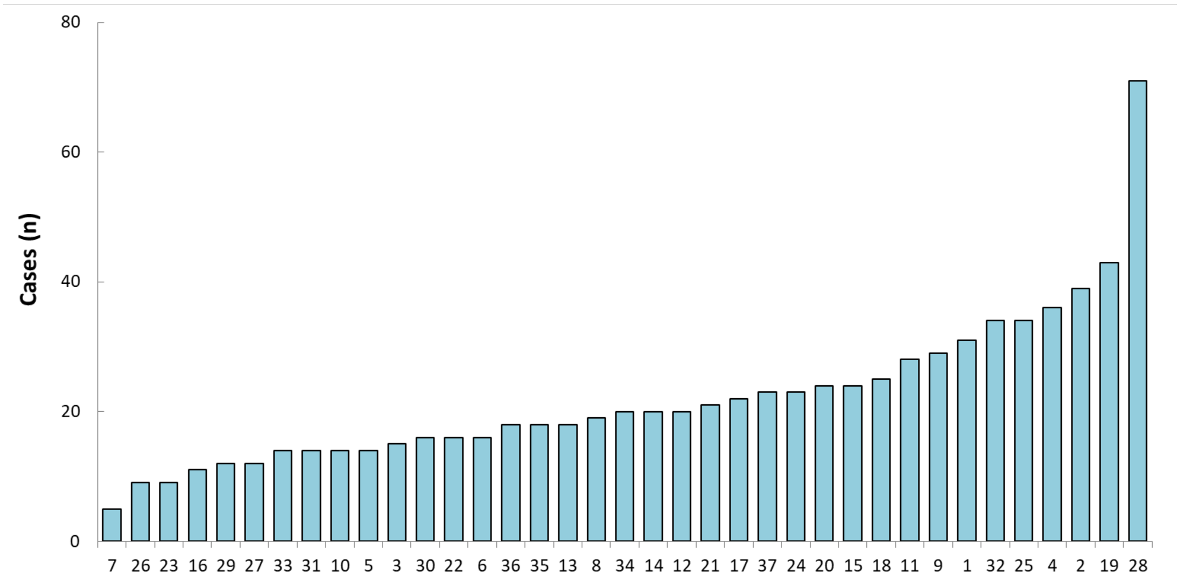
^17 and four cases missing EF data for AVR with CABG and all other Valve with CABG, respectively. 34 and 15 cases had no angiogram performed for AVR with CABG and all other Valve with CABG, respectively

*One case missing from all other Valve with CABG

4.5 Aortic valve replacement with CABG

In 2018, the lowest volume unit with respect to AVR with CABG submitted five cases to the Database, and the highest submitted 71 (Figure 57).

Figure 57. AVR with CABG procedures performed by unit, 2018



4.5.1 Effect of co-morbidities on complications

4.5.1.1 Pre-existing diabetes and renal impairment

This report compares two parameters of renal impairment: patients with a pre-operative creatinine level of ≥200 μmol/L or those with a pre-operative estimated glomerular filtration rate (eGFR) ≤60 mL/min/1.73m^2.

AVR with CABG patients with diabetes or impaired pre-operative renal function had a higher incidence of post-operative permanent stroke, DSWI and re-operation for bleeding (Table 29).

Table 29. Complications (%) for AVR with CABG patients on the basis of pre-operative diabetes and renal function status

		Diabetes*^		Pre-op creatinine		Pre-op eGFR	
		No	Yes	<200 μmol/L	≥200 μmol/L	>60mL /min/1.73m^2	≤60mL /min/1.73m^2
n	2018	516	301	792	25	586	231
	2014-2017	2100	1194	3174	121	2006	1289
Permanent stroke#	2018	1.0	1.3	1.1	0.0	1.4	0.4
	2014-2017	1.8	2.5	2.0	2.5	1.7	2.6
DSWI~	2018	1.0	2.7	1.4	9.1	1.6	1.8
	2014-2017	1.2	2.0	1.5	1.8	1.5	1.5
NCA†	2018	41.0	34.4	38.8	32.0	38.9	37.8
	2014-2017	37.5	36.8	37.2	40.5	36.6	38.3
Re-op for bleeding‡	2018	4.7	6.3	5.1	12.0	5.1	5.7
	2014-2017	4.1	3.7	3.9	5.0	3.8	4.2

*One case missing in 2014-2017
^Refers to all diabetes, regardless of type of therapy
#Three and six cases missing permanent stroke data in 2018 and 2014-2017, respectively
~21 and 85 cases missing DSWI data in 2018 and 2014-2017, respectively
†Three and six cases missing NCA data in 2018 and 2014-2017, respectively
‡Two and 6 cases missing Re-op bleeding data in 2018 and 2014-2017, respectively

4.5.1.2 Age

Advancing age was frequently, but not consistently, associated with higher rates of post-operative complications in patients having AVR with CABG (Table 30).

Table 30. Complications (%) for AVR with CABG patients on the basis of patient age^

		Age*			
		<50 y	50-69 y	70-79 y	≥80 y
n	2018	5	234	412	166
	2014-2017	39	869	1572	814
Permanent stroke	2018	0.0	0.9	1.7	0.0
	2014-2017	2.6	1.3	2.2	2.5
DSWI	2018	0.0	1.7	1.5	1.9
	2014-2017	2.6	2.2	1.0	1.6
NCA	2018	20.0	33.0	40.1	43.0
	2014-2017	15.4	33.2	39.3	38.6
Re-op for bleeding	2018	0.0	7.3	4.9	3.6
	2014-2017	10.3	3.1	4.1	4.3

^Same missing data for complications applies as for Table 29
*One case missing in 2014-2017

4.5.1.3 Surgical history

Redo surgery for AVR with CABG patients was associated with higher rates of DSWI and re-operation for bleeding (Table 31).

Table 31. Complications (%) for AVR with CABG patients on the basis of redo surgery

		Surgery	
		Initial	Redo
n	2018	781	36
	2014-2017	3121	173
Permanent stroke	2018	1.2	0.0
	2014-2017	2.0	2.3
DSWI	2018	1.6	2.9
	2014-2017	1.4	3.6
NCA	2018	38.3	44.4
	2014-2017	37.3	36.4
Re-op for bleeding	2018	5.1	8.3
	2014-2017	3.8	6.4

^Same missing data for complications applies as for Table 29

4.5.1.4 Effect of comorbidities on derived new renal impairment

Patients with pre-operative renal impairment, increasing age, or who underwent redo cardiac surgery had an increased incidence of DNRI following AVR with CABG surgery (Table 32). This data excludes patients who received pre-operative dialysis.

Table 32. DNRI (%) for AVR with CABG patients on the basis of diabetes, renal impairment, age, surgical history and use of CPB

	2018		2014-2017	
	n	DNRI (%)‡	n	DNRI (%)‡
Diabetes^				
No	505	5.0	1980	4.7
Yes	284	4.6	1108	6.4
Pre-op creatinine				
<200 µmol/L	779	4.2	3019	4.8
≥200 µmol/L	10	50.0	69	26.1
Pre-op eGFR				
>60mL/min/1.73m^2	578	3.1	1903	3.7
≤60mL/min/1.73m^2	211	9.5	1185	7.9
Age*				
<50y	4	0.0	38	5.3
50-69y	224	4.9	800	4.9
70-79y	400	3.0	1473	4.6
≥80y	161	9.3	776	7.1
Previous surgery				
Initial	754	4.5	2926	5.2
Redo	35	11.4	162	7.4

‡7 and 144 cases missing DNRI data in 2018 and 2014-2017, respectively

Note: the amount of missing data for DNRI in 2014-2017 is largely due to a lack of post-operative creatinine data from one hospital for a portion of this period.

^Refers to all diabetes, regardless of type of therapy

*One case missing for 2014-2017

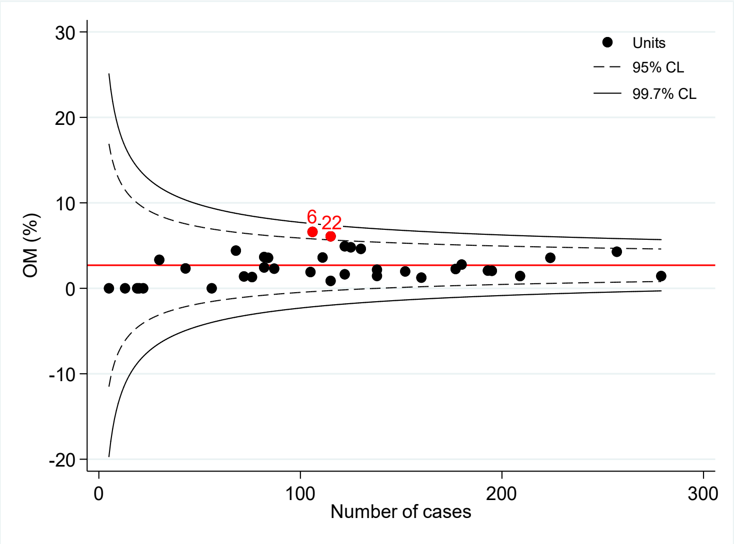
4.5.2 Unit outcomes – mortality, complications and resource utilisation

Due to low procedure numbers, the unit outcome data for AVR with CABG is presented for the pooled 2014-2018 period.

4.5.2.1 Mortality

The average OM for all units was 2.70% for AVR with CABG patients in the 2014-2018 period (Figure 58). This is comparable to that reported by the SCTS of 3.22% in 2015 for first-time isolated AVR with CABG, and to the STS which reported approximately 3.7% mortality for the January to September 2018 period[8,10]. All units were within the upper 99.7% CL for OM.

Figure 58. Observed mortality by unit following AVR with CABG, 2014-2018

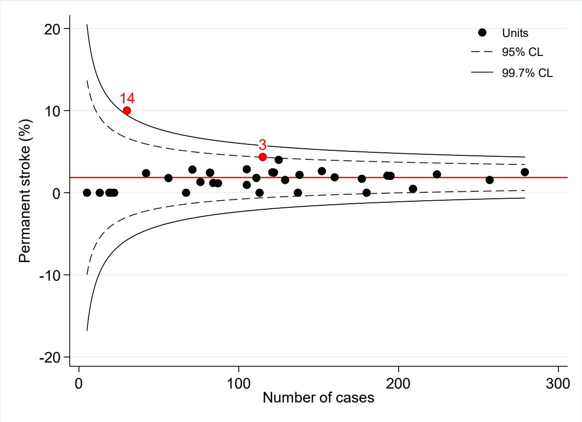


4.5.2.2 Complications

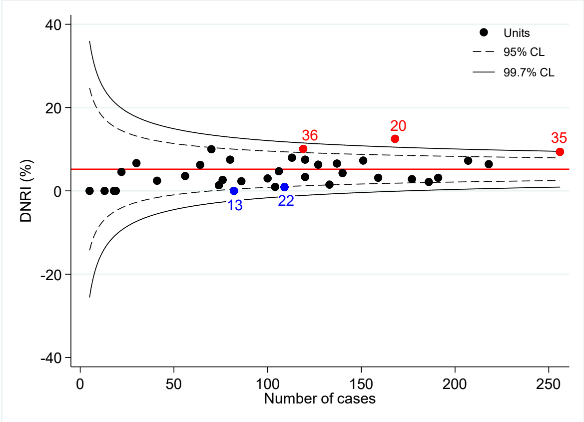
While the frequency of permanent stroke (mean of 1.85%) and of DSWI (1.52%) was similar for most units, there was notable variation in the incidences of DNRI (5.21%), NCA (37.5%), re-operation for bleeding (4.22%), and readmission (10.7%; Figure 59). The data for DNRI excludes patients who received pre-operative dialysis (Figure 59b).

Figure 59. Complications by unit following AVR with CABG, 2014-2018

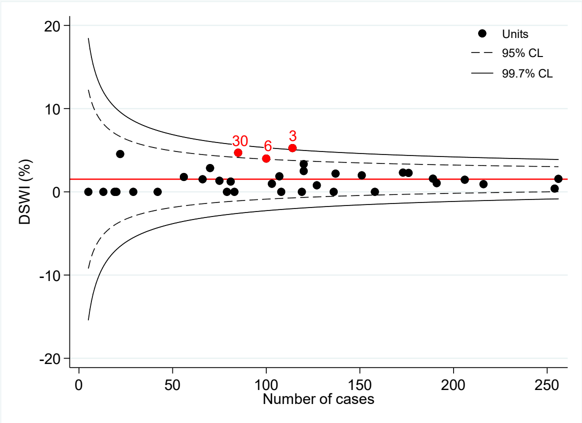
a. Permanent stroke



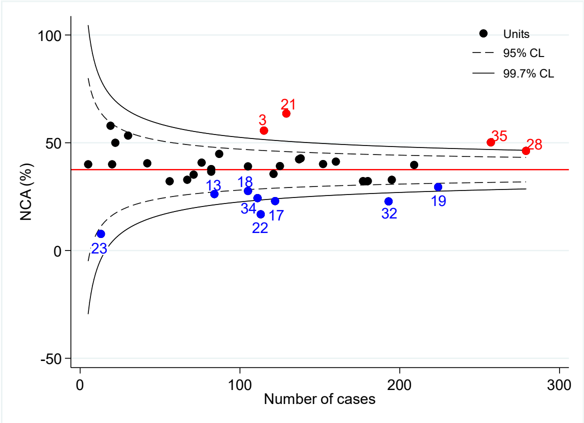
b. DNRI



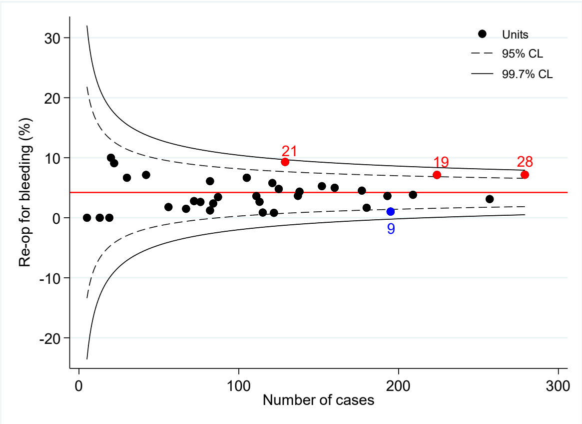
c. DSWI



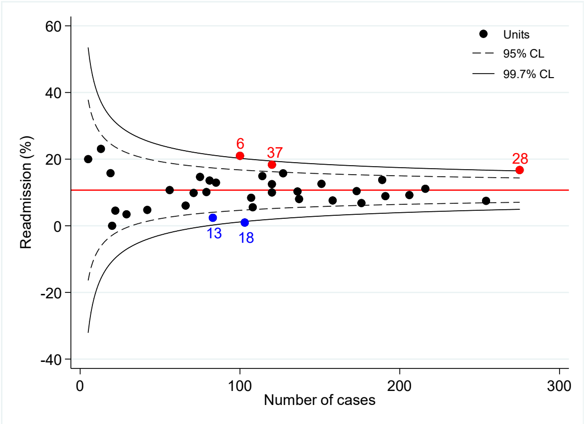
d. NCA



e. Re-op for bleeding



f. Readmission



4.5.2.3 Resource utilisation

Due to the skewed distribution of the ICU length of stay and ventilation data, the GM are presented. The GM is defined as the nth root of a product of n numbers. It is useful to describe the central tendency of a set of skewed data, as it is less sensitive to outlying values.

The pooled data shows marked variation between units for the time patients spent in the ICU, the duration of ventilation, and the percentage of patients who received RBC or NRBC transfusions (Table 33).

Table 33. Resource utilisation by unit for AVR with CABG patients, 2014-2018

	2014-2018			
Unit	ICU (GM, h)	Ventilation (GM, h)	RBC usage (%)	NRBC usage (%)
1	58.3	10.4	23.3	13.3
2	62.7	10.6	48.8	31.6
3	49.7	12.9	25.2	24.3
5	80.0	8.0	31.6	52.6
6	49.1	19.7	47.6	34.3
7	59.2	8.2	20.0	0.0
8	40.0	13.6	47.2	45.8
9	44.0	8.2	43.1	37.4
10	40.8	10.1	42.1	42.1
11	53.5	13.3	65.9	34.1
12	80.9	15.3	39.9	26.1
13	43.5	9.7	40.5	31.0
14	103.4	27.2	46.7	13.3
15	35.8	13.6	53.8	29.4
16	64.7	10.4	41.1	33.9
17	60.1	15.8	43.4	25.4
18	94.0	17.1	30.5	13.3
19	77.9	13.9	47.8	33.0
20	40.9	11.3	48.0	22.0
21	102.7	16.3	60.0	36.9
22	37.4	13.8	51.3	47.0
23	34.5	5.5	53.8	53.8
24	78.9	19.7	23.2	18.3
25	28.5	11.3	19.7	13.8
26	40.1	11.1	27.9	14.0
27	71.8	9.9	65.0	45.0
28	41.5	11.0	42.3	32.3
29	34.8	9.9	34.3	13.4
30	66.5	15.0	46.0	25.3
31	74.5	18.9	89.0	68.3
32	127.4	16.9	58.5	40.9
33	61.5	15.9	22.7	77.3
34	45.4	9.0	36.0	21.6
35	69.0	11.7	56.4	35.8
36	55.3	13.8	65.6	44.3
37	47.7	14.5	52.0	44.0
Total	56.1	12.7	45.7	31.6

In the 2014-2018 period, there was variability between units in the pre- and post-PLOS data for AVR with CABG cases (Figures 60 and 61). The medians ranged from zero to four days for pre-PLOS and six to 11 days for post-PLOS.

Figure 60. Pre-procedural length of stay for AVR with CABG patients by unit, 2014-2018

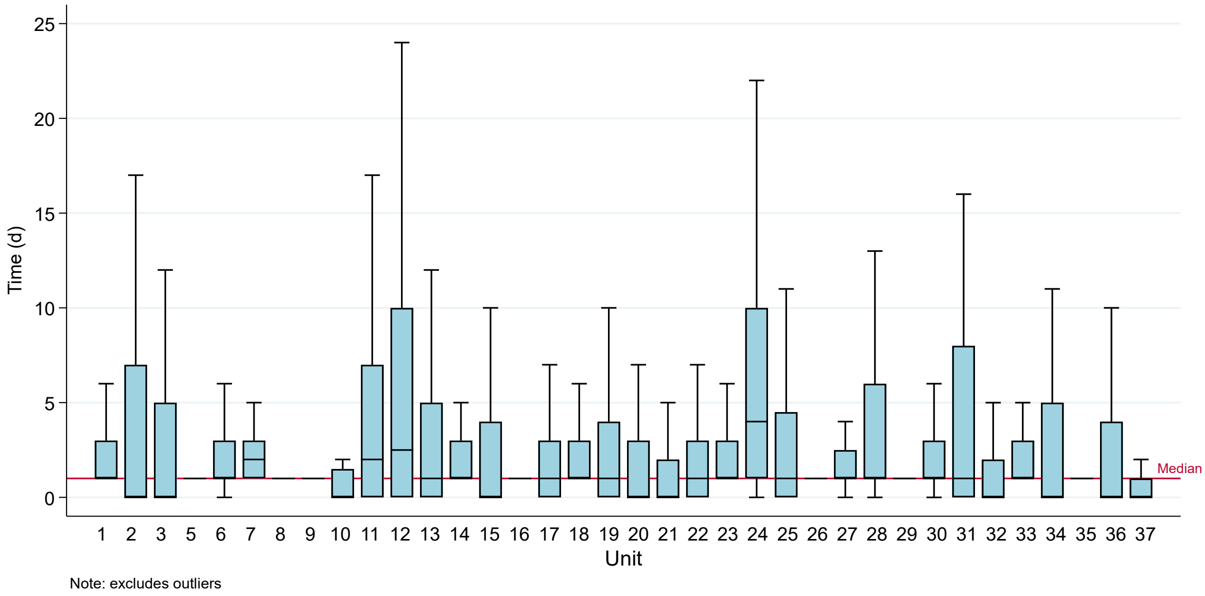
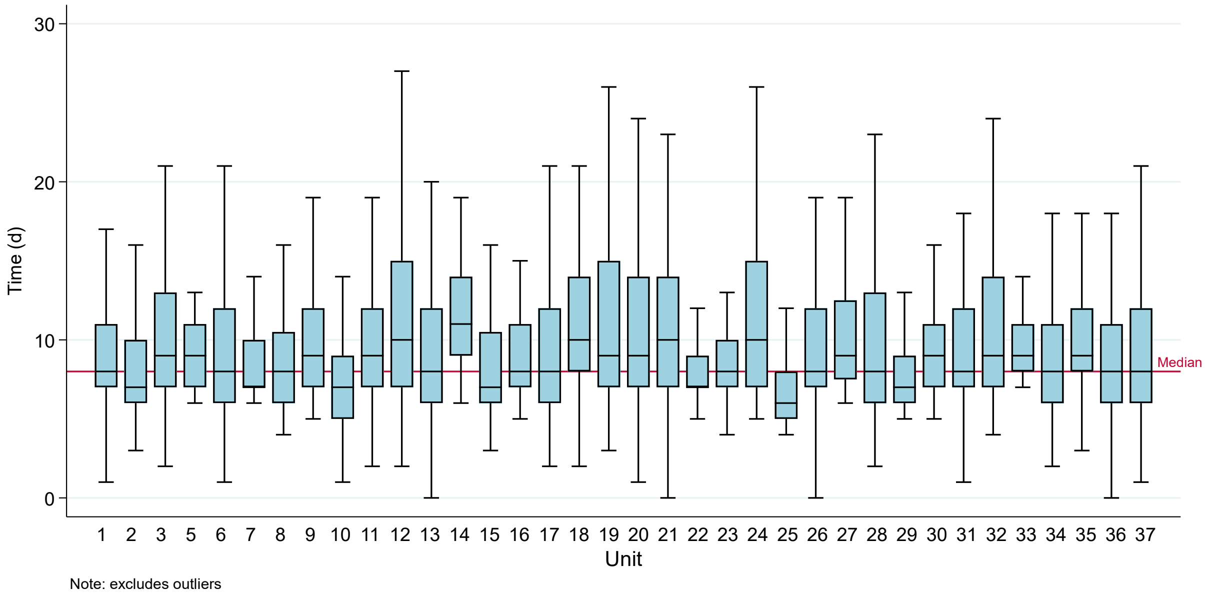


Figure 61. Post-procedural length of stay for AVR with CABG patients by unit, 2014-2018



5. Other Cardiac Surgery

Table 34 lists the 2018 case numbers for all other cardiac procedures not covered in Sections 1, 3 or 4. Many of these procedures are not performed in isolation, therefore OM is not necessarily indicative of that specific procedure, and is not presented.

Table 34. Case numbers for other uncommon procedures, 2018

Surgery type (not mutually exclusive)	n
LV aneurysm	27
Acquired ventricular septal defect	30
Aortic replacement^	946
Ascending only	677
Ascending + arch	190
Arch only	28
Descending	7
Thoracic/abdominal only	12
Arch + descending	7
Descending + thoracic/abdominal	2
Ascending + arch + descending	16
Other	5
Aortic repair*	201
Endarterectomy	22
Patch repair	92
Endarterectomy + patch repair	3
Indication for aortic procedure~	1169
Aneurysm	689
Dissection	248
Traumatic transection (<2 weeks)	2
Calcification	50
Other	179
Cardiac trauma	9
LV outflow tract myectomy	111
LV rupture repair	7
Pericardiectomy	34
Pulmonary thrombo-endarterectomy	26
Carotid endarterectomy	14
LV reconstruction	4
Pulmonary embolectomy	18
Cardiac tumour	100
Congenital	
Atrial septal defect	209
Other	163
Permanent LV epicardial lead	27
Atrial arrhythmia surgery	237
Left atrial appendage closure	399

^Two cases missing aortic procedure type data
*84 cases missing aortic repair type data
~One case missing aetiology/pathology type data

Table 35 provides case numbers for valve procedures that were performed in isolation or in conjunction with other types of cardiac surgery.

Table 35. Case numbers for other valve procedures performed without and with CABG, 2018 and 2014-2017

Valve Procedure (not mutually exclusive)		Without CABG	With CABG
Aortic root replacement with valved conduit	2018	242	49
	2014-2017	823	191
Pulmonary autograft aortic root replacement (Ross)	2018	49	2
	2014-2017	90	-
Root reconstruction with valve sparing (David)	2018	72	5
	2014-2017	168	32
Total other valve procedures	**2018**	**363**	**56**
	2014-2017	**1081**	**223**

Table 36 presents case numbers and OM for transplants performed without any concomitant procedures.

Table 36. Case numbers and observed mortality (%) for transplants, 2018

Surgery type (performed in isolation)	n	OM (%)
Cardiac transplant	95	6.3
Cardiopulmonary transplant	51	13.7

Concluding Remarks

The ANZSCTS Database has greater than 95% data completeness for all reported KPIs, assuring minimal to no selection bias in analyses. Compliance with the data definitions and completeness of case entry is assessed via triennial site audits, which consistently show the data submitted to the Database is of very high quality. We strive toward the ideal of including all adult patients from every cardiac surgical unit so that the performance of all units and surgeons may be evaluated.

The significant changes made by the Program in 2018/2019 have been: to continually improve and update our Web System, including expansion of the reporting functions; recruitment of more hospital sites, reaching close to 100% coverage of the public hospitals in Australia and bringing on board our first New Zealand site, Auckland City Hospital; enhancing our engagement with Data Managers through biannual meetings; and continuing the growth of our research program, with more than 31 projects in progress at the time of this report being published.

Our goals for the remainder of 2019 are to develop new risk adjustment models so that we can benchmark for derived new renal insufficiency and re-operation for bleeding while factoring in case mix; review the current Data Definitions Manual, refining some definitions and adding new variables to reflect changes in clinical practice; continue to enhance the web system data entry portal for efficient data entry; bring on board the final public hospital site in Australia; and engage with further sites in Australia and New Zealand to work towards the achievement of total bi-national coverage.

Long-term goals for ANZSCTS Database will focus on extending the scope of the information collected through linkage of our data with other key external data sources; establishing a Cardiac Surgical Prosthesis Registry; evaluation of quality of life through collecting longitudinal Patient Reported Outcome Measures (PROMs); collecting twelve-month follow-up data; and improving our reporting processes to health professionals and to the public.

We take this opportunity to thank contributors for their dedicated efforts with data collection and financial support, both of which are integral to our efforts.

Appendix A

Management of Unit Outliers – Review Timeline

Units sitting above the 99.7% control limit (CL) are managed according to the following timeline.

Week 0: Identification of an outlier during the SC Clinical Quality Meeting (CQM).

Week 2: The Head of Department (HOD) is written to by the Chair of the SC and asked to undertake an internal review of the data, particularly with respect to potential data definition or data entry issues. The ANZSCTS Database offers to collaborate with the site to assist with identifying any data discrepancies.

Week 12: SC reviews the results of that review and the current data at the CQM.

- If the results are within control limits, no further action is taken.
- If the KPI remains outside of range, the Chair will write to the HOD, Medical Director and/or hospital Safety and Quality Committee and recommend they conduct an investigation, and communicate their plans to address the situation to the SC. For Victorian public hospitals, Safer Care Victoria will be notified at this time. The ANZSCTS Database will provide a list of the data elements that may be relevant to their investigations, and offer to supply supplementary data to the unit to assist with the investigation, if requested.

Week 24: SC–CQM reviews the report from the unit regarding their plans and activity to correct the situation. It also reviews the unit's current quarterly data.

- If results are within control limits, unit is informed, and no further specific action is taken.
- If the outcome for the KPI remains outside of range and the SC believe, based on correspondence, that the unit are on track for addressing the issue, the unit continues to be monitored.
- If the KPI remains outside of range and the SC believe the unit needs further engagement, the Peer Review and Quality Assurance Committee (PRQAC) is involved and asked to conduct an external review.
- If the KPI remains outside of range and the unit has not responded to the SC thus far, a meeting with the PRQAC, hospital administration, and HOD is set up.
- If relevant, SCV will be updated on progress and/or included in meetings.

Week 36: SC reviews correspondence from unit and/or PRQAC and the current data at the CQM.

- If the results have fallen back within control limits, the Chair will write to the HOD to request a report about the processes put in place to remedy the situation, because that information may inform improved procedures that may be promulgated. No further specific action will be taken.
- If the KPI remains out of range, a meeting with the PRQAC (regardless of whether they have been previously engaged), the hospital administration, HOD and SCV, if relevant, is set up.

If, at any time period, there is insufficient data to determine whether the unit has returned to within the control limits, the unit will in any case, be monitored until 36 weeks, at which time, if the KPI outcome is outside CL, a meeting with the PRQAC, hospital administration, and HOD will be convened. Should a unit be detected an outlier for a KPI it had previously been an outlier for, the SC will, at its discretion, expedite the initial stages of the escalation policy.

Appendix B

Key Performance Indicator Definitions

The KPIs presented in this report are based on the ANZSCTS Database Program Data Definitions Manual, as follows:

In-hospital and 30-day mortality or observed mortality

- *Observed mortality*
  Includes all in-hospital mortality and any post discharge mortalities that occurred within 30 days of the procedure.
- *Risk-adjusted mortality*
  Derived based on the ANZSCTS Database Program's risk model (Appendix E), and used to account for the degree of risk associated with the surgery and patient profile.

Re-operation for bleeding

Did the patient return to theatre for bleeding/tamponade?

Derived new renal insufficiency

Acute post-operative renal insufficiency is characterised by one of the following:

a. Increased serum creatinine to >0.2mmol/L (>200µmol/L) AND a doubling or greater increase in creatinine over the baseline pre-operative value AND the patient did not require pre-operative dialysis/haemofiltration, or
b. A new post-operative requirement for dialysis/haemofiltration (when the patient did not require this pre-operatively).

Deep sternal wound infection (DSWI)

Did the patient develop infection of sternal bone, muscle and/or mediastinum? The patient must have **wound debridement and** one of the following:

a. Positive cultures
b. Treatment with antibiotics

Includes all in-hospital DSWI events and any readmissions due to DSWI within 30 days of procedure.

Permanent stroke

Did the patient experience a stroke or new central neurologic deficit (persisting for >72 hours) peri- or post-operatively?

New cardiac arrhythmia (NCA)

NCA is any new form of cardiac arrhythmia that occurred post-procedurally that required treatment. This includes:

a. Heart block requiring permanent pacemaker
b. New other bradyarrhythmia requiring permanent pacemaker
c. Cardiac arrest documented by one of the following:
   - Ventricular fibrillation OR
   - Rapid ventricular tachycardia with haemodynamic instability OR
   - Asystole OR
   - Pulseless electrical activity (PEA)*
d. New atrial arrhythmia (requiring treatment) - atrial fibrillation or flutter
e. New ventricular tachycardia

*This type of cardiac arrest was not specified prior to the change in the Data Definitions Manual on September 1st 2016.

Duration of ICU stay (initial stay only)

Number of hours spent by the patient in the ICU prior to transfer to the high dependency unit or general ward (does not include readmission to ICU). Calculated by subtracting the ICU admission date and time from ICU discharge date and time, where both values are available.

Duration of ventilation (initial post-operative ventilation only)

Number of hours post-operation for which the patient was ventilated. Calculated by subtracting ICU admission time from the ICU extubation time, where both values are available. If the patient was extubated on the operating table, duration of ventilation is zero. Delayed re-intubation time is not counted.

Red blood cell transfusions

Were allogeneic red blood cells transfused during the intra-operative or post-operative period? Does not include:

a. Pre-donated blood
b. Cell saver blood
c. Pump residual blood
d. Chest tube recirculated blood

Non-red blood cell transfusions

Were blood products other than RBC (e.g. FFP and Platelets) transfused during the intra-operative or post-operative period? Does not include albumin.

Appendix C

Data Preparation and Key Variable Definitions

Data preparation and presentation

Data includes operative details and outcomes of cardiac surgery performed in 37 participating units in 2018, and from 2014-2017 (sections 1 and 5) or 2014-2018 (sections 3 and 4) for pooled analyses.

Final data related to this report was received by the ANZSCTS Database Program Data Management Team in the Centre of Cardiovascular Research and Education in Therapeutics (CCRET) of the Department of Epidemiology and Preventive Medicine, Monash University, on April 8th, 2019. Submitted data was checked for completeness and Data Managers in each unit were given opportunities to amend any errors. Any changes to the data after April 8th, 2019 are not reflected in this report.

Variable definitions

All definitions are based on the ANZSCTS Database Data Definitions Manual. Version 3.0 applies to all patients with admission dates prior to September 1st, 2016 and version 4.0 applies to patients with admission dates on and after September 1st, 2016.

Key variables presented in this report are defined below.

- Clinical Status

Elective
The procedure could be deferred without risk of compromised cardiac outcome.

Urgent
a. Within 72 hours of angiography if initial operation was performed in the same admission as angiography ('same admission' includes where angiography was performed in another unit prior to direct transfer to unit where initial operation is performed); or
b. Within 72 hours of an unplanned admission (patient who had a previous angiogram and was scheduled for surgery but was admitted acutely); or
c. Procedure required during same hospitalisation in a clinically compromised patient in order to minimise chance of further clinical deterioration.^

^Additional criteria in version 4.0

Emergency*
Unscheduled surgery required in the next available theatre on the same day (as admission) due to refractory angina or haemodynamic compromise.

Salvage*
The patient underwent cardiopulmonary resuscitation *en route* to, or in the operating room, prior to surgical incision.

** Due to low number of cases, emergency and salvage patients are combined within the report, and labelled as emergency.*

- Readmission ≤ 30 day from surgery

Patient readmitted as an in-patient within 30 days from the date of surgery for ANY reason to general hospital; not emergency, short-stay wards or planned transfer to rehabilitation facility. Date of surgery counts as day zero.

- Redo operation

Operation performed on a patient who has undergone a prior cardiac surgery.

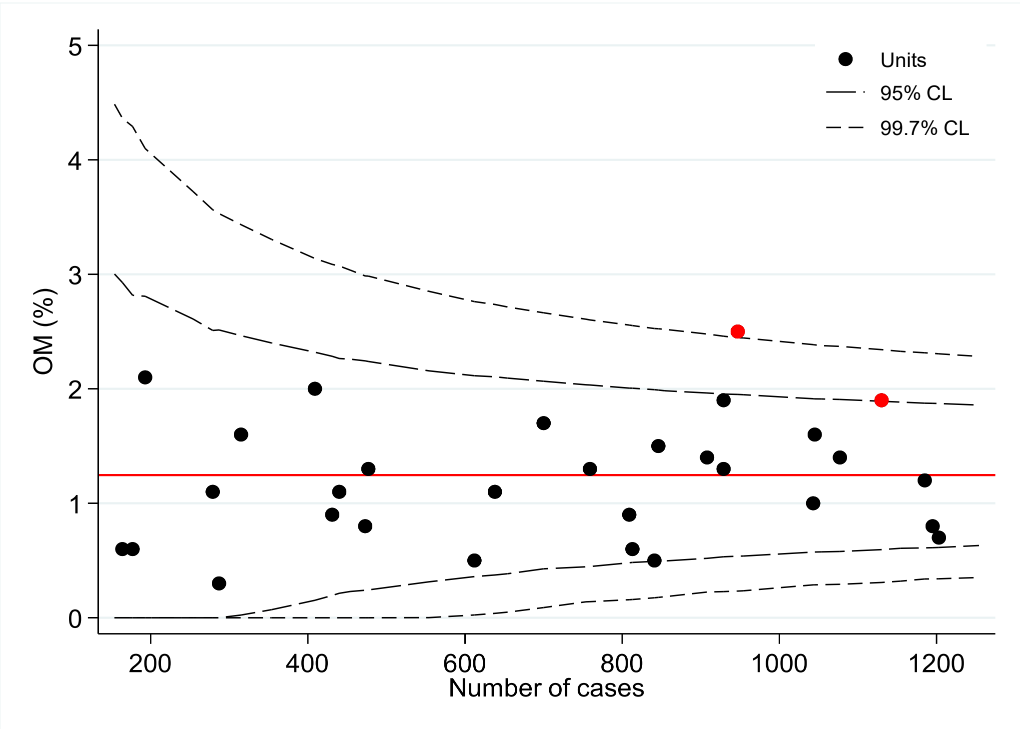
Appendix D

Appendix D-I - Interpretation of Funnel Plots

Funnel plots are an approach to compare performance standards of hospital units. They are especially useful in this situation as there is usually a difference in the numbers of procedures (sample size) included in the data plot. For example, the figure below illustrates the observed mortality (OM) after coronary artery bypass surgery in Australia between 2012 and 2015.

The solid line represents the average OM, the two-dotted lines are the 95% control limits (CL) and the two-dashed lines are the 99.7% CLs. The funnel plot allows the CLs to narrow as the number of procedures increases. This representation supports the 95% CL plot to illustrate the invalidity of ranking all of those units from “best” to “worst” as only two were worse than the majority, all of which had statistically similar outcomes.

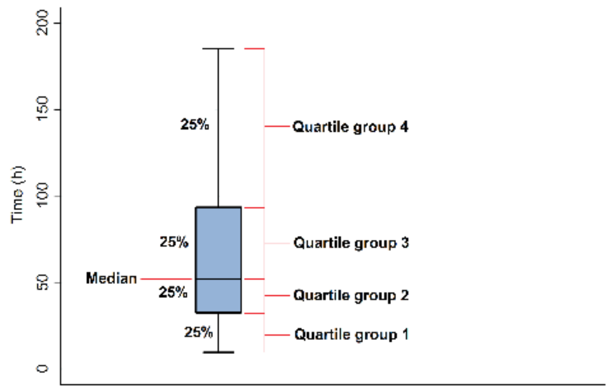
Figure D-I. Observed mortality following CABG by unit



Appendix D-II - Interpretation of Box Plots

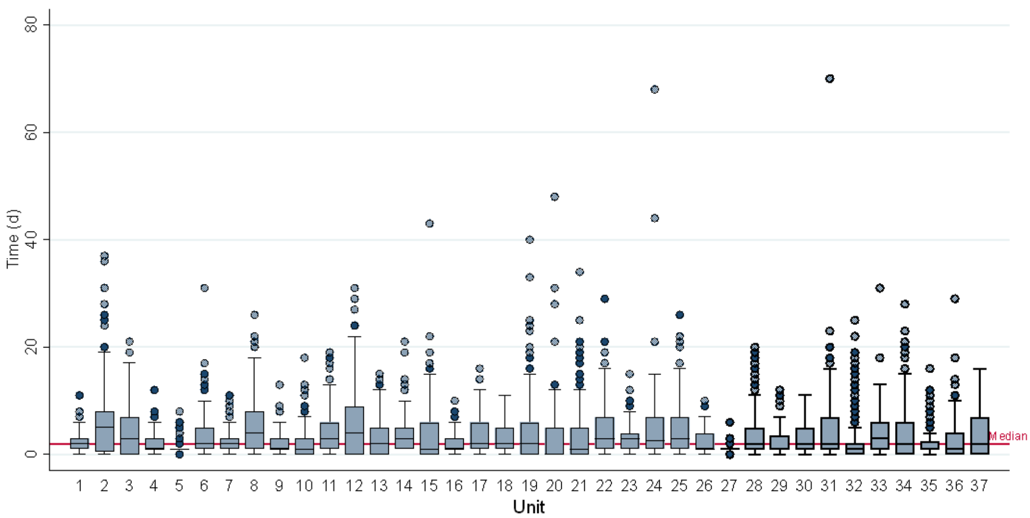
A Box Plot is a demonstration of statistical information that illustrates the maximum and minimum values (the upper and lower whiskers), the second and third quartiles (the lower and upper limits of the box, so that the box contains the middle half of the observations) and the median value (the line within the box), for a set of observations.

Figure D-II. Box plot example



The box plots presented in this report do not include observations that the statistical software package (Stata 15) has determined to be outliers (i.e. those that significantly deviate from where the majority of the observations lie). Where data is clustered particularly tightly, exclusion of outliers means the data may look compressed. For instance, in the length of stay data presented in Figure D-IIA, unit 27 has a number of outliers (represented by black circles) clustered around the median. When the outliers are removed, it looks as though all patients in unit 27 had a length of stay of one day, with no variation. Removing the outliers improves the readability of the graph, but does result in a small loss of information.

Figure D-IIA. Box Plot example: length of stay data with outliers



Appendix E

All Procedures Risk Adjustment Model

The All Procedures Score (Billah, *et. al.*, 2010) is a validated pre-operative risk prediction model, used for risk-adjustment for 30-day mortality for all cardiac surgery, in Australia[33]. The model was developed based on a large number of procedures using standardised data collection methodology. Subsequent validation of the model showed that it is a good fit for Australian data and correctly classified the risk of a large number of procedures.

The Risk Adjusted Mortality Rate (RAMR) takes into account a number of risk factors listed in Table E-I. The ratio of the observed mortality (OM) rate to the predicted mortality rate indicates the relative performance adjusted for the severity of illness or risk. A ratio of 1 indicates results as expected, less than 1 indicates results better than expected, and greater than 1 indicates results worse than expected. This ratio is then multiplied by the Observed Average Mortality Rate to yield a RAMR which normalises the individual unit for its case mix.

RAMR is calculated as follows:

$$\text{RAMR} = \left(\frac{\text{OM Rate}}{\text{Predicted Mortality Rate}} \right) \times \text{Average OM Rate}$$

RAMR is therefore, a predictor of mortality for a given patient set which takes into account the risks for those patients.

Table E-I. Variables that define overall patient risk in the All Procedures Risk-Adjustment Model

Age	Sex	Clinical Status
Procedure type	Previous Cardiac Surgery	NYHA* class
EF Grade	Pre-operative Dialysis	Hypercholesterolaemia
Previous vascular disease	BMI>25kg/m^2	

* New York Heart Association functional classification for dyspnoea

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