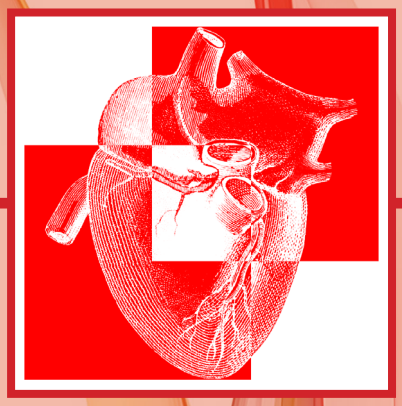
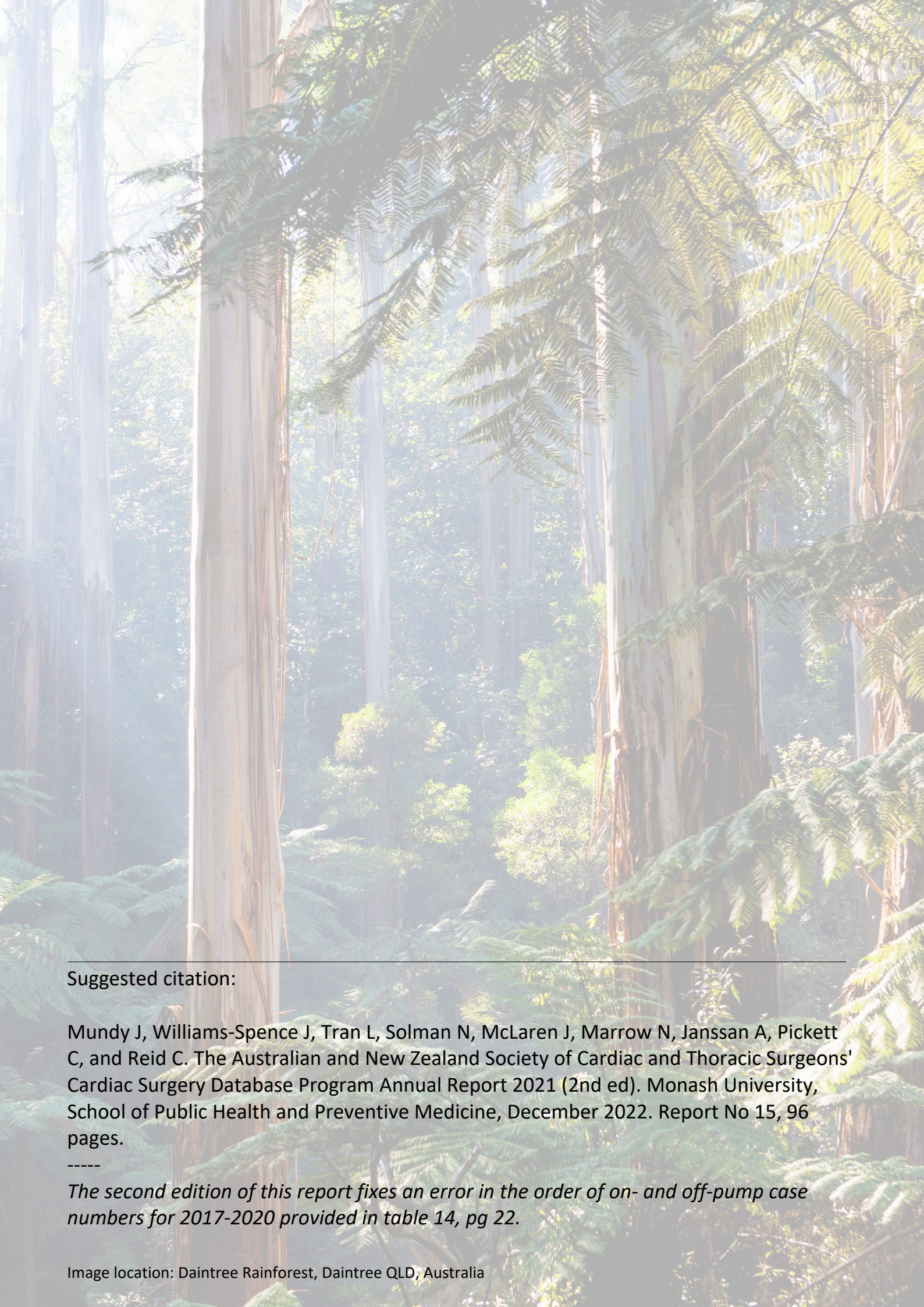
ANZSCTS Cardiac Surgery Database Program



Annual Report

2021

Second Edition



Suggested citation:

Mundy J, Williams-Spence J, Tran L, Solman N, McLaren J, Marrow N, Janssan A, Pickett C, and Reid C. The Australian and New Zealand Society of Cardiac and Thoracic Surgeons' Cardiac Surgery Database Program Annual Report 2021 (2nd ed). Monash University, School of Public Health and Preventive Medicine, December 2022. Report No 15, 96 pages.

The second edition of this report fixes an error in the order of on- and off-pump case numbers for 2017-2020 provided in table 14, pg 22.

Image location: Daintree Rainforest, Daintree QLD, Australia

Table of Contents

List of Figures

List of Tables

Acronyms

AKI	Acute Kidney Injury
ANZDATA	Australia and New Zealand Dialysis and Transplant
ANZSCTS	Australian and New Zealand Society for Cardiac and Thoracic Surgeons
ASM	Annual Scientific Meeting
AVR	Aortic valve replacement
BITA	Bilateral internal thoracic artery
CABG	Coronary artery bypass graft
CCRET	Centre of Cardiovascular Research and Education in Therapeutics
CKD	Chronic kidney disease
CPB	Cardiopulmonary bypass
CUSUM	Cumulated sum
CVD	Cardiovascular disease
dNRI	Derived new renal insufficiency
DSWI	Deep sternal wound infection
EF	Ejection fraction
ICU	Intensive care unit
IQR	Interquartile range
KPI	Key performance indicator
LITA	Left internal thoracic artery
LOS	Length of stay
LV	Left ventricular
LVF	Left ventricular function
MI	Myocardial infarction
MV	Mitral valve
MVR	Mitral valve replacement
NBA	National Blood Authority
NSTEMI	Non-ST-elevation myocardial infarction
OM	Operative mortality
PINBALL	Prophylactic INtra-aortic BALLoon Counterpulsation in High-Risk Cardiac Surgery
RA	Radial artery
RA-dNRI	Risk-adjusted derived new renal insufficiency
RA-OM	Risk-adjusted operative mortality
RCT	Randomised clinical trial
RBC	Red blood cell
RITA	Right internal thoracic artery
RTT	Return to theatre
SeRP	Secure eResearch Platform
SVG	Saphenous vein graft
TAR	Total arterial revascularisation

Acknowledgements

The Australian and New Zealand Society of Cardiac and Thoracic Surgeons (ANZSCTS) Cardiac Surgery Database is funded by the Department of Health and Human Services, Victoria; the Clinical Excellence Commission, New South Wales; Queensland Health, Queensland; and through participation fees from contributing private and public units. The ANZSCTS Database is based in the Centre of Cardiovascular Research and Education in Therapeutics (CCRET) within the School of Public Health and Preventive Medicine at Monash University.

We acknowledge the contributions made by the ANZSCTS Database Steering and Research Committees, which oversee all registry activities including the quality assurance and research programs. We thank the Database Data Custodian, Prof Chris Reid, the Co-Director of the CCRET, A/Prof Dion Stub, the Steering Committee Chair, A/Prof Julie Mundy, and the Research Committee Chair, Prof Julian Smith, for their essential support of the Database. Prof Chris Reid is supported by a National Health and Medical Research Council Principal Research Fellowship and A/Prof Stub is supported by a National Heart Foundation Future Leader Fellowship.

We extend our gratitude to Mr Gil Shardey who stepped down as the Chair of the Steering Committee in April 2022 after more than two decades of service to the Database, for his lasting influence on the Program.

We also acknowledge the Data Management and Analysis Centre staff at the CCRET (Dr Jenni Williams-Spence, Dr Lavinia Tran, Mr Noah Solman, Ms Jenna McLaren, Mrs Nicole Marrow, Mr Alex Janssan, Dr Craig Pickett and Mr Mark Lucas).

The work of the ANZSCTS Database relies on the continuing interest and efforts of surgeons, Data Managers, and other relevant hospital staff who contribute data. We sincerely thank these individuals for their participation, and particularly for the consistent submission of data for all cases throughout the pandemic.

Photograph by Mark Lucas 2018 ©

Foreword

This is the 15th annual report of the ANZSCTS Cardiac Surgery Database Program. There are currently 60 units both public and private across Australia and New Zealand submitting data to the registry. This report includes data from 50 units including 26 private units and 15,712 cases from 2021 and again underpins the importance of data in ensuring quality outcomes in cardiac surgery.

Data presented in this report provide unit comparisons for surgery performed in the 2021 calendar year. 30-day follow-up dictates that surgical outcomes are collected to the end of January 2022. Information is also presented as pooled (four or five year) and annual (five years) data.

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

The Program has an important quality assurance function. Therefore, unit outcomes are compared against a set of performance indicators. The Steering Committee has a quarterly clinical quality meeting in which statistical analysis of performance is presented to identify variance in performance. If there is a signal that a specific aspect of surgical performance needs attention then Heads of units are notified of outlying status in accordance with the ANZSCTS Database's Special Cause Variation Management Policy.

Overall, in the five-year period, although there is variation in practice, most participating cardiac surgical units had satisfactory outcomes for key performance indicators (mortality and complications). The Society's purpose is to ensure that high standards are maintained in all units performing cardiac surgery in Australia and New Zealand and where necessary, assist units to achieve that standard.

This year we have also reviewed some effects of the pandemic particularly with regard to redirection of patients. This effect was largely seen in New South Wales, Victoria and South Australia. It also looks at perioperative COVID infection.

Associate Professor Julie Mundy
Chair, ANZSCTS Database Program Steering Committee

Introduction

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 since 2002 for Victorian units, and since 2007 at a national level. It expanded to include Aotearoa New Zealand in 2019 with the addition of Auckland City Hospital and reached full public hospital coverage of cardiac surgery in Australia in 2020.

The ANZSCTS Database 2021 Annual Report presents data on patient characteristics, operative details and unit outcomes for a range of key performance indicators (KPIs), including post-operative complications and mortality. This year's report also includes an additional section highlighting some key collaborative research projects making use of the dataset. The report is presented as follows:

- Section 1: Brief Overview of COVID-19 Pandemic Activity
- Section 2: Isolated Coronary Artery Bypass Graft (CABG) Surgery
- Section 3: Isolated Valve Surgery
- Section 4: Combined Valve and CABG Surgery
- Section 5: Other Cardiac Surgery
- Section 6: The ANZSCTS Database Research Program
- Section 7: Concluding Remarks

Key performance indicators

The Database collects and analyses data for a range of clinically relevant surgical outcomes for the purpose of monitoring the performance of the following KPIs across cardiac surgical units:

- Unadjusted operative (in-hospital and 30-day) mortality (OM) and risk-adjusted OM (RA-OM)
- Permanent stroke
- Unadjusted derived new renal insufficiency (dNRI) and risk-adjusted dNRI (RA-dNRI)
- Deep sternal wound infection (DSWI)
- Return to theatre (RTT) for bleeding

The KPIs are defined in detail in Appendix A (pg. 84). Information about the ANZSCORE risk-adjustment models can be found in Appendix B (pg. 86). Units that fall outside the upper 99.7% control limit for any of these KPIs are supported in line with the Database *Special Cause Variation Management Policy*.

Data completeness and analysis

Of the cases submitted in 2021, 98.8% were flagged as complete. Incomplete cases miss one or more variables for a variety of reasons. The tables presented in this report include all available data. Accordingly, there are small variations in the total number of cases in each table due to the differing amount of missing data for each variable.

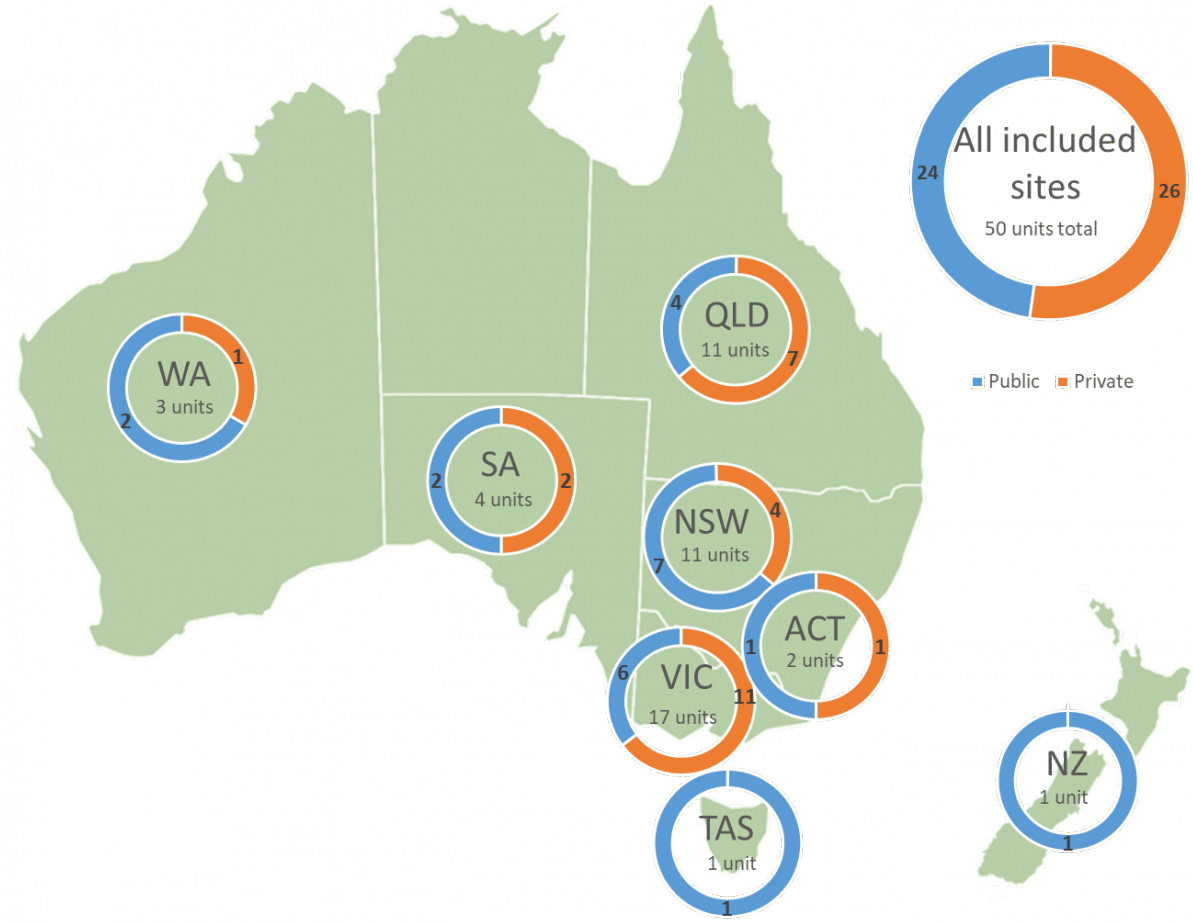
Where the number of cases in the current year is low (Sections 3 and 4), data is pooled with the preceding four years. Details of data preparation and key variable definitions are presented in Appendix C (pg. 88).

It should be noted that in 2021, many cardiac surgery units continued to be affected by the COVID-19 pandemic, which is reflected in case numbers and case mix for some units.

Contributing hospitals

Data from 50 cardiac surgery units are presented in this report, including 26 private hospitals. Some units joined the Program more recently, therefore have not provided data over the full period analysed. Only units that submitted greater than 75% of their expected caseload in 2021 are included in the report. A list of sites included in the report can be found in Appendix D (pg. 90).

Figure 1. Participating hospitals featured in the 2021 Annual Report, by state and country



Overview of procedures

In 2021, 15,712 cardiac surgical procedures were performed at the 50 hospitals included in this report. Figure 2 and Table 1 show the frequency of the major procedure groups by unit and over the last five years, respectively.

Figure 2. Cardiac surgery cases by procedure group and unit, 2021

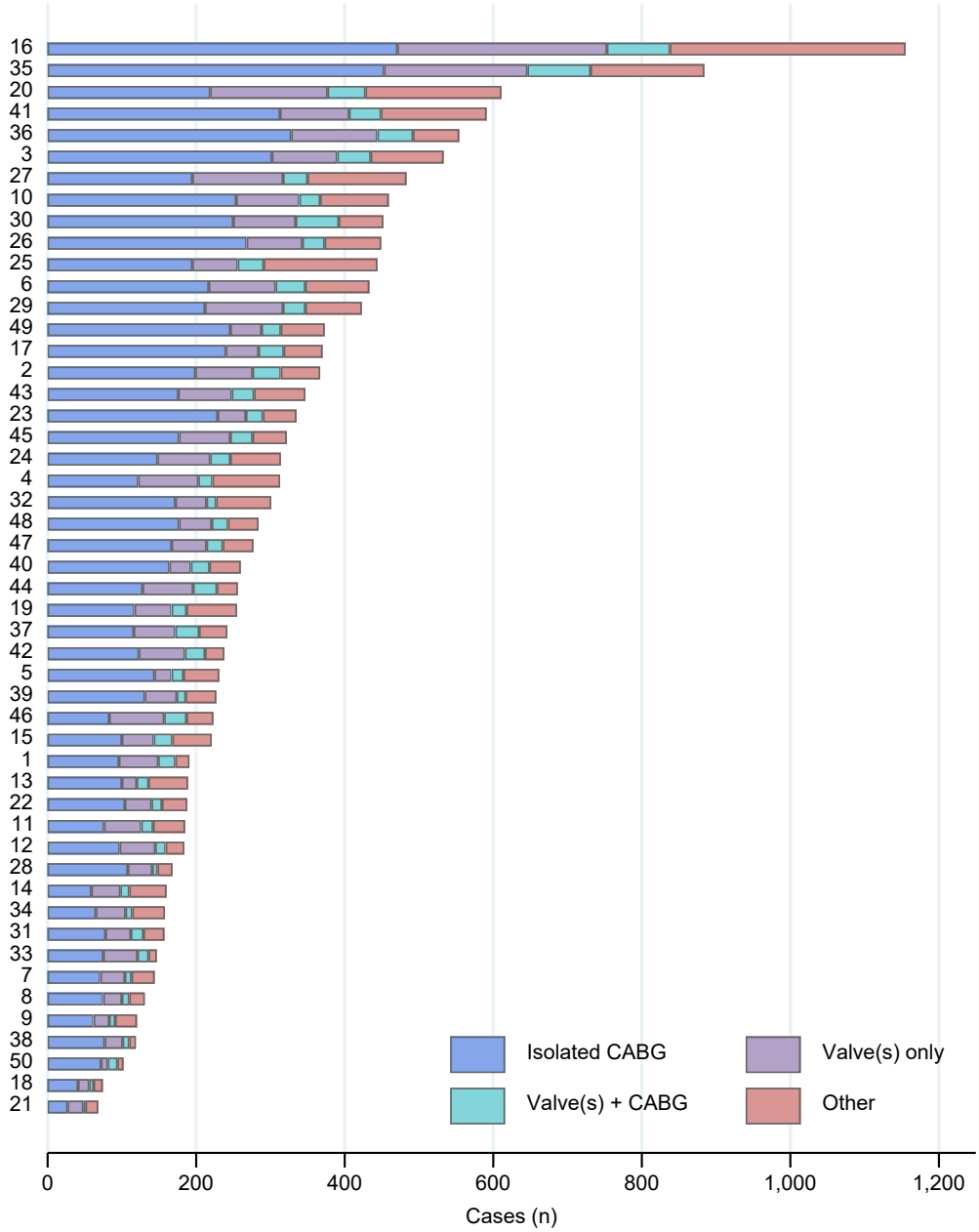


Table 1. Cardiac surgery procedure groups by year

	2017	2018	2019	2020	2021	Total
Total cases (n)	12,691	13,543	14,717	14,888	15,712	71,551
Isolated CABG (%)	51.3	50.0	50.8	51.4	51.7	51.1
Valve(s) only (%)	21.0	22.1	20.3	20.9	20.2	20.9
Valve(s) + CABG (%)	9.8	8.9	8.6	8.3	8.4	8.7
Other (%)	17.9	19.1	20.2	19.4	19.8	19.3

1. Brief overview of COVID-19 pandemic activity

In 2021, the COVID-19 pandemic continued to affect cardiac services, with particularly high COVID-19 case burdens in both Victoria and New South Wales, and the first Australian case with the omicron variant at the end of November(1). The ANZSCTS Database continued to collect data on peri-operative patient COVID-19 diagnoses and the redirection of cases from public hospitals to private hospitals due to restrictions on surgery and changing resource allocation.

There was a high level of patient movement in the second half of the year, peaking at 11.3% in October, and with 464 patients redirected over the course of 2021 (Figure 3 and Table 2). Of the redirected cases, 62.1% were isolated CABG and 76.1% were elective, compared to 51.4 and 60.8% in non-redirected cases, respectively (Figure 4 and Figure 5). Despite these redirections, key outcome measures including OM, permanent stroke, DSWI, RTT for bleeding and dNRI remained consistent throughout the year (Figure 4).

There were relatively few peri-operative COVID-19 diagnoses overall, with the highest numbers reported in post-operative patients in Victoria and New South Wales (Table 2).

The clinical status of all patients for each region has fluctuated over the last three years but it is noteworthy that the proportion of urgent cases has increased in Victoria and New South Wales (Figure 7). The Database will continue to report on pandemic-related activity as more data becomes available.

Figure 3. Australian COVID-19 cases, total cardiac surgery cases, and proportion of redirected cases to the private sector, by month, 2021

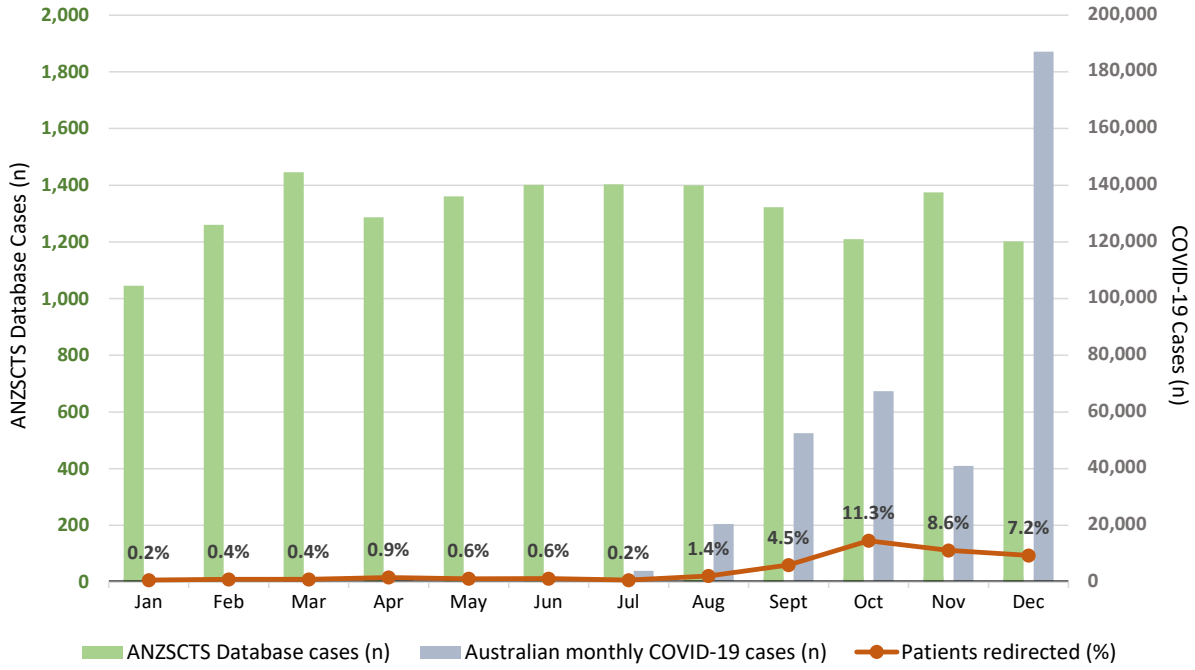


Figure 4. All-hospital KPI incidence by month, 2021

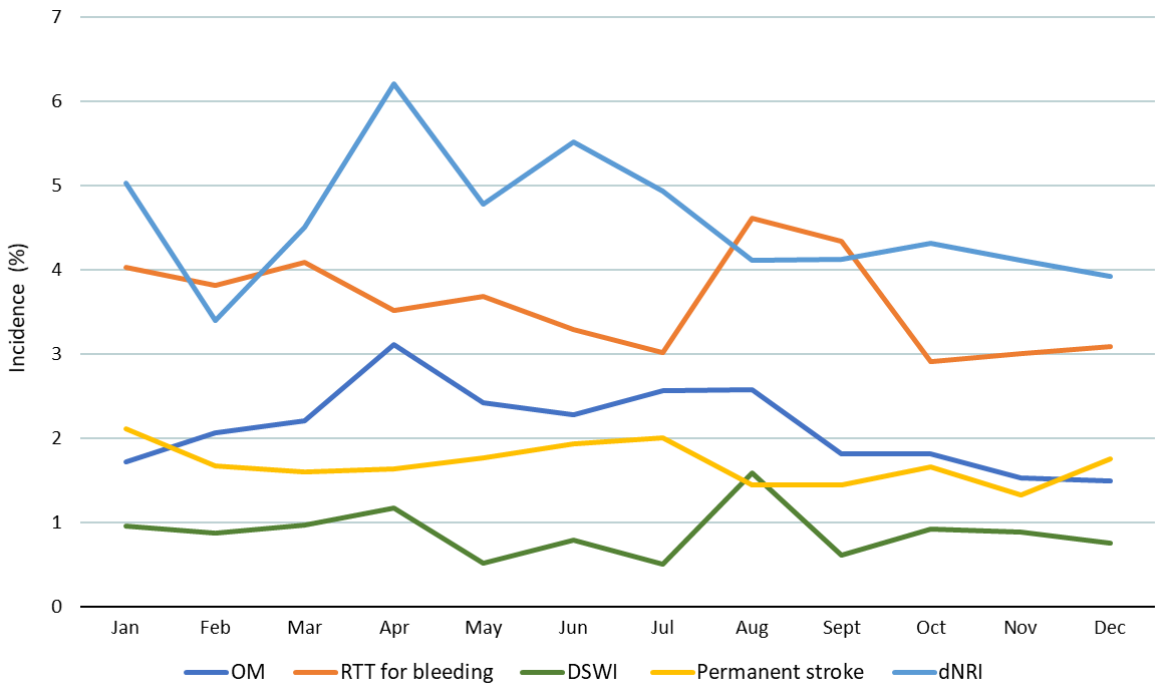


Table 2. Total cases, redirected cases and COVID-19 cases by state, 2021

State*	Total cases (n)	Total cases redirected (n)	COVID-19 positive prior to admission (n)	COVID-19 positive during admission (n)	COVID-19 positive post-discharge~ (n)
VIC	4,736	301	2	3	13
NSW	3,292	134	2	1	15
QLD	4,240	0	0	1	1
SA	1,020	27	0	0	1
WA	1,031	0	0	1	0
ACT	267	2	0	0	0
Total	15,712	464	4	6	30

*Regions with only one participating hospital are not included, to protect privacy
~At time of 30-day follow-up

Figure 5. Type of cardiac procedure for routine vs redirected patients, 2021

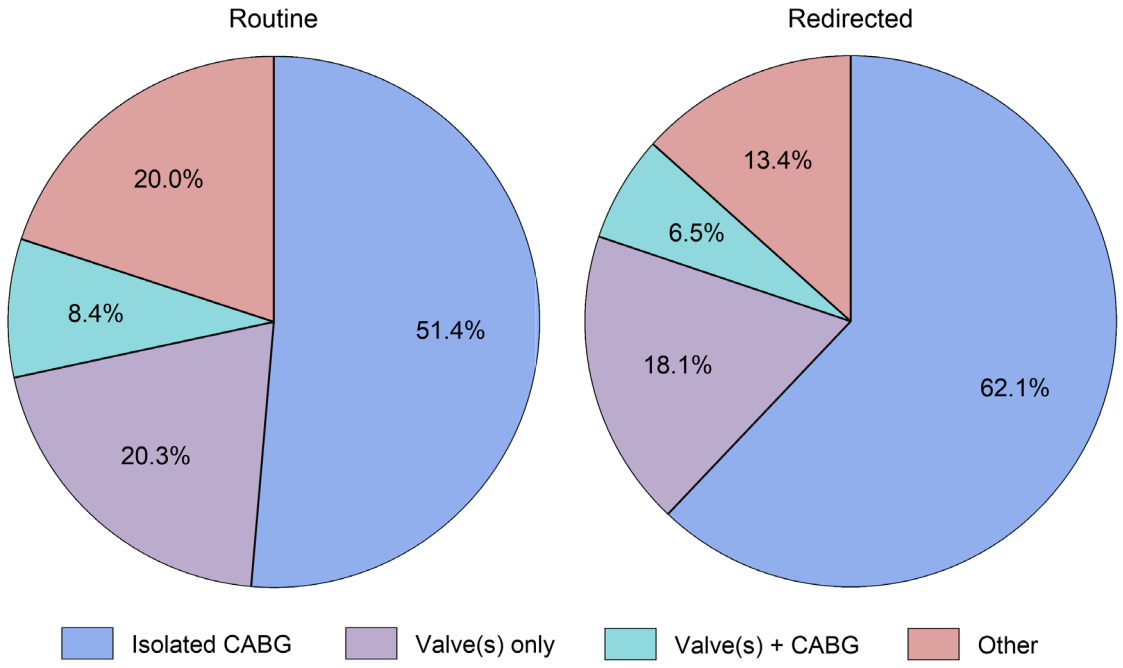
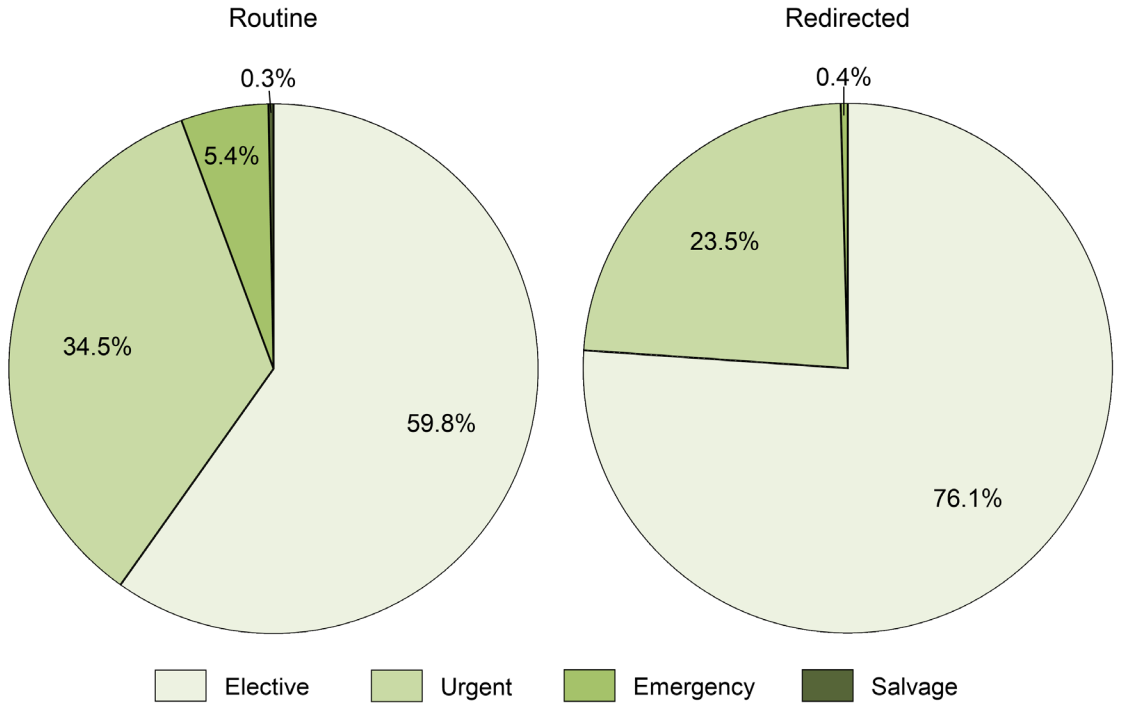
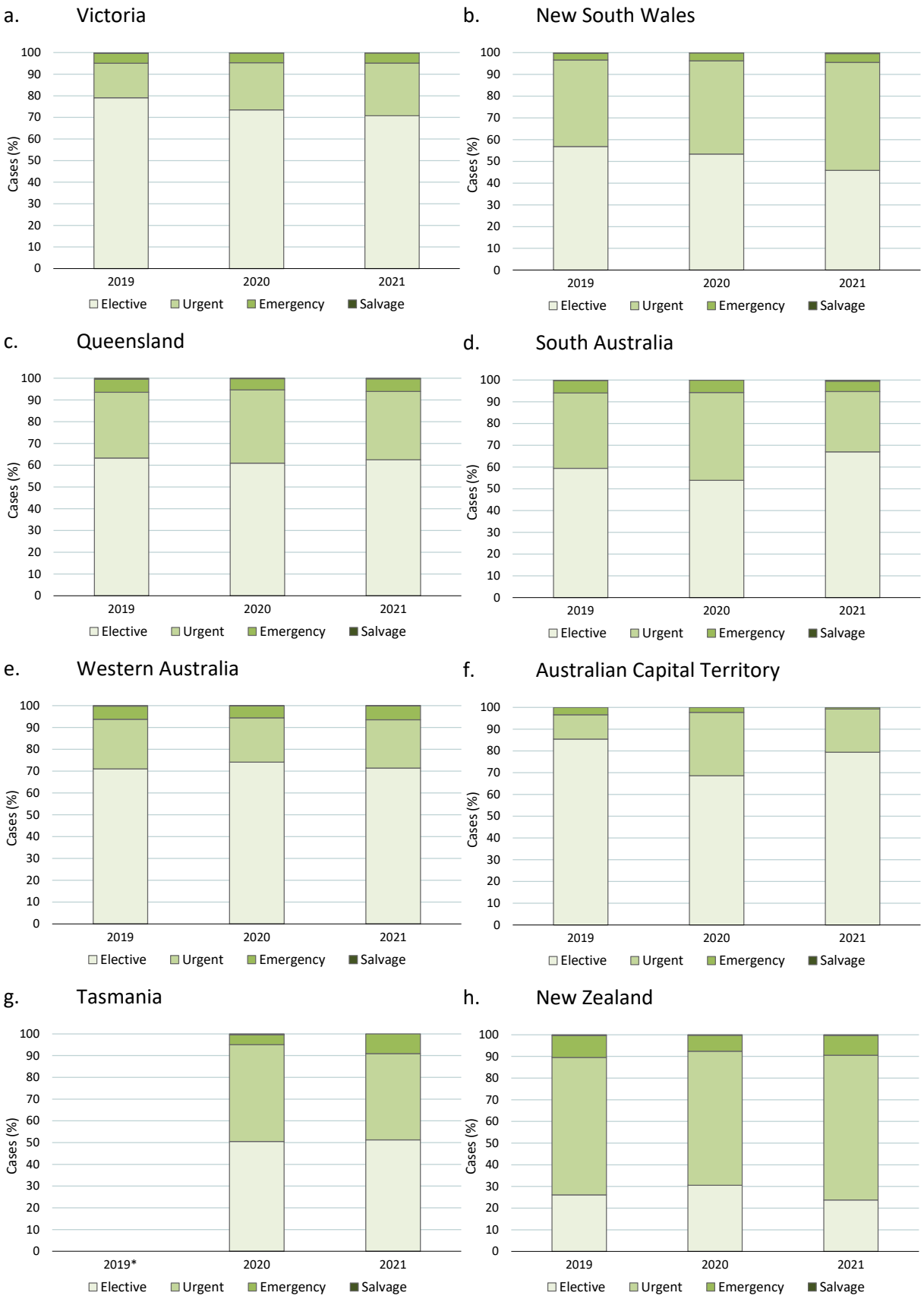


Figure 6. Clinical status for routine vs redirected patients, 2021



It should be noted that clinical status is a reported variable, therefore variation can occur due to the interpretation of the Database's data definition (Appendix C, pg. 88).

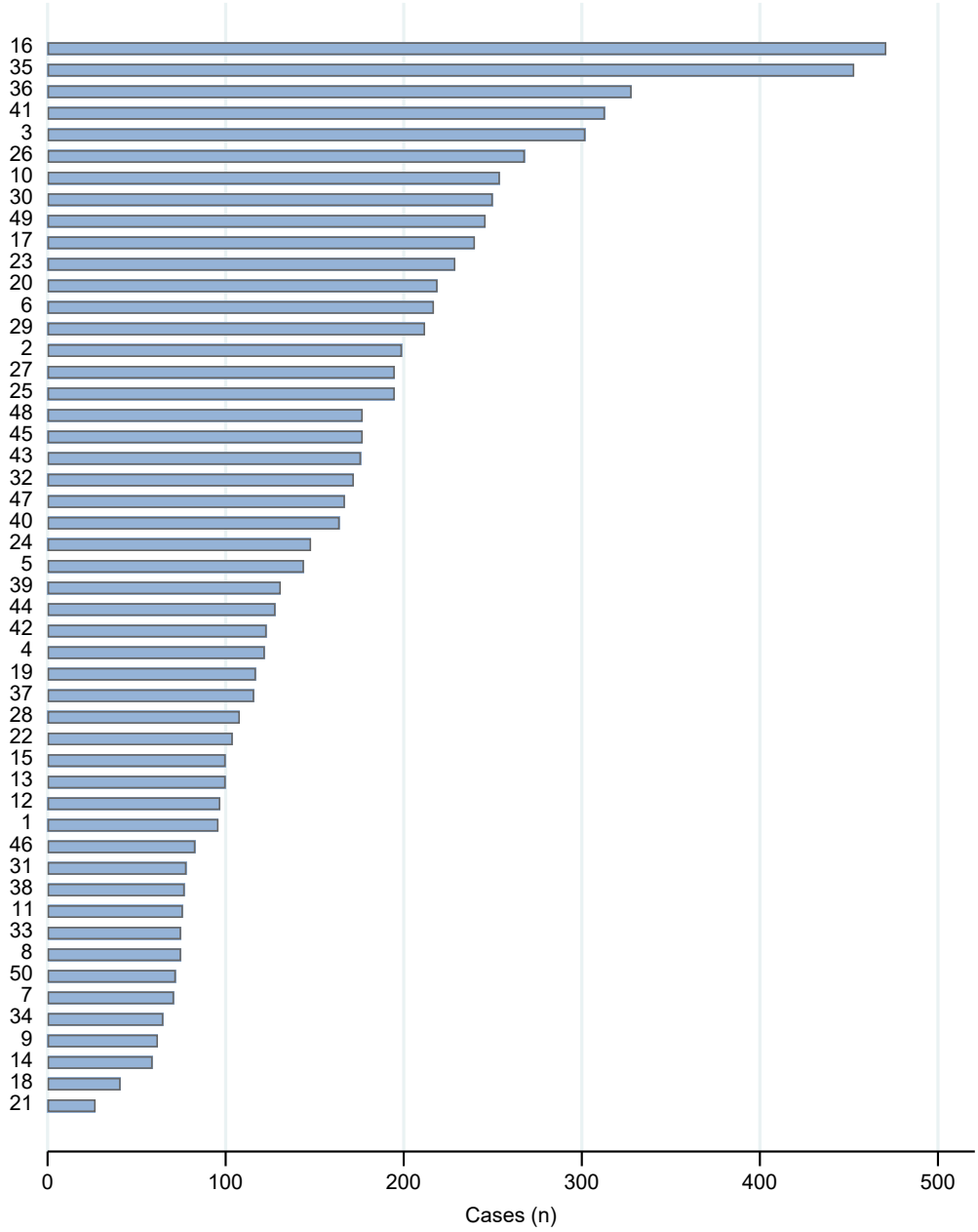
Figure 7. Clinical status by region, 2019-2021



*No participating hospitals in 2019

2. Isolated CABG Surgery

Figure 8. Isolated CABG cases by unit, 2021



Summary of isolated CABG surgery activity

Case volume and risk factors

Isolated CABG surgery accounted for 51.7% of cases submitted to the ANZSCTS Database in 2021 (Table 1). Case volume varied between units, with 15 performing less than 100 cases and 14 performing more than 200 (Figure 8). The majority of patients were male and the most highly represented age group was 60 – <70 years for males, compared to 70 – <80 years for females (Figure 11).

The distribution of ejection fraction (EF) categories has been consistent over five years, with 81% of patients having an EF >45% in 2021 (Table 5). Approximately half (49.6%) of isolated CABG patients in 2021 had a previous myocardial infarction (MI), which were most commonly a non-ST-elevation MI (NSTEMI) and historical (greater than seven days; Table 6 and Table 7). In 2021, 40.1% of pre-operative MIs were within seven days of surgery (Table 7). Redo surgery has stayed consistently low at 1.2% over the last five years and off-pump procedures were slightly less common in 2020 and 2021, down to 5.8% (Table 8 and Table 9).

Choice of conduits

There was large variation between units with the type of conduits used, particularly with radial arteries vs saphenous vein (Figure 17). Bilateral internal thoracic artery (BITA) grafts were associated with the most anastomoses (mean of 2.3), followed by saphenous vein graft (SVG) (mean of 1.8; Table 10). The mean number of grafts per patient did not notably vary between age groups; however, the proportion of patients having total arterial revascularisation generally decreased with increasing age, from 40% in 18-50-years old to 26.4% in patients 80 years and older (Table 10 and Table 11). Patients having off-pump surgery more commonly had total arterial revascularisation (TAR) compared to on-pump surgery (58.3 vs 27.2%) and the proportion of cases involving TAR varied substantially between units (Table 11 and Figure 18).

Complications with risk factors and use of cardiopulmonary bypass (CPB)

Consistent with expectations, complications varied for patients with key pre-operative risk factors. In particular, patients with markers of pre-operative renal dysfunction or diabetes had consistently higher incidences of permanent stroke, DSWI, new cardiac arrythmias and RTT for bleeding (Table 12). Unsurprisingly, these patients also had a higher post-operative incidence of dNRI. There were weak trends suggesting increasing incidence of permanent stroke and new cardiac arrythmia with age; however, age did not appear to affect post-operative dNRI, DSWI and RTT for bleeding, on average (Table 13 and Table 15).

There was no measurable benefit for off-pump procedures with respect to key outcomes but patients having redo surgery did have higher incidences of dNRI, permanent stroke and RTT for bleeding, noting that there was a small sample size (Table 14 and Table 15). OM was consistent with the previous four years and did not show a relationship with age. Emergency and salvage surgery had an eight-fold increase in mean OM, compared to elective surgery. Low EF and pre-operative creatinine >200 µmol/L were associated with markedly increased OM (Table 16).

KPIs

The majority of units performed comparably in 2021, and units with outcomes outside the 99.7% control limit on funnel plot analysis were engaged by the ANZSCTS Database Steering Committee, in line with the *Special Cause Variation Management Policy*.

The OM for isolated CABG patients was 1.0% in 2021, which is consistent with 2017-20 (1.1%) and in-hospital and 30-day mortality rates reported by registries in the United States, Sweden, Germany, and the United Kingdom, which ranged from 1.1 – 2.7% for recent years (Figure 19a and Figure 19b)(2-5). The risk-adjusted OM calculated using the Database's ANZSCORE model was 0.7% in 2021 (Figure 19c). In 2021, the incidences of other KPIs were consistent with previous years, including dNRI (2.4%), risk-adjusted dNRI (2.1%), permanent stroke (0.9%), DSWI (0.9%) and RTT for bleeding (2.1%; Figures 20-23). For the interpretation of funnel plots see Appendix E (pg. 91).

Resource utilisation

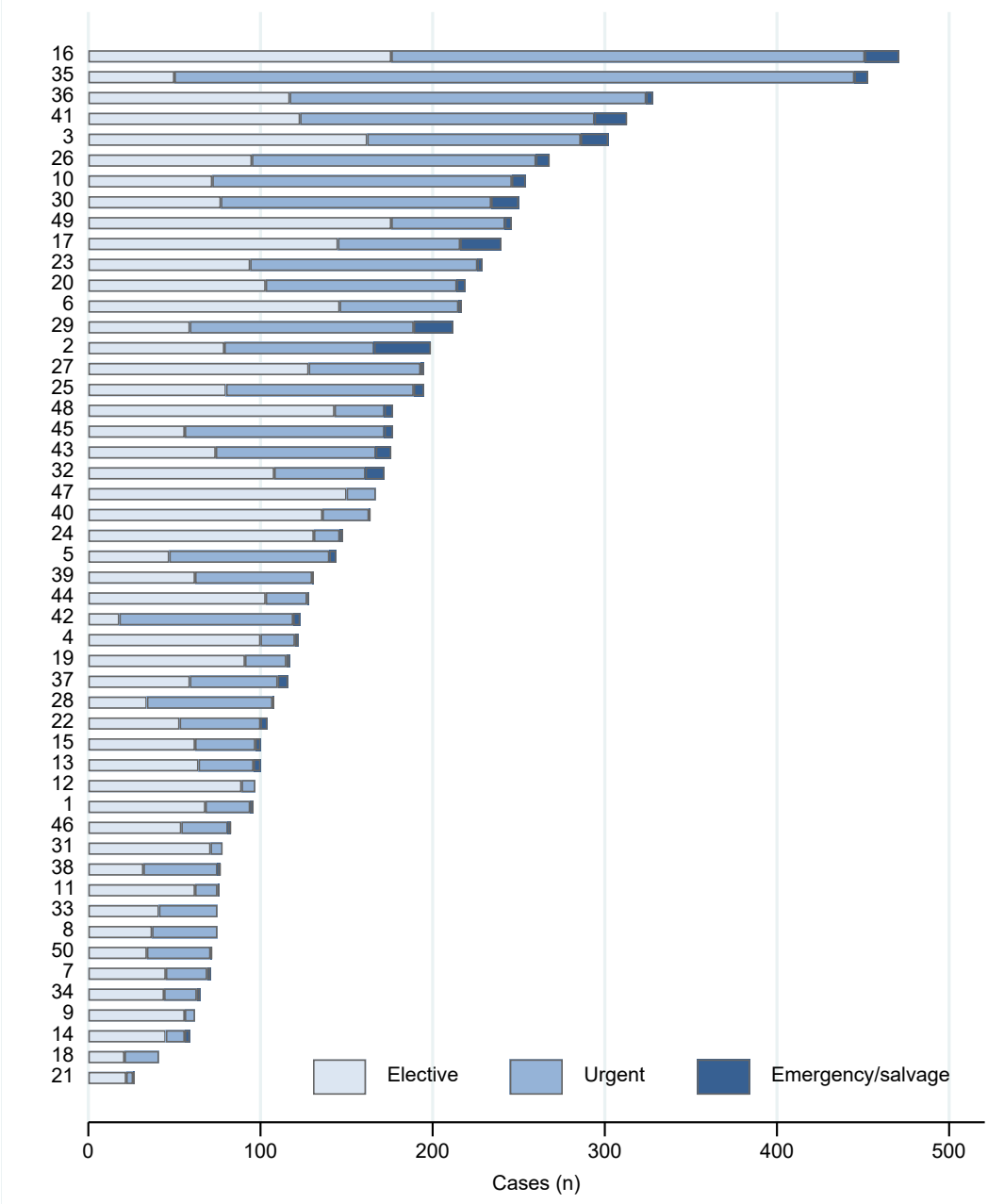
Almost half the patients (48.4%) were admitted the day before or day of their surgery, and the median pre-operative length of stay (LOS) was higher at public hospitals (two days) than private hospitals (one day; Figure 26 and Table 17). Approximately 77.5% of patients were discharged less than ten days after their surgery, with a median stay of seven days in the public hospitals and eight days in the private hospitals (Figure 27 and Table 18).

Almost one third (30.2%) of patients were extubated within six hours and 68.8% within 12 hours of surgery (Table 19). The length of intensive care unit (ICU) stay showed a cyclical pattern with patients frequently discharged at 24-hour intervals (Figure 29). Slightly more than half of patients were discharged from the ICU within 48 hours (Table 21). The mean length of ICU stay was lower in public hospitals (59.7 hours) compared to private hospitals (67.8 hours; Table 22). Approximately one third of isolated CABG patients received some type of blood product transfusion and there was similar use of red blood cell (RBC) and non-RBC products at public and private hospitals (Figure 30).

2.1 Patient characteristics

2.1.1 Clinical status

Figure 9. Clinical status of isolated CABG patients by unit, 2021



It should be noted that clinical status is a reported variable, therefore variation can occur due to the interpretation of the Database's data definition (Appendix C, pg. 88).

Table 3. Clinical status of isolated CABG patients by year

	2017	2018	2019	2020	2021	Total
Elective (%)	58.0	59.8	55.3	51.0	50.4	54.6
Urgent (%)	38.7	37.3	41.1	45.8	46.1	42.0
Emergency/salvage (%)	3.3	2.9	3.5	3.3	3.5	3.3

2.1.2 Sex and age

Figure 10. Sex of isolated CABG patients by unit, 2021

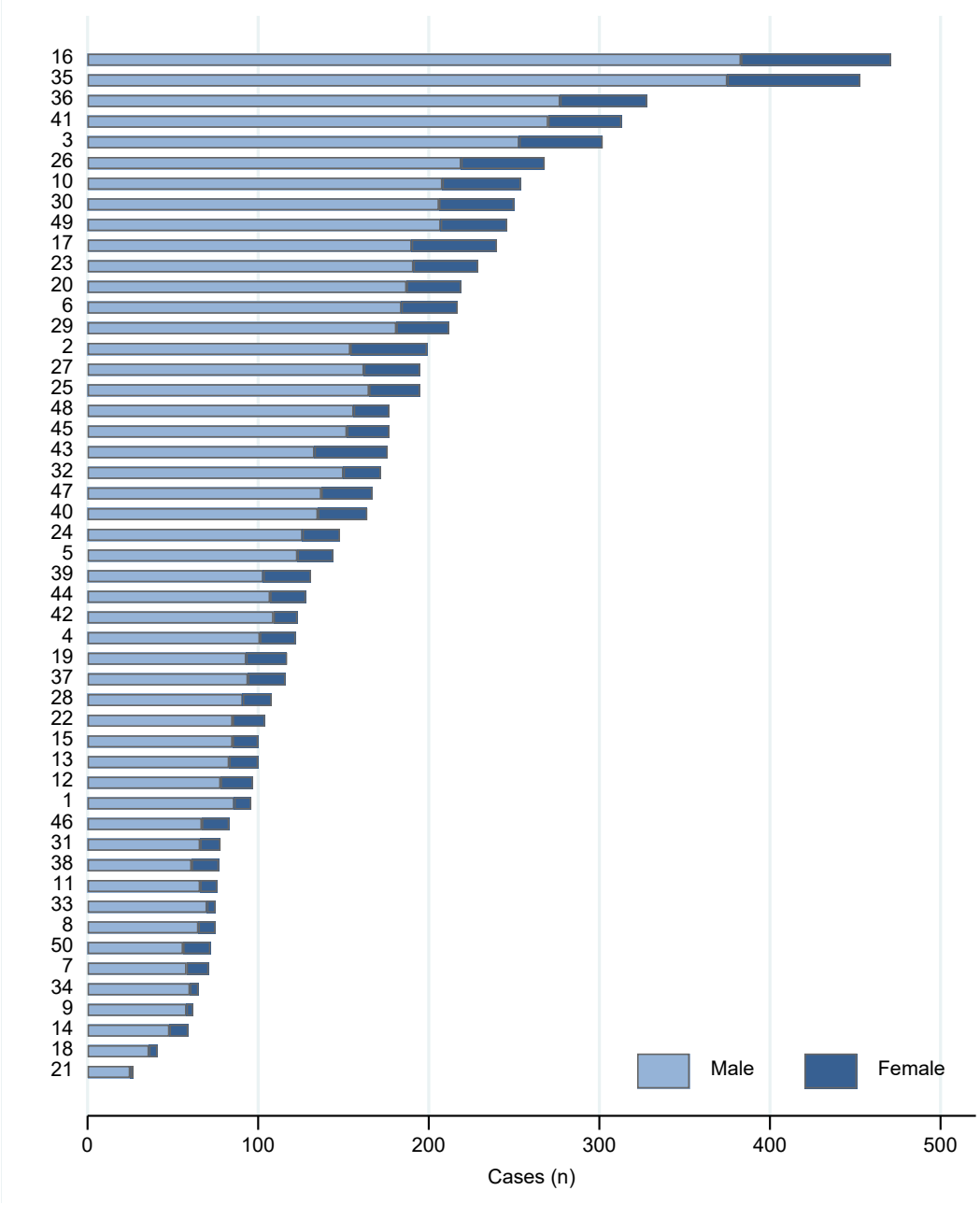
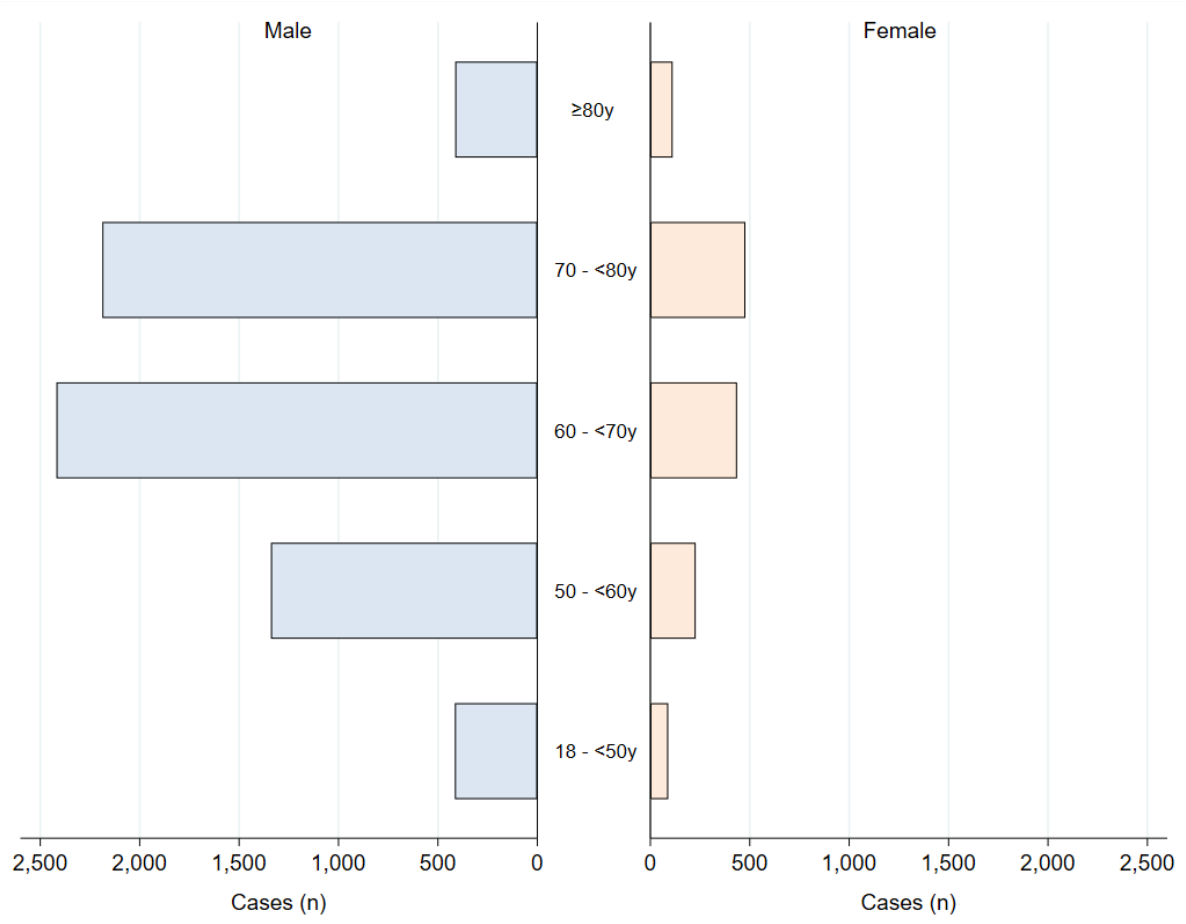


Table 4. Sex of isolated CABG patients by year

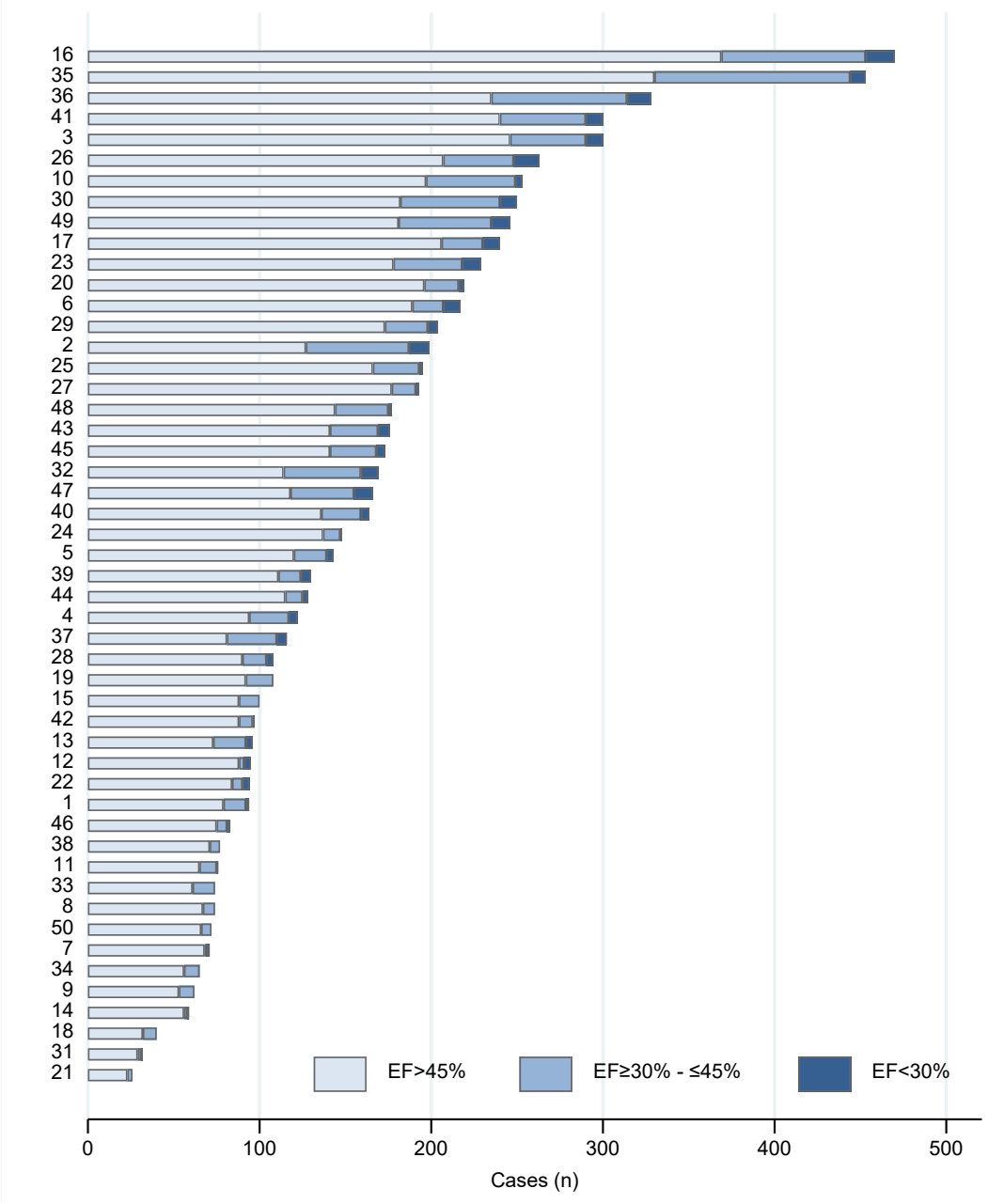
	2017	2018	2019	2020	2021	Total
Male (%)	81.7	82.1	82.2	82.7	83.4	82.5
Female (%)	18.3	17.9	17.8	17.3	16.6	17.5

Figure 11. Age of isolated CABG patients by sex, 2021



2.1.3 Left ventricular function

Figure 12. Pre-operative left ventricular function (LVF) of isolated CABG patients by unit, 2021



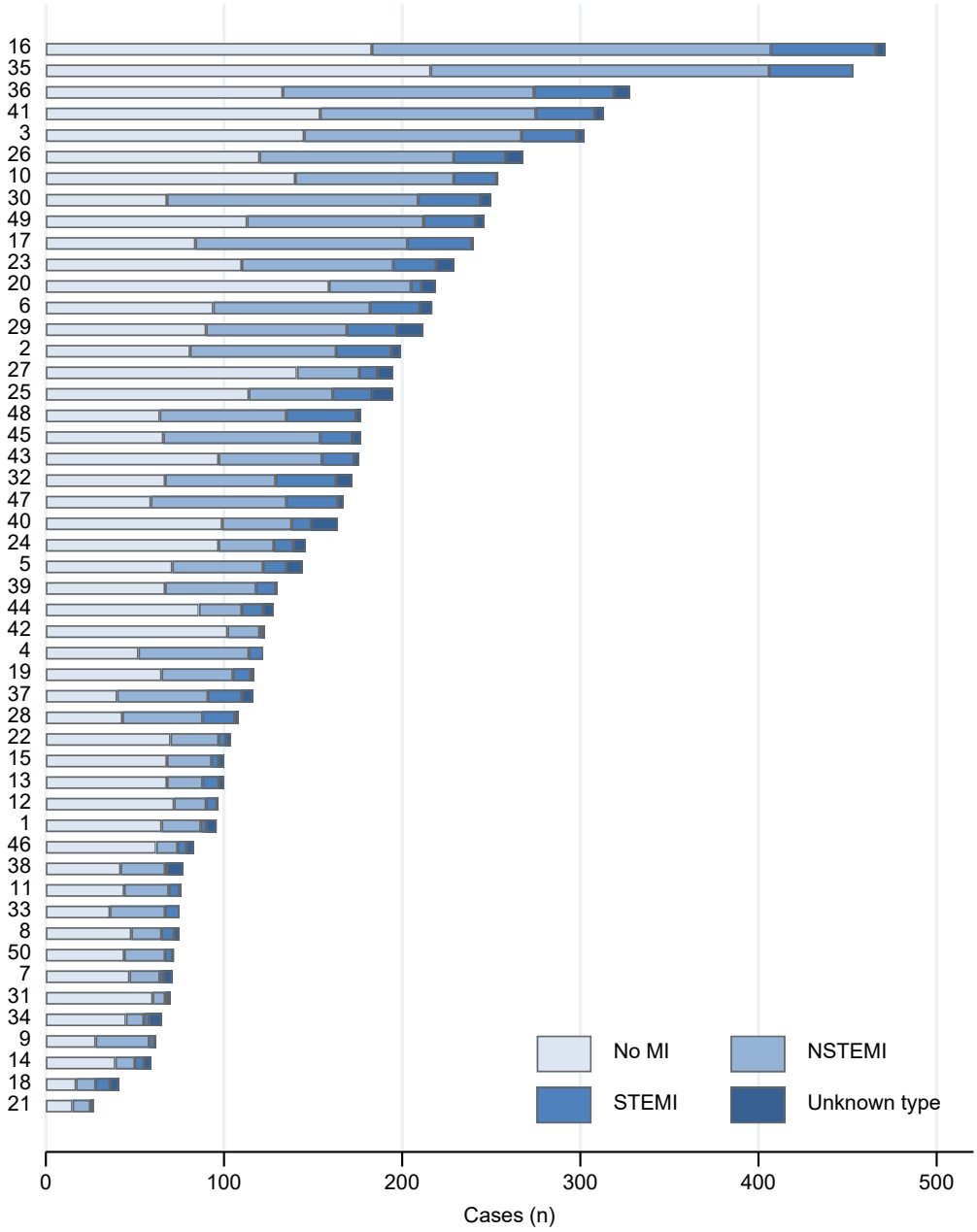
The ANZSCTS Database classifies an EF>45% as normal or mildly reduced, an EF≥30% - ≤45% as moderately reduced and an EF<30% as severely reduced LVF, respectively (Appendix C, pg.88).

Table 5. Pre-operative LVF of isolated CABG patients by year

	2017	2018	2019	2020	2021	Total
EF>45% (%)	81.4	80.4	81.0	80.1	81.0	80.8
EF≥30% - ≤45% (%)	14.8	15.8	15.9	16.6	16.0	15.8
EF<30% (%)	3.8	3.8	3.1	3.2	3.1	3.4

2.1.4 Previous myocardial infarction

Figure 13. Previous MI in isolated CABG patients by unit, 2021



MI indicates myocardial infarction; NSTEMI, non-ST-elevation MI; STEMI, ST-elevation MI

Table 6. Previous MI in isolated CABG patients by year

	2017	2018	2019	2020	2021	Total
No MI (%)	47.8	48.7	48.3	47.4	50.4	48.6
NSTEMI (%)	38.0	37.3	38.1	39.5	36.1	37.8
STEMI (%)	10.5	10.0	10.1	10.1	10.5	10.2
Unknown type (%)	3.7	4.1	3.6	3.0	3.0	3.4

2.1.5 Timing of previous myocardial infarction

Figure 14. Timing of previous MI in isolated CABG patients by unit, 2021

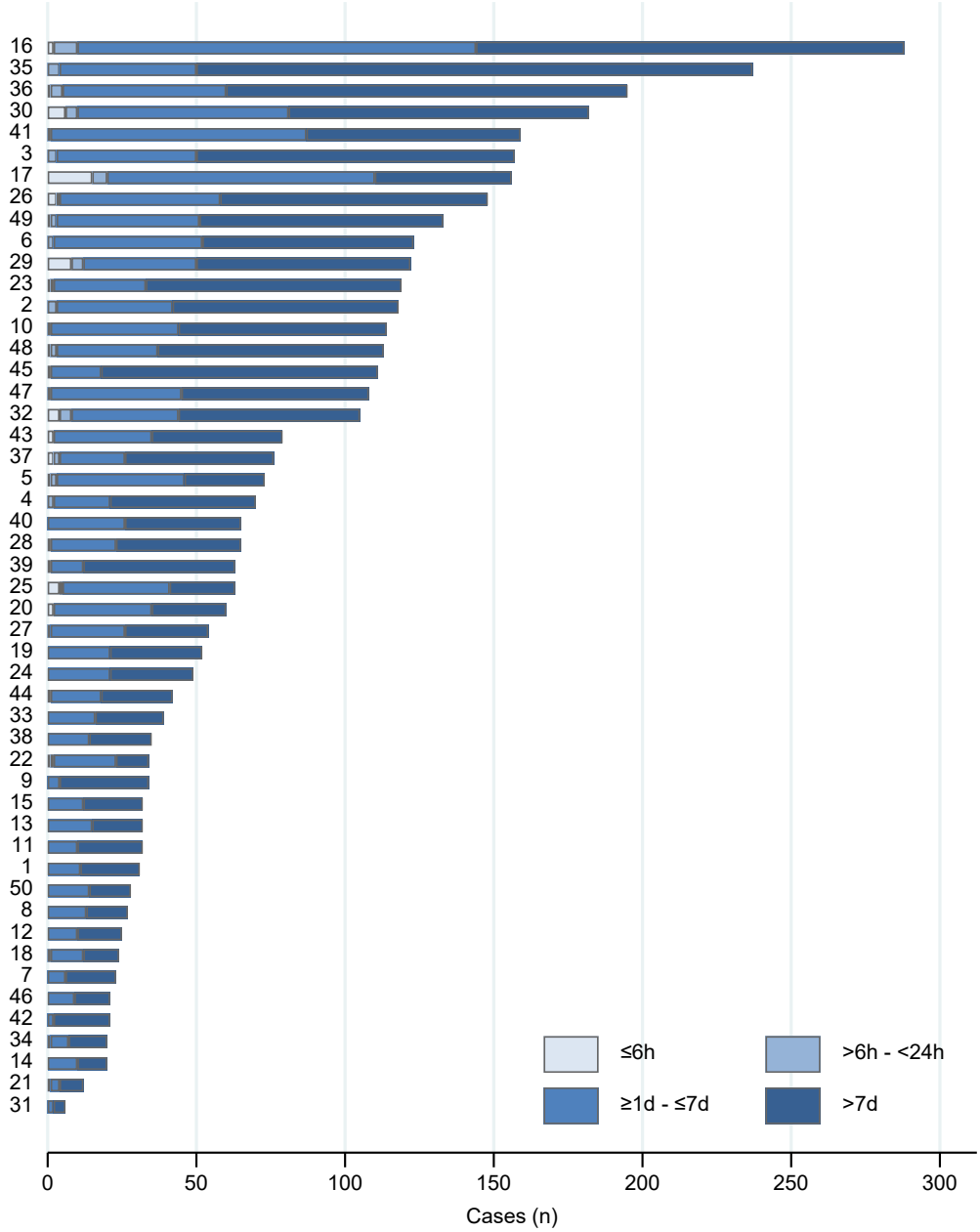


Table 7. Timing of previous MI in isolated CABG patients by year

	2017	2018	2019	2020	2021	Total
≤6hr (%)	1.1	1.2	1.1	1.4	1.5	1.3
>6hr - <24hr (%)	2.2	2.2	2.0	2.0	1.5	2.0
≥1d - ≤7d (%)	31.7	31.6	31.6	36.5	37.1	33.9
>7d (%)	64.9	64.9	65.2	60.1	59.9	62.9

2.2 Previous cardiac surgery

Figure 15. Initial vs redo surgery in isolated CABG patients by unit, 2021

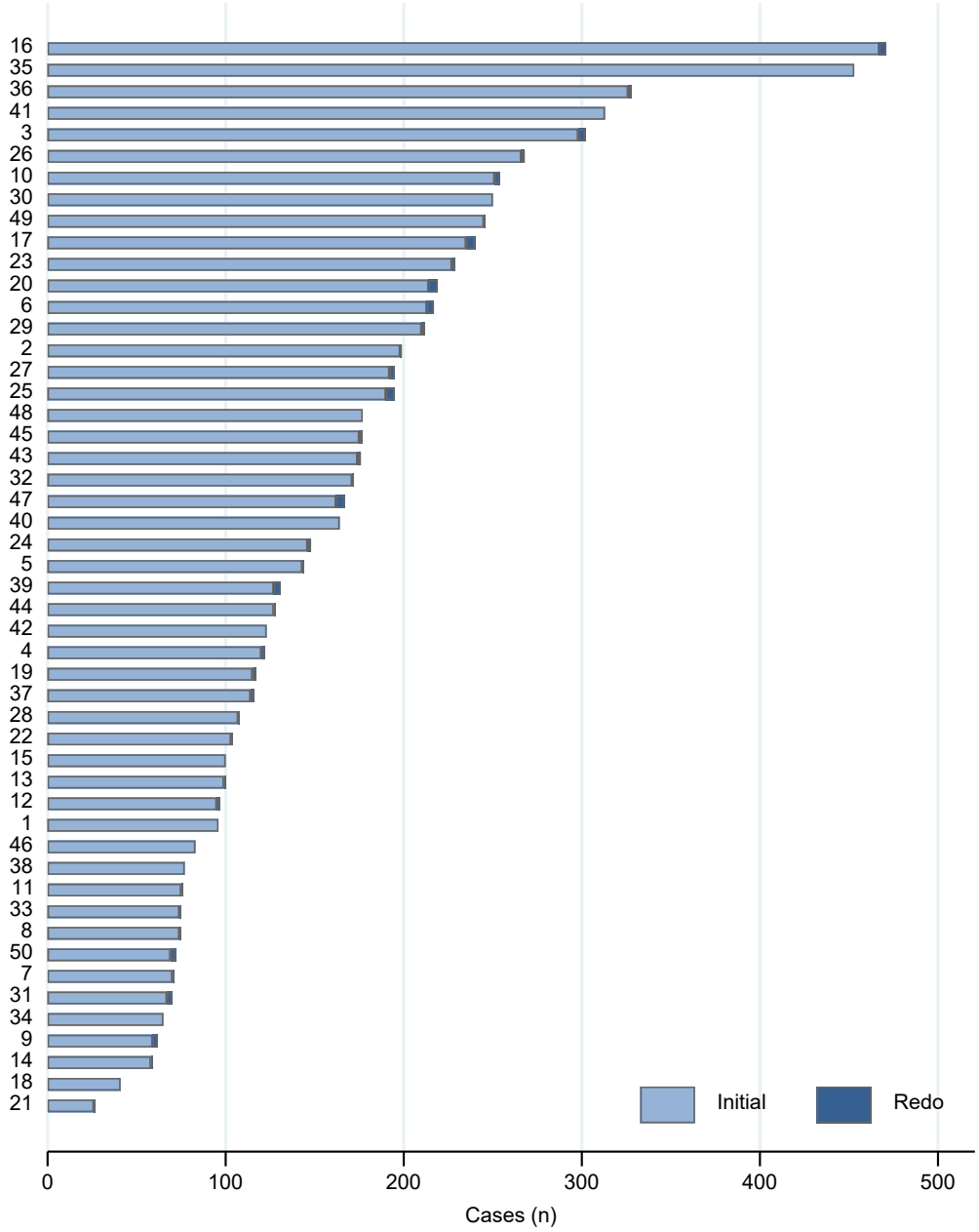


Table 8. Initial vs redo surgery in isolated CABG patients by year

	2017	2018	2019	2020	2021	Total
Initial (%)	98.7	98.8	98.8	98.9	98.9	98.8
Redo (%)	1.3	1.2	1.2	1.1	1.1	1.2

2.3 On-pump and off-pump coronary surgery

Figure 16. On-pump vs off-pump surgery in isolated CABG patients by unit, 2021

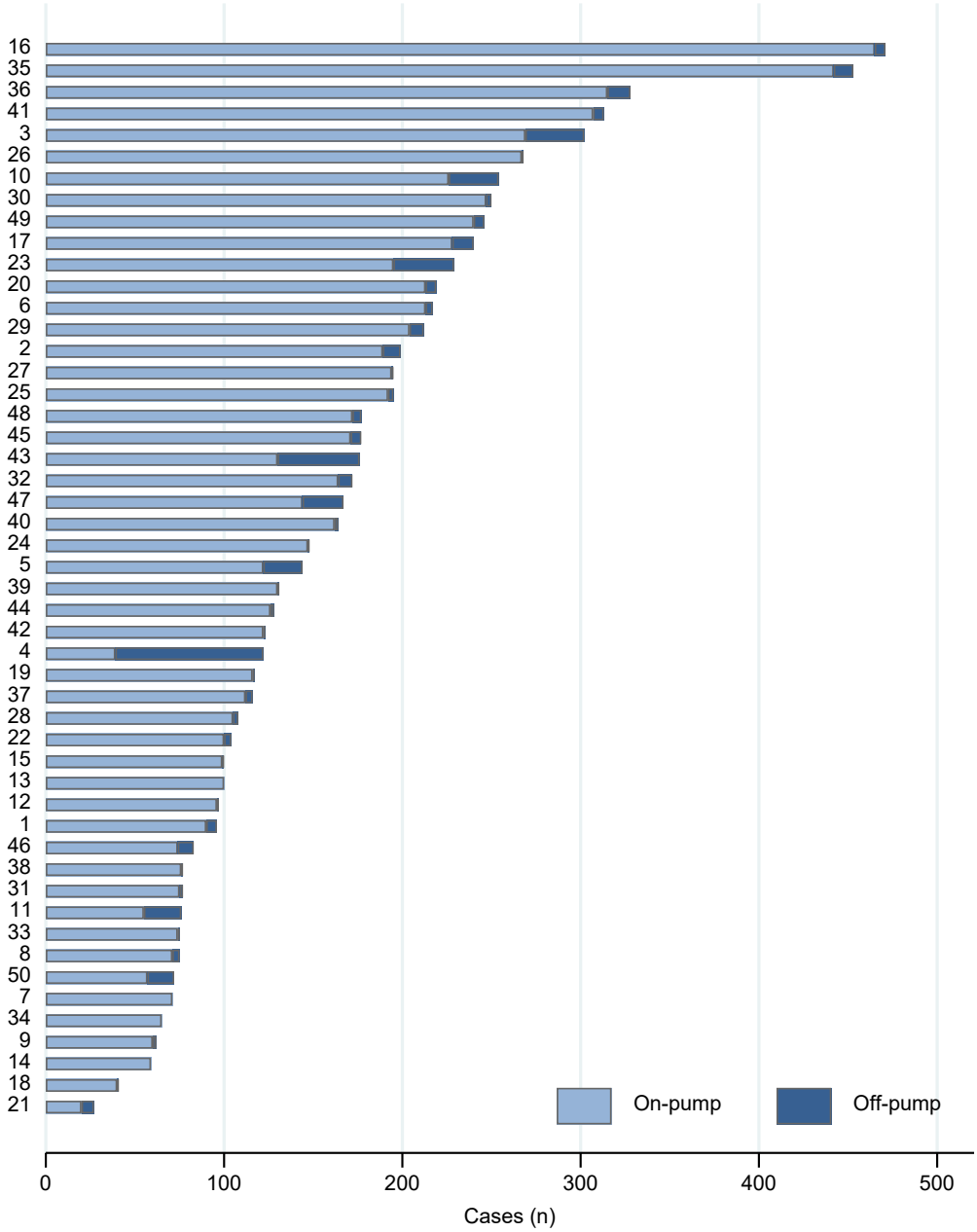


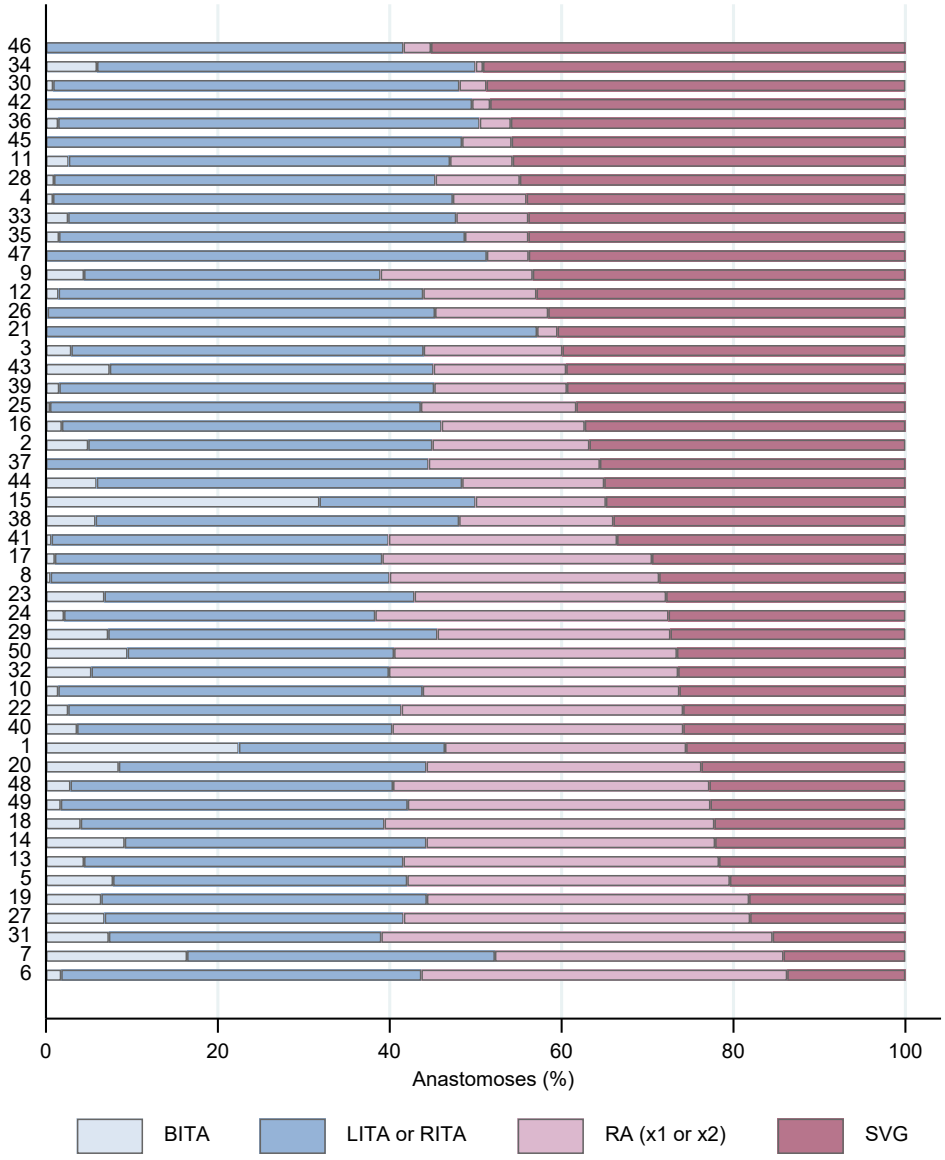
Table 9. On-pump vs off-pump surgery in isolated CABG patients by year

	2017	2018	2019	2020	2021	Total
On-pump (%)	93.4	92.6	93.3	94.2	94.2	93.6
Off-pump (%)	6.6	7.4	6.7	5.8	5.8	6.4

2.4 Conduit selection

2.4.1 Conduits used for anastomoses

Figure 17. Type of arterial and venous conduits harvested for isolated CABG surgery by unit, 2021



BITA indicates bilateral internal thoracic artery; LITA, left internal thoracic artery; RITA, right internal thoracic artery; RA, radial artery; SVG, saphenous vein graft

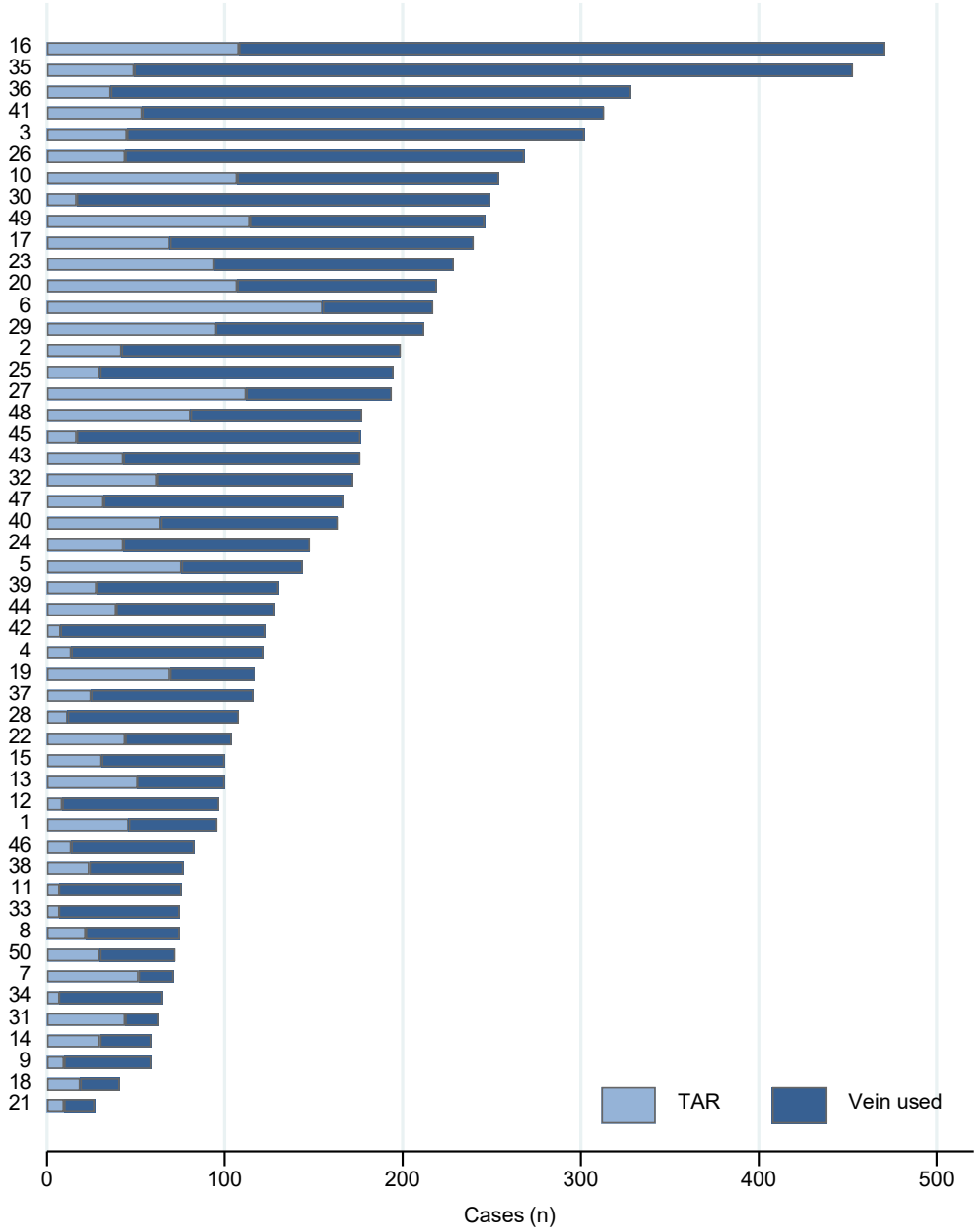
Table 10. Summary of the number of distal anastomoses based on conduit type used for isolated CABG surgery, 2021

	Mean	Median	IQR	Range
BITA	2.3	2	2 - 3	2 - 5
LITA or RITA	1.1	1	1 - 1	1 - 4
RA (x1 or x2)	1.4	1	1 - 2	1 - 8
SVG	1.8	2	1 - 2	1 - 6

Table 11. Grafts and multi-vessel disease in isolated CABG surgery by age and CPB, 2021

	Mean grafts (n)	Multi-vessel disease (%)	All arterial grafts (%)
Age			
18 - <50y	3.0	91.3	40.0
50 - <60y	3.1	94.9	34.3
60 - <70y	3.1	95.3	29.1
70 - <80y	3.1	96.2	24.2
≥80y	2.9	95.6	26.4
CPB			
On-pump	3.1	96.2	27.2
Off-pump	2.5	79.7	58.3

Figure 18. TAR vs vein used in isolated CABG surgery by unit, 2021



TAR indicates total arterial vascularisation. It should be noted that this analysis is based on any use of a vein for a case, and does not take into consideration the total number of grafts for each case.

2.5 Influence of co-morbidities on complications

2.5.1 Pre-existing diabetes and renal impairment

Table 12. Complications following isolated CABG surgery, by pre-operative diabetes and renal function

		Insulin dependent diabetes		Pre-operative creatinine		Pre-operative eGFR	
		No	Yes	≤200 µmol/L	>200 µmol/L	>60mL /min/1.73m^2	≤60mL /min/1.73m^2
n	2021	7,188	929	7,887	221	6,701	1,400
	2017 - 2020	24,840	3,571	27,603	805	23,130	5,278
Permanent stroke (%)	2021	0.8	1.2	0.9	1.4	0.8	1.2
	2017 - 2020	0.9	1.9	1.0	2.6	0.8	1.9
DSWI (%)	2021	0.7	2.5	0.9	1.8	0.9	1.1
	2017 - 2020	0.9	2.6	1.1	3.3	1.1	1.5
New cardiac arrythmia (%)	2021	27.6	27.0	27.4	30.6	26.6	31.8
	2017 - 2020	26.5	24.6	26.1	30.6	25.3	30.7
RTT for bleeding (%)	2021	2.0	2.7	1.9	8.2	1.7	3.8
	2017 - 2020	2.5	2.4	2.4	4.9	2.3	3.2

2.5.2 Age

Table 13. Complications following isolated CABG surgery, by age group

		Age				
		18 - <50y	50 - <60y	60 - <70y	70 - <80y	≥80y
n	2021	505	1,568	2,855	2,666	525
	2017 - 2020	1,878	5,670	10,057	8,986	1,824
Permanent stroke (%)	2021	0.6	0.6	0.8	1.2	1.0
	2017 - 2020	0.6	0.8	0.9	1.3	1.4
DSWI (%)	2021	0.6	1.6	0.7	0.9	0.4
	2017 - 2020	1.1	1.0	1.2	1.3	0.9
New cardiac arrythmia (%)	2021	12.7	18.4	25.6	35.4	39.8
	2017 - 2020	11.3	17.9	26.4	32.3	37.6
RTT for bleeding (%)	2021	1.6	1.9	1.9	2.3	2.5
	2017 - 2020	2.6	2.3	2.4	2.5	3.1

2.5.3 Previous cardiac surgery or use of cardiopulmonary bypass

Table 14. Complications following isolated CABG surgery, by redo and CPB

		Surgery		CPB	
		Initial	Redo	On-pump	Off-pump
n	2021	8,024	87	7,650	468
	2017 - 2020	28,076	337	26,528	1,884
Permanent stroke (%)	2021	0.9	3.4	0.9	0.4
	2017 - 2020	1.0	1.8	1.0	1.1
DSWI (%)	2021	0.9	0.0	0.9	1.5
	2017 - 2020	1.1	0.6	1.2	1.0
New cardiac arrythmia (%)	2021	27.5	26.4	27.5	28.4
	2017 - 2020	26.2	27.5	26.4	24.6
RTT for bleeding (%)	2021	2.1	3.4	2.1	2.1
	2017 - 2020	2.5	3.3	2.5	2.4

2.5.4 Influence of comorbidities on derived new renal insufficiency

Table 15. Incidence of dNRI following isolated CABG surgery, by pre-operative demographics and risk factors

	2021		2017 - 2020	
	n	dNRI (%)	n	dNRI (%)
Insulin dependent diabetes				
No	7,081	2.0	24,569	2.3
Yes	878	6.1	3,340	4.0
Pre-operative creatinine				
≤200 µmol/L	7,860	2.3	27,526	2.3
>200 µmol/L	91	15.7	380	16.7
Pre-operative eGFR				
>60mL/min/1.73m^2	6,684	1.7	23,081	1.8
≤60mL/min/1.73m^2	1,260	6.0	4,825	6.2
Age				
18 - <50y	488	2.0	1,816	2.1
50 - <60y	1,527	2.1	5,534	1.8
60 - <70y	2,797	2.1	9,887	2.3
70 - <80y	2,634	2.9	8,863	3.0
≥80y	513	2.5	1,810	4.3
Previous surgery				
Initial	7,875	2.4	27,582	2.5
Redo	84	4.8	328	4.0
CPB				
On-pump	7,505	2.5	26,066	2.6
Off-pump	453	1.3	1,841	2.2

dNRI indicates derived new renal insufficiency.

2.6 Influence of patient characteristics on operative mortality

Table 16. OM following isolated CABG surgery, by patient demographics and risk factors

	2021		2017 - 2020	
	n	OM (%)	n	OM (%)
Clinical status				
Elective	4,094	0.5	15,869	0.7
Urgent	3,743	1.2	11,617	1.2
Emergency/salvage	282	3.9	929	7.4
Sex/age				
Male	6,775	0.9	23,365	1.0
18 - <50y	415	1.2	1,577	1.0
50 - <60y	1,340	0.5	4,804	0.4
60 - <70y	2,419	0.7	8,395	0.7
70 - <80y	2,188	1.1	7,211	1.4
≥80y	413	1.0	1,378	2.3
Female	1,344	1.3	5,050	1.7
18 - <50y	90	2.2	301	0.3
50 - <60y	228	0.4	866	1.5
60 - <70y	436	1.4	1,662	0.8
70 - <80y	478	1.7	1,775	2.6
≥80y	112	0.9	446	3.4
LVF				
EF>45%	6,455	0.6	22,663	0.7
EF≥30% - ≤45%	1,272	1.9	4,442	2.2
EF<30%	247	4.5	974	5.1
Previous MI				
No MI	4,090	0.6	13,645	0.8
NSTEMI	2,925	1.2	10,867	1.3
STEMI	851	1.9	2,886	2.1
Unknown type	242	0.4	1,011	0.9
Timing of previous MI				
≤6hr	59	10.2	182	11.0
>6hr - <24hr	61	6.6	308	6.8
≥1d - ≤7d	1,481	1.0	4,864	1.6
>7d	2,394	1.1	9,392	1.0
Previous surgery				
Initial	8,032	0.9	28,078	1.1
Redo	87	1.1	337	3.0
CPB				
On-pump	7,650	0.9	26,528	1.1
Off-pump	468	0.9	1,884	1.4
Dialysis				
No	7,959	0.8	27,910	1.0
Yes	156	7.1	501	7.2
Pre-operative creatinine				
≤200 µmol/L	7,887	0.8	27,603	1.0
>200 µmol/L	221	5.4	805	6.7

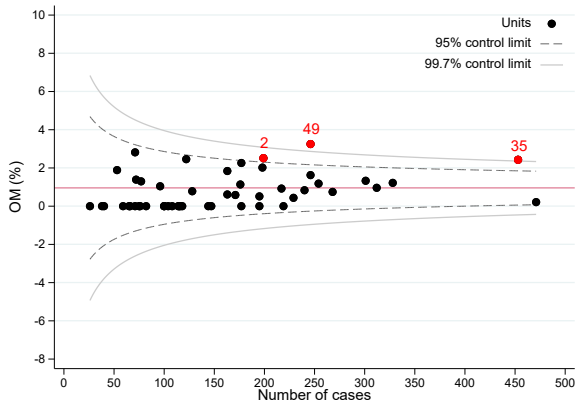
2.7 Unit outcomes – mortality, complications and resource utilisation

The data reported in Figures 19-23 have been tabulated in Appendix F (Tables F1 and F2, pg. 92 - 93).

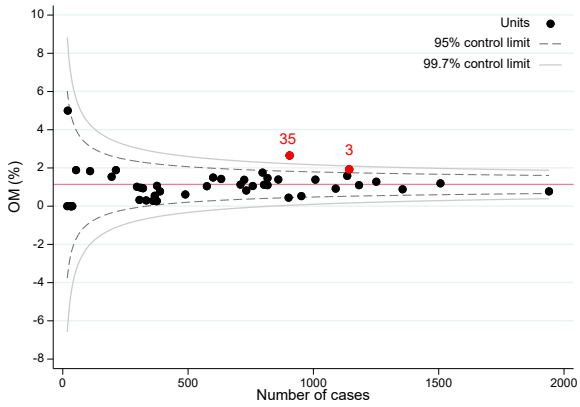
2.7.1 Operative mortality

Figure 19. OM following isolated CABG surgery, by unit

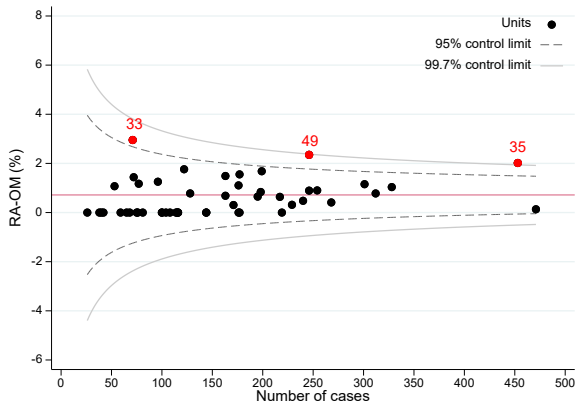
a. 2021 OM



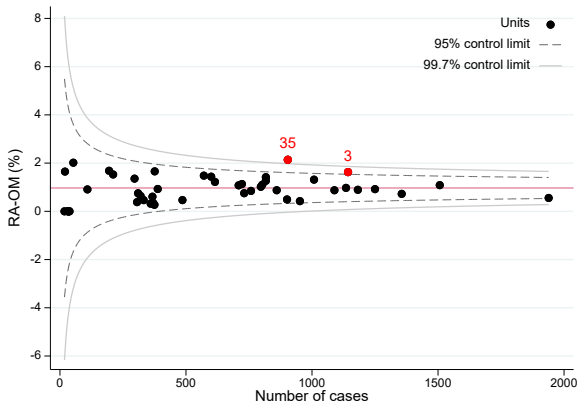
b. 2017 – 2020 OM



c. 2021 RA-OM



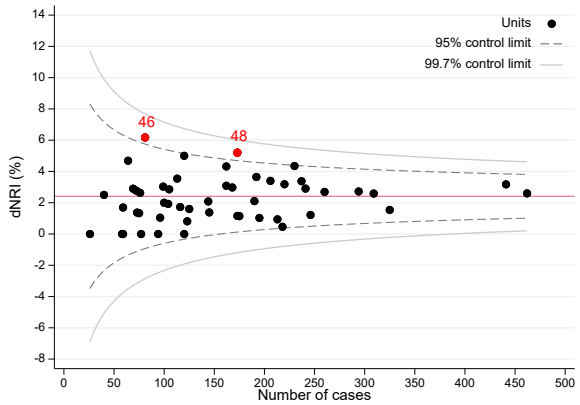
d. 2017 – 2020 RA-OM



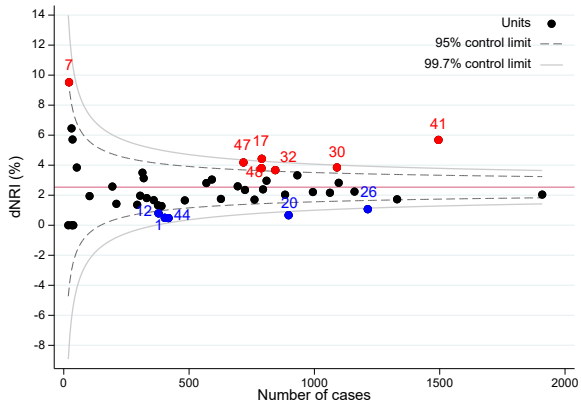
2.7.2 Complications

Figure 20. dNRI following isolated CABG surgery, by unit

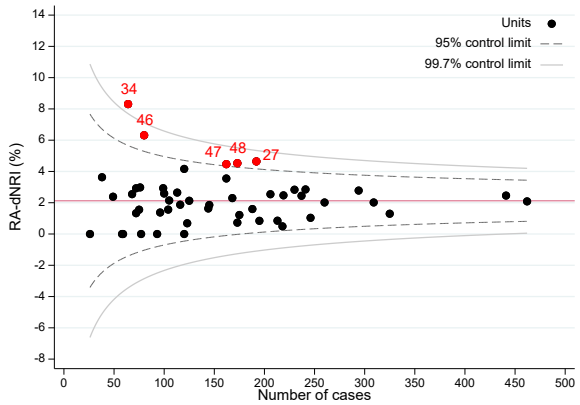
a. 2021 dNRI



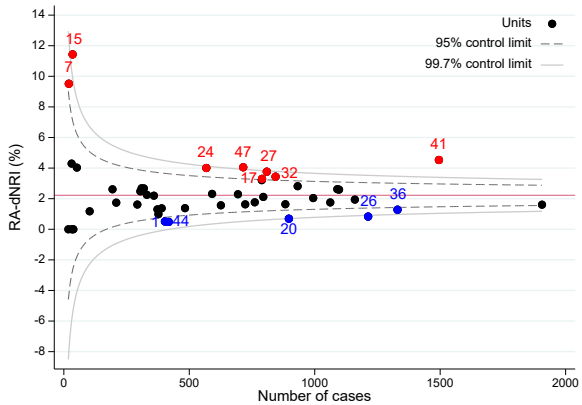
b. 2017 – 2020 dNRI



c. 2021 RA-dNRI



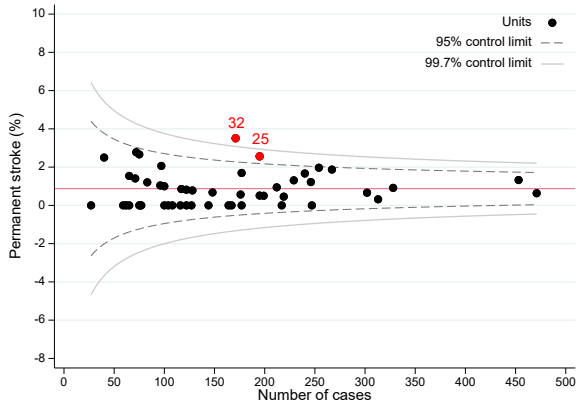
d. 2017 – 2020 RA-dNRI



dNRI indicates derived new renal insufficiency.

Figure 21. Permanent stroke following isolated CABG surgery, by unit

a. 2021 permanent stroke



b. 2017 – 2020 permanent stroke

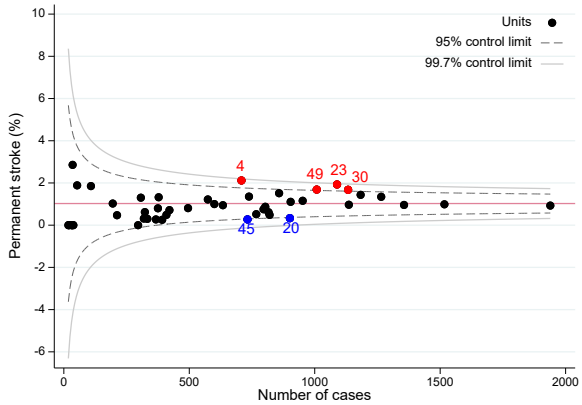
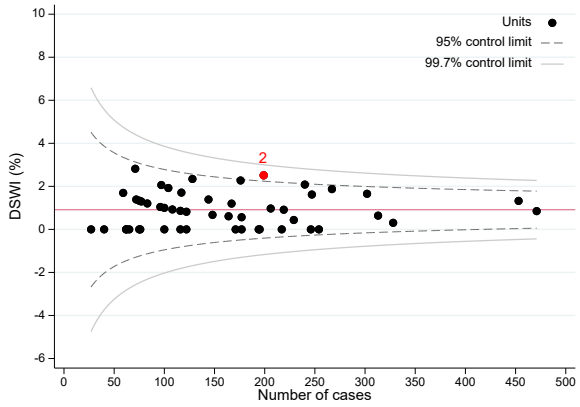


Figure 22. DSWI following isolated CABG surgery, by unit

a. 2021 DSWI



b. 2017 – 2020 DSWI

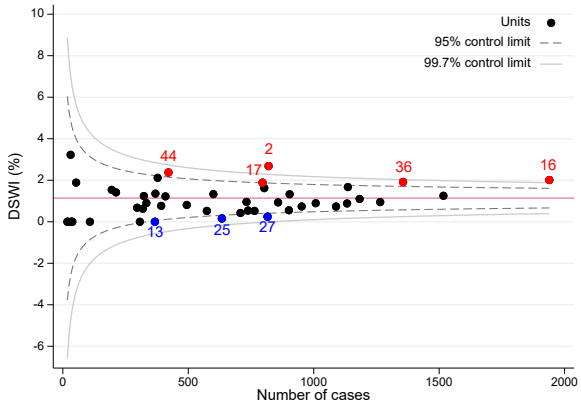
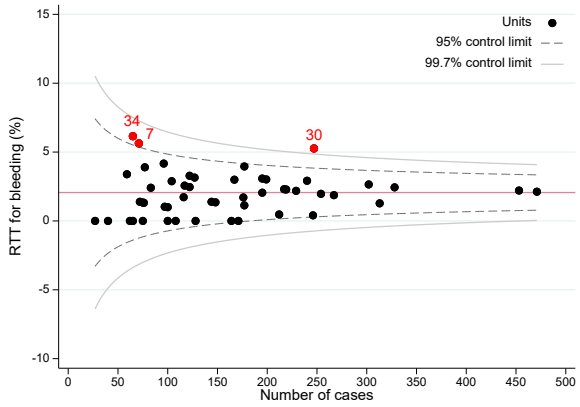


Figure 23. RTT for bleeding following isolated CABG surgery, by unit

a. 2021 RTT for bleeding



b. 2017 – 2020 RTT for bleeding

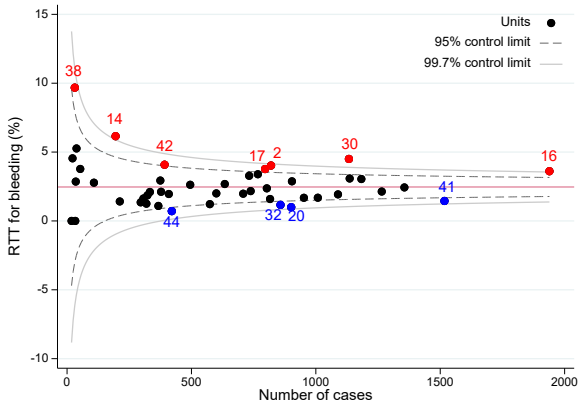
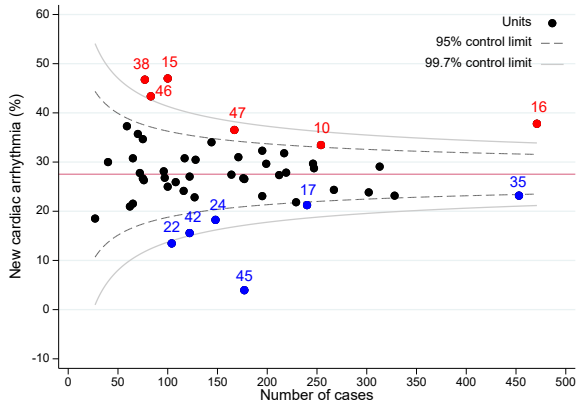


Figure 24. New cardiac arrhythmia following isolated CABG surgery, by unit

a. 2021 new cardiac arrhythmia



b. 2017 – 2020 new cardiac arrhythmia

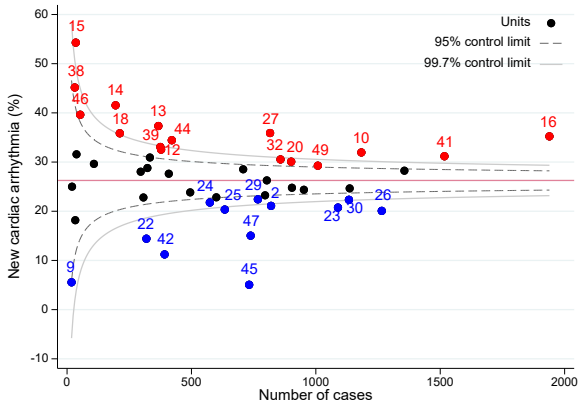
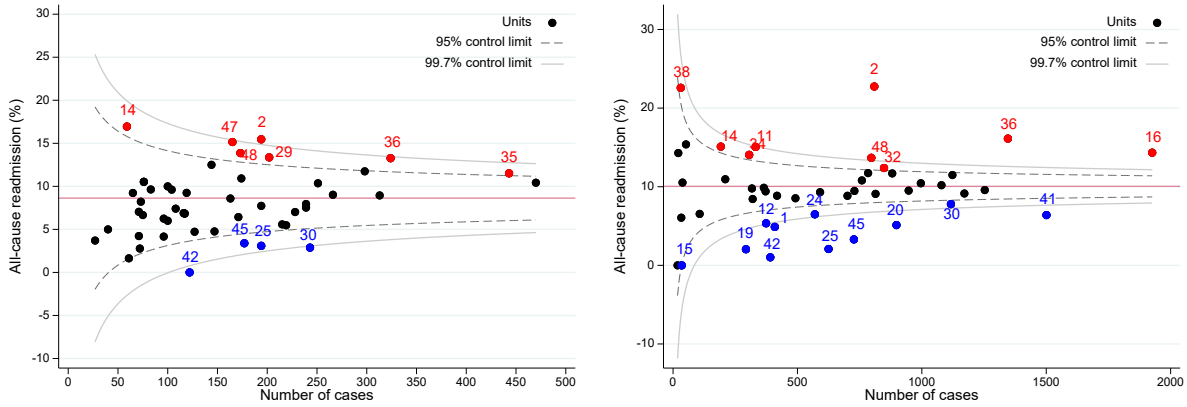


Figure 25. All-cause readmission following isolated CABG surgery, by unit

a. 2021 all-cause readmission b. 2017 – 2020 all-cause readmission



2.7.3 Resource utilisation

Figure 26. Distribution of pre-operative LOS for isolated CABG patients, 2021

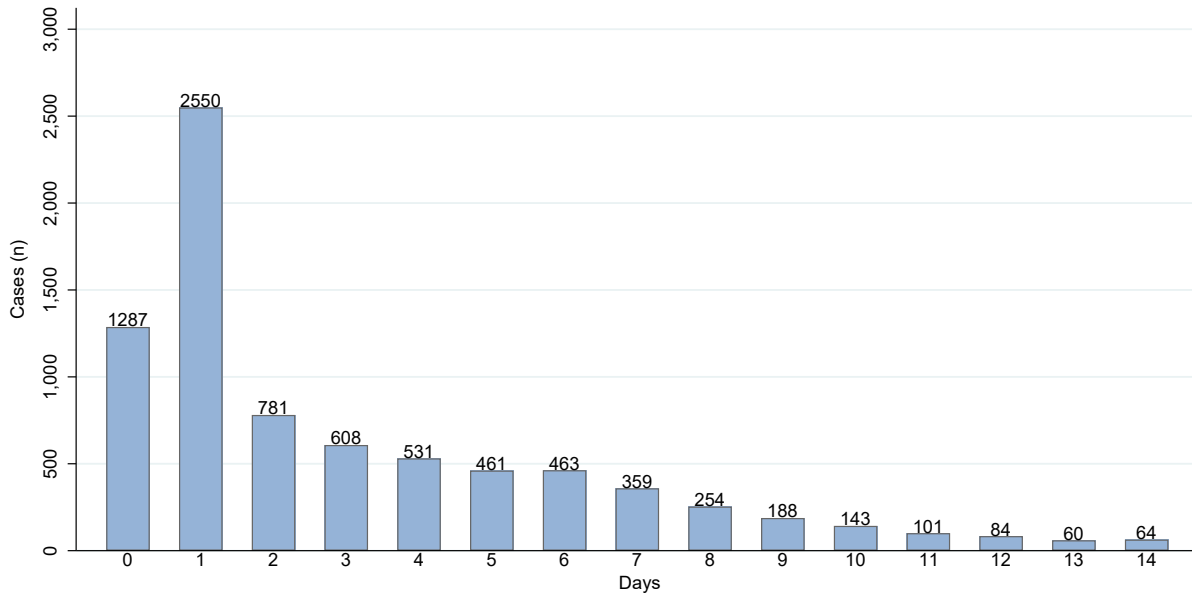


Table 17. Summary of pre-operative LOS for public and private isolated CABG patients, 2021

	Mean (d)	Median (d)	IQR (d)
Public	3.4	2	1 - 6
Private	2.5	1	1 - 4
Total	3.1	2	1 - 5

Cases with a pre-operative LOS of more than 14 days were classified as clinical outliers and excluded from the analysis.

Figure 27. Distribution of post-operative LOS for isolated CABG patients, 2021

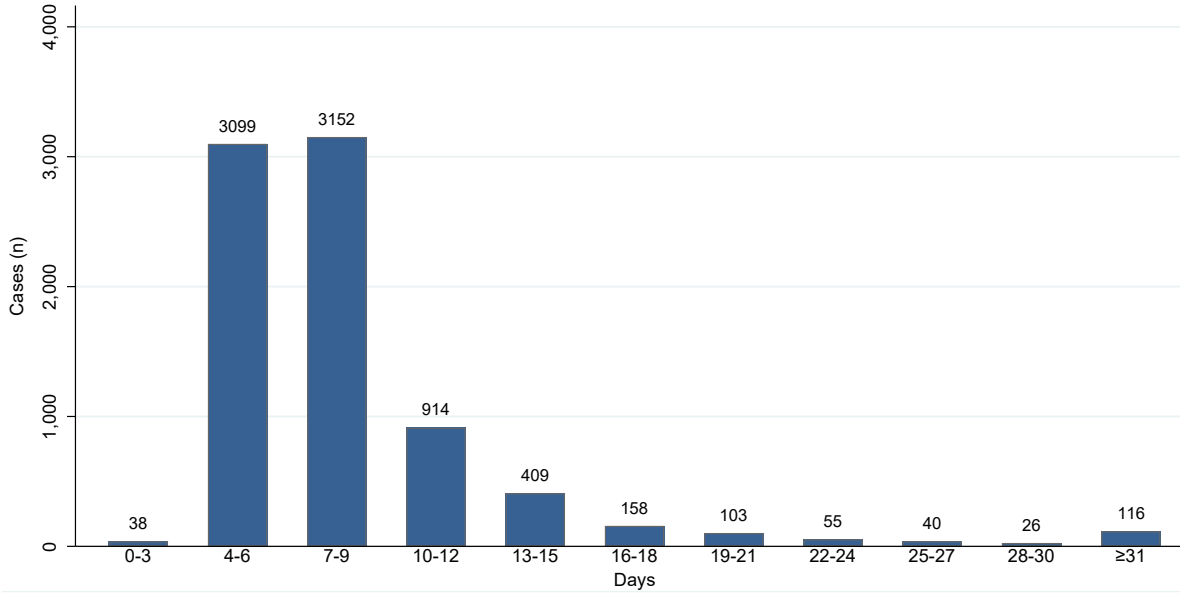


Table 18. Summary of post-operative LOS for public and private isolated CABG patients, 2021

	Mean (d)	Median (d)	IQR (d)
Public	8.4	7	5 - 9
Private	9.0	8	7 - 10
Total	8.6	7	6 - 9

Cases with a post-operative LOS of more than 30 days were classified as clinical outliers and excluded from the analysis.

Figure 28. Distribution of initial post-operative ventilation time for isolated CABG patients, 2021

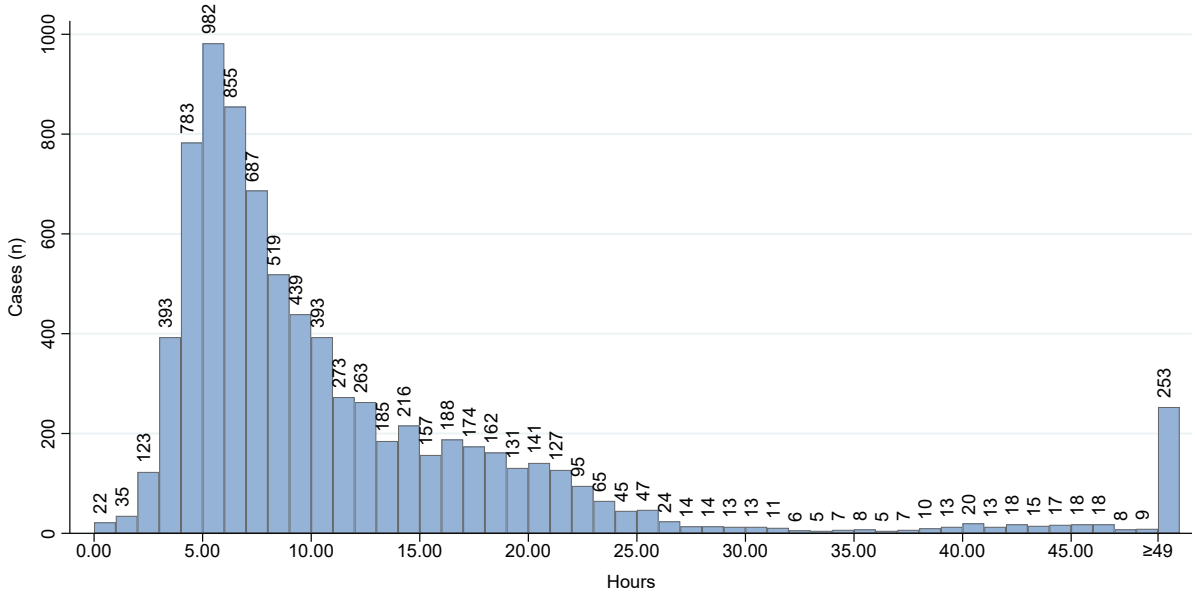


Table 19. Cumulative proportion of patients extubated by hour up to 28 days for isolated CABG surgery, 2021

	6h	12h	24h	48h	96h	192h	384h	672h
Cumulative patients (n)	2,425	5,529	7,412	7,778	7,919	8,003	8,031	8,039
Cumulative percentage (%)	30.2	68.8	92.2	96.8	98.5	99.6	99.9	100.0

Table 20. Summary of initial post-operative ventilation time for public and private isolated CABG patients, 2021

	Mean (h)	Median (h)	IQR (h)
Public	15.6	8.3	5.8 - 14.7
Private	11.4	7.8	5.3 - 13.8
Total	14.2	8.2	5.6 - 14.3

Cases with a ventilation time of more than four weeks were classified as clinical outliers and excluded from the analysis.

Figure 29. Distribution of ICU length of stay for isolated CABG patients, 2021

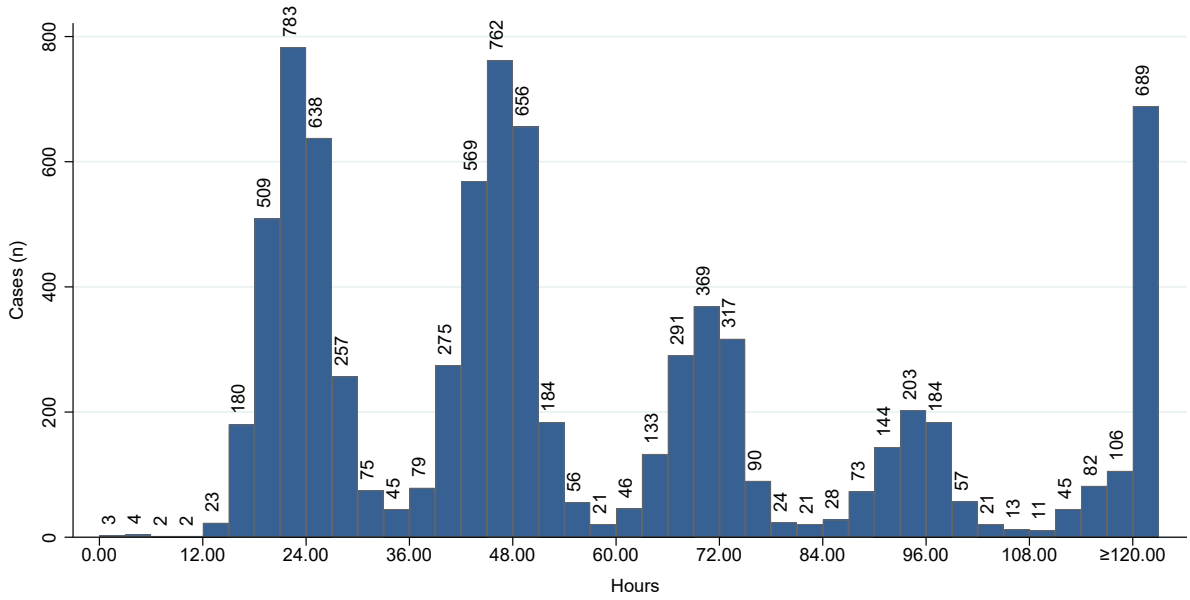


Table 21. Cumulative proportion of patients discharged from ICU by hour up to 42 days for isolated CABG surgery, 2021

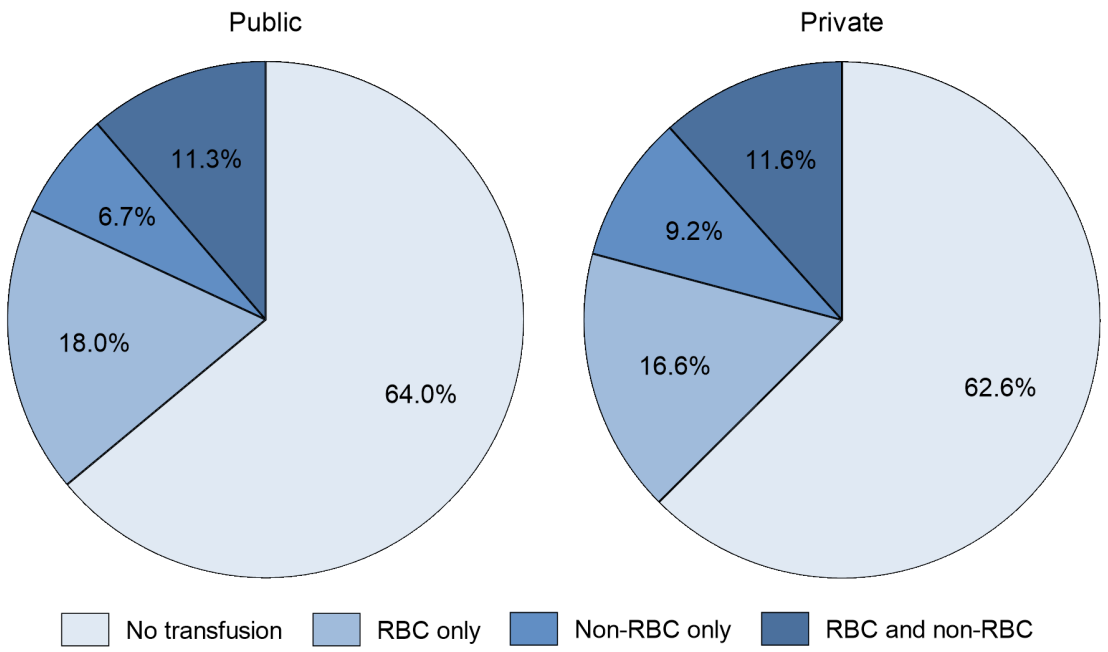
	12h	24h	48h	72h	144h	288h	576h	1008h
Cumulative patients (n)	11	1,536	4,239	5,969	7,654	7,984	8,055	8,070
Cumulative percentage (%)	0.1	19.0	52.5	74.0	94.8	98.9	99.8	100.0

Table 22. Summary of ICU length of stay for public and private isolated CABG patients, 2021

	Mean (h)	Median (h)	IQR (h)
Public	59.7	44.5	23.8 - 71.6
Private	67.8	50.0	44.9 - 74.2
Total	62.3	47.3	26.1 - 72.8

Cases with an ICU length of stay of more than six weeks were classified as clinical outliers and excluded from the analysis.

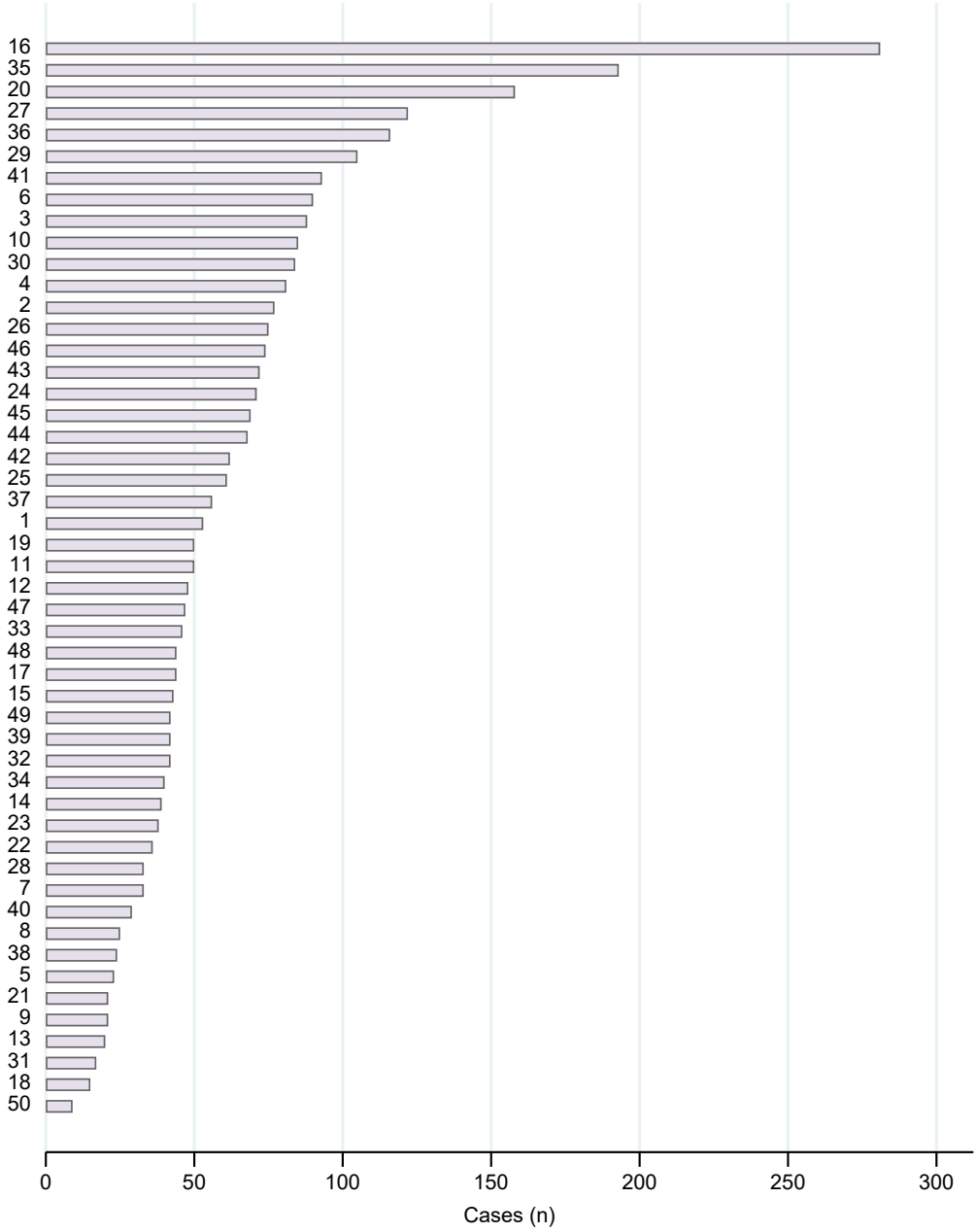
Figure 30. Blood product usage at public and private hospitals for isolated CABG patients, 2021



Note: non-RBC consists of platelets, NovoSeven, cryoprecipitate and FFP

3. Isolated Valve Surgery

Figure 31. Isolated valve cases by unit, 2021



Summary of isolated valve surgery activity

Case volume and patient characteristics

There were 3,174 isolated valve procedures performed in 2021 and case volume varied largely between units. Half of the participating units performed less than 50 procedures and only six units performed more than 100 (Figure 31). In 2021, 61.9% of isolated valve surgery patients were male and the most common age group for both sexes was 70 – <80 years old (Table 24 and Figure 34). The proportion of redo procedures has been largely consistent over the last five years, around 15% (Table 25).

All isolated valve procedures: Type and mortality

There has been a reduction in the proportion of isolated aortic valve replacement (AVR) surgery, relative to all isolated valve surgery, in the last ten years. In contrast, the procedures with the most notable percentage increases between 2011 and 2021 were seen with MVR, MV repair and double valve procedures. (Figure 36). In-hospital and OM for all isolated valve patients were 1.8 and 1.9%, respectively, in 2021 (MV repair indicates mitral valve repair; MVR, mitral valve replacement; AVR, aortic valve replacement

Table 26).

Single valve procedures: Valve choice and mortality

Bioprosthetic valves were used in 83.7% of AVR procedures in 2021, compared to 65.2% in mitral valve replacement (MVR; Figure 38). Use of homo- or allo-grafts for either procedure was rare (<1%).

For single valve surgery, emergency or salvage procedures were associated with a five or ten-fold increase in OM, compared to elective procedures, for MVR and AVR, respectively. There was no clear relationship between age or previous MI on OM; however, patients with low EF, having redo procedures, or with pre-operative markers of renal issues had higher OM than their counterparts (Table 28).

Isolated AVR: Case volume and outcomes

AVR is the most common valve procedure, though 90% of participating units had a case volume of less than 50 procedures in 2021 (Figure 39).

Data for the last five years was pooled to provide sufficient case numbers for analysis of outcomes. The majority of units performed comparably with respect to outcomes of AVR surgery, and units with outcomes outside the 99.7% control limit on funnel plot analysis were engaged by the ANZSCTS Database Steering Committee, in line with the *Special Cause Variation Management Policy*.

The OM for isolated AVR patients was 1.3% in 2017-21 (Figure 40a), which was comparable to in-hospital and 30-day mortality rates reported by international registries (range 1.7 – 2.9%)(2-4). The risk-adjusted OM calculated using the Database's ANZSCORE model was 0.9% for 2017-21 (Figure 40b). The incidences of the other key performance indicators were dNRI (3.1%), risk-adjusted dNRI (2.2%), permanent stroke (1.3%), DSWI (0.5%) and RTT for bleeding (3.9%; Figure 41 and 42).

Resource utilisation

Most patients (75.1%) were admitted the day before or day of their surgery, and the median pre-operative LOS was one day at public and private hospitals (Figure 43 and Table 29). The majority of patients (73.0%) were discharged less than ten days after their surgery, with a slightly higher median post-operative LOS at the private hospitals (eight days), compared to the public hospitals (seven days; Table 30).

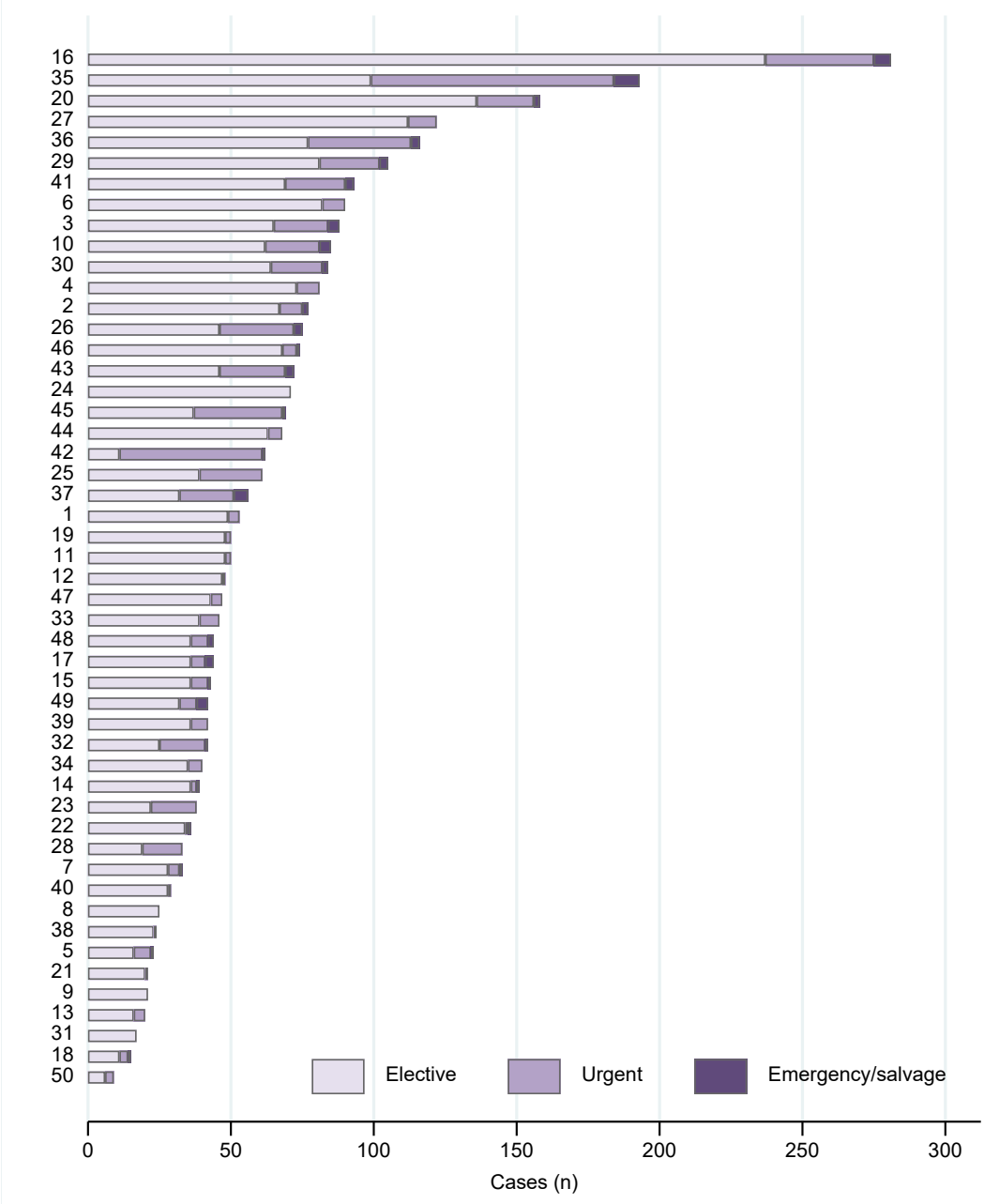
Slightly less than one third of patients (30.9%) were extubated within six hours and 91.6% within 24 hours of surgery (Figure 45 and Table 31). Mean ventilation time was higher in public hospitals, compared with private hospitals (15.9 vs. 12.6 hours, respectively; Table 32). ICU lengths of stay showed a cyclical pattern with patients often discharged at 24-hour intervals (Figure 46). Slightly more than half of patients were discharged from the ICU within 48 hours (53.7%; Table 33). The mean length of ICU stay was lower in public hospitals (59.1 hours) compared to private hospitals (68.4 hours; Table 34).

Blood product transfusions were given to approximately one third of patients, and there was similar use of RBC and non-RBC products at public and private hospitals (Figure 47).

3.1 Patient characteristics

3.1.1 Clinical status

Figure 32. Clinical status of isolated valve patients by unit, 2021



It should be noted that clinical status is a reported variable, therefore variation can occur due to the interpretation of the Database's data definition (Appendix C, pg. 88).

Table 23. Clinical status of isolated valve patients by year

	2017	2018	2019	2020	2021	Total
Elective (%)	82.6	85.1	81.7	78.3	78.3	81.1
Urgent (%)	15.3	13.3	16.3	19.9	19.6	17.0
Emergency/salvage (%)	2.1	1.5	2.0	1.8	2.2	1.9

3.1.2 Sex and age

Figure 33. Sex of isolated valve patients by unit, 2021

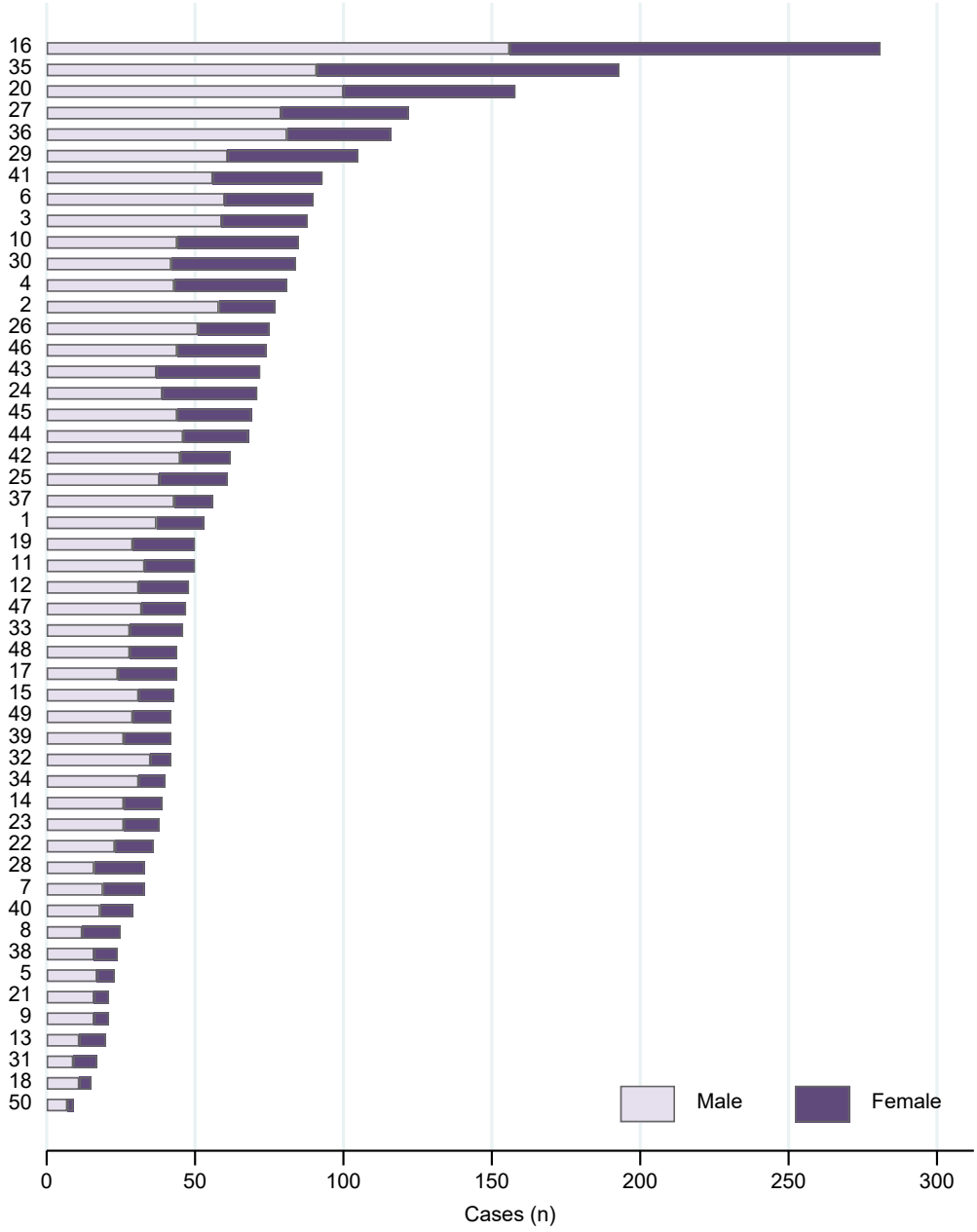
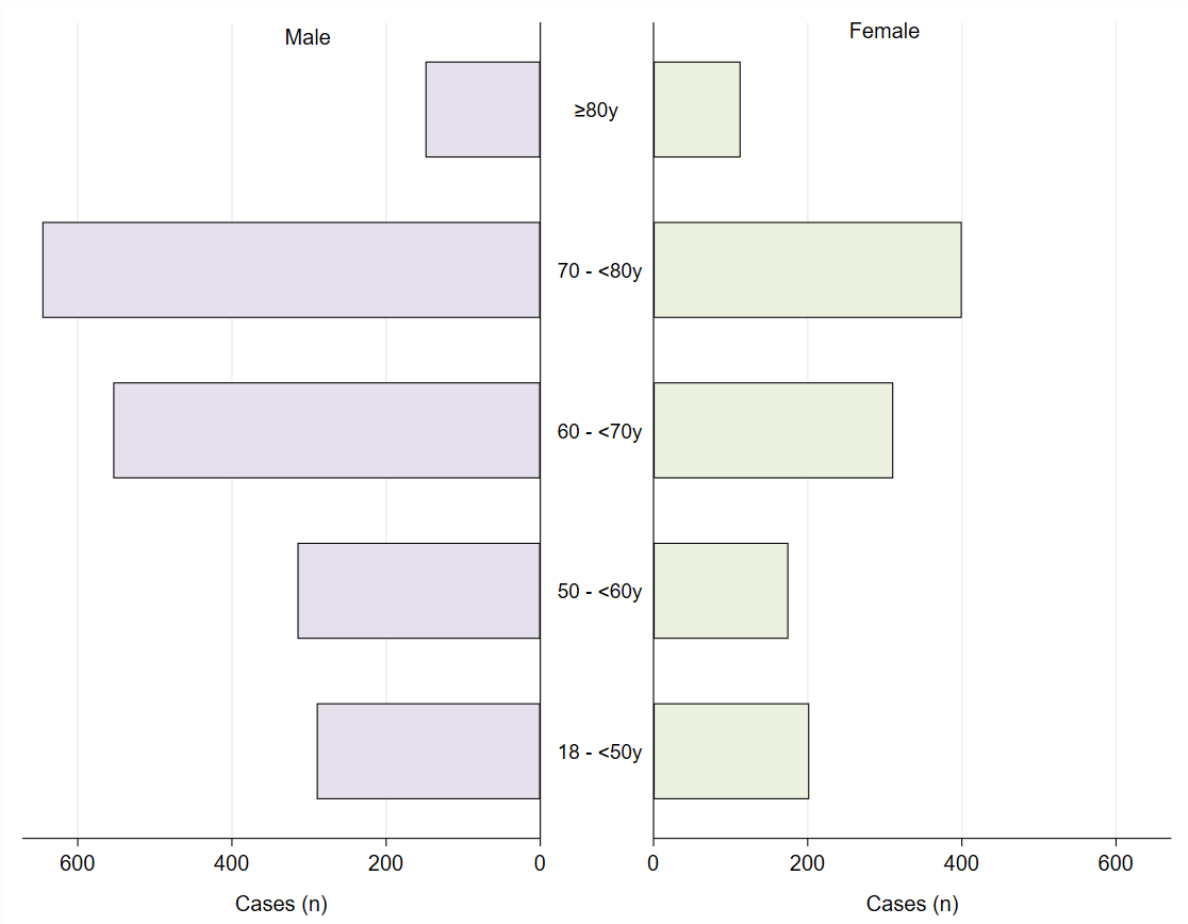


Table 24. Sex of isolated valve patients by year

	2017	2018	2019	2020	2021	Total
Male (%)	63.2	62.3	61.7	62.2	61.9	62.2
Female (%)	36.8	37.7	38.3	37.8	38.1	37.8

Figure 34. Age of isolated valve patients by sex, 2021



3.2 Previous cardiac surgery

Figure 35. Initial vs redo surgery in isolated valve patients by unit, 2021

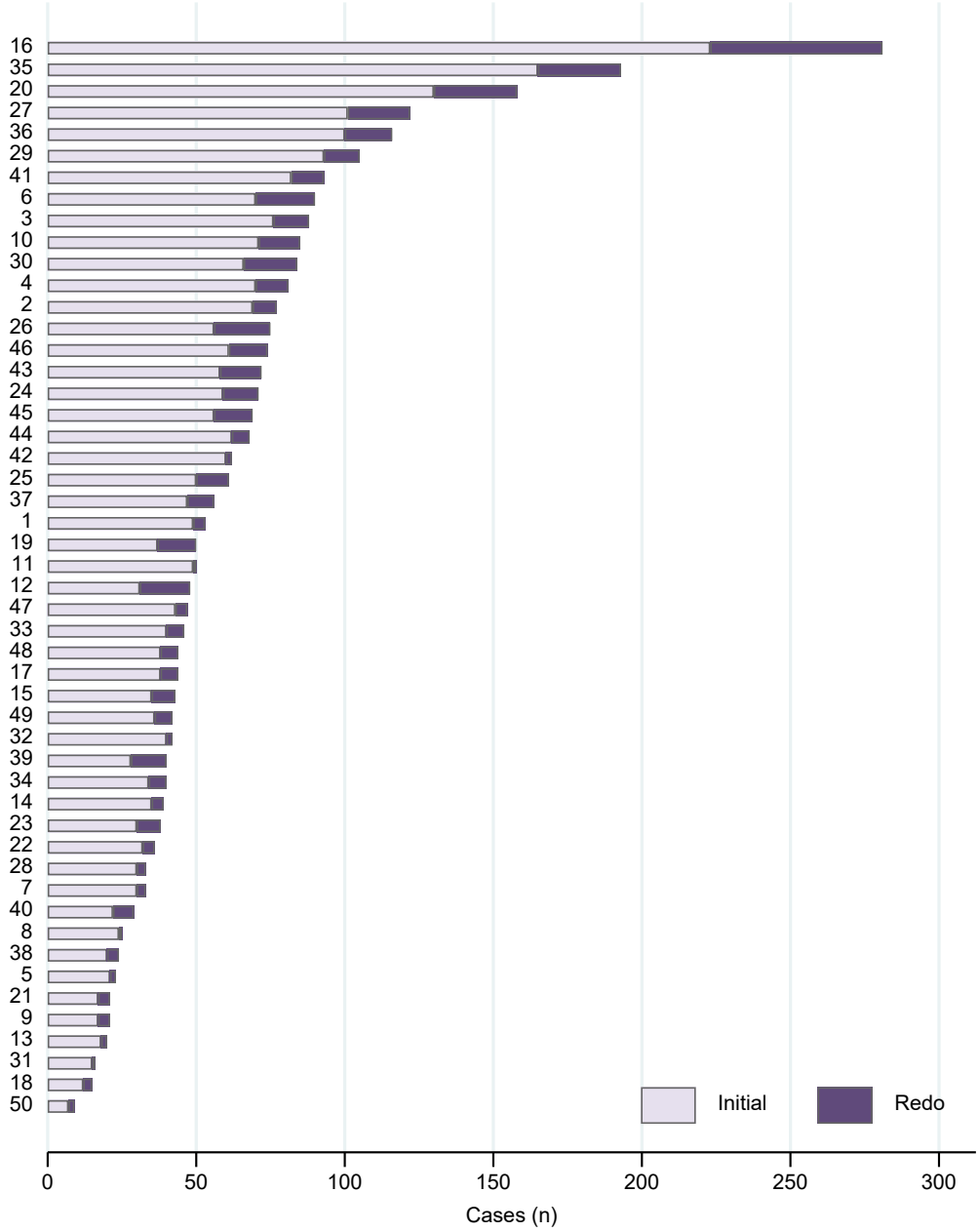
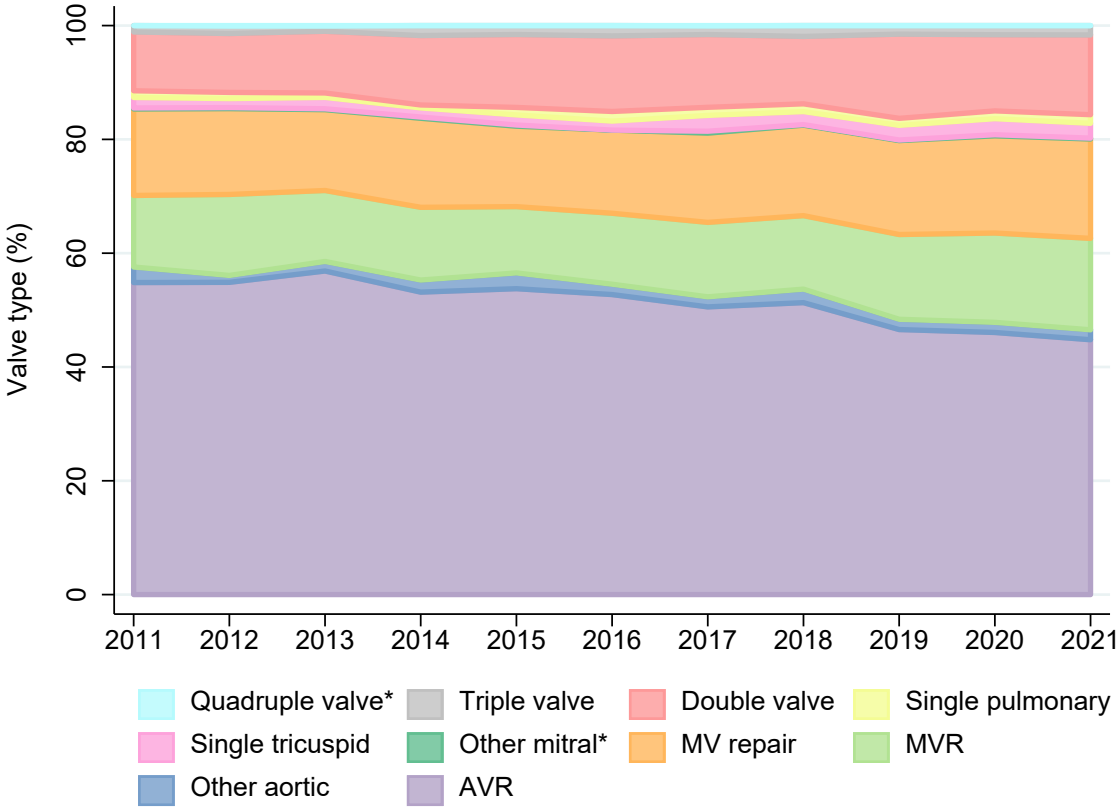


Table 25. Initial vs redo surgery in isolated valve patients by year

	2017	2018	2019	2020	2021	Total
Initial (%)	85.5	85.5	84.1	85.5	84.2	85.0
Redo (%)	14.5	14.5	15.9	14.5	15.8	15.0

3.3 Overview of all valve surgery

Figure 36. Isolated valve surgery by year, 2011 – 2021



* Not visible on figure as these categories represent a total of 47 out of 26,931 cases, combined, between 2011 and 2021

MV repair indicates mitral valve repair; MVR, mitral valve replacement; AVR, aortic valve replacement

Table 26. In-hospital mortality and total OM in isolated valve patients, 2021

	Total cases		In-hospital mortality		Total OM	
Valve surgery type	n	%	n	%	n	%
Single aortic	1,468	46.5	18	1.2	20	1.4
AVR	1,413	44.8	17	1.2	18	1.3
Other aortic	55	1.7	1	1.8	2	3.6
Single mitral	1,063	33.7	16	1.5	17	1.6
MVR	507	16.1	13	2.6	14	2.8
MV repair	551	17.5	3	0.5	3	0.5
Other mitral	5	0.2	0	0.0	0	0.0
Single tricuspid	82	2.6	0	0.0	0	0.0
Single pulmonary	48	1.5	0	0.0	0	0.0
Aortic and mitral	180	5.7	12	6.7	12	6.7
Mitral and tricuspid	233	7.4	4	1.7	4	1.7
Aortic and tricuspid	16	0.5	3	18.8	3	18.8
Other double valve	13	0.4	1	7.7	1	7.7
Triple valve	52	1.6	2	3.8	2	3.8
Quadruple valve	0	-	0	-	0	-
Total valve surgery	3,155	100	56	1.8	59	1.9

3.4 Single valve surgery

Figure 37. Types of isolated single valve surgery performed by unit, 2021

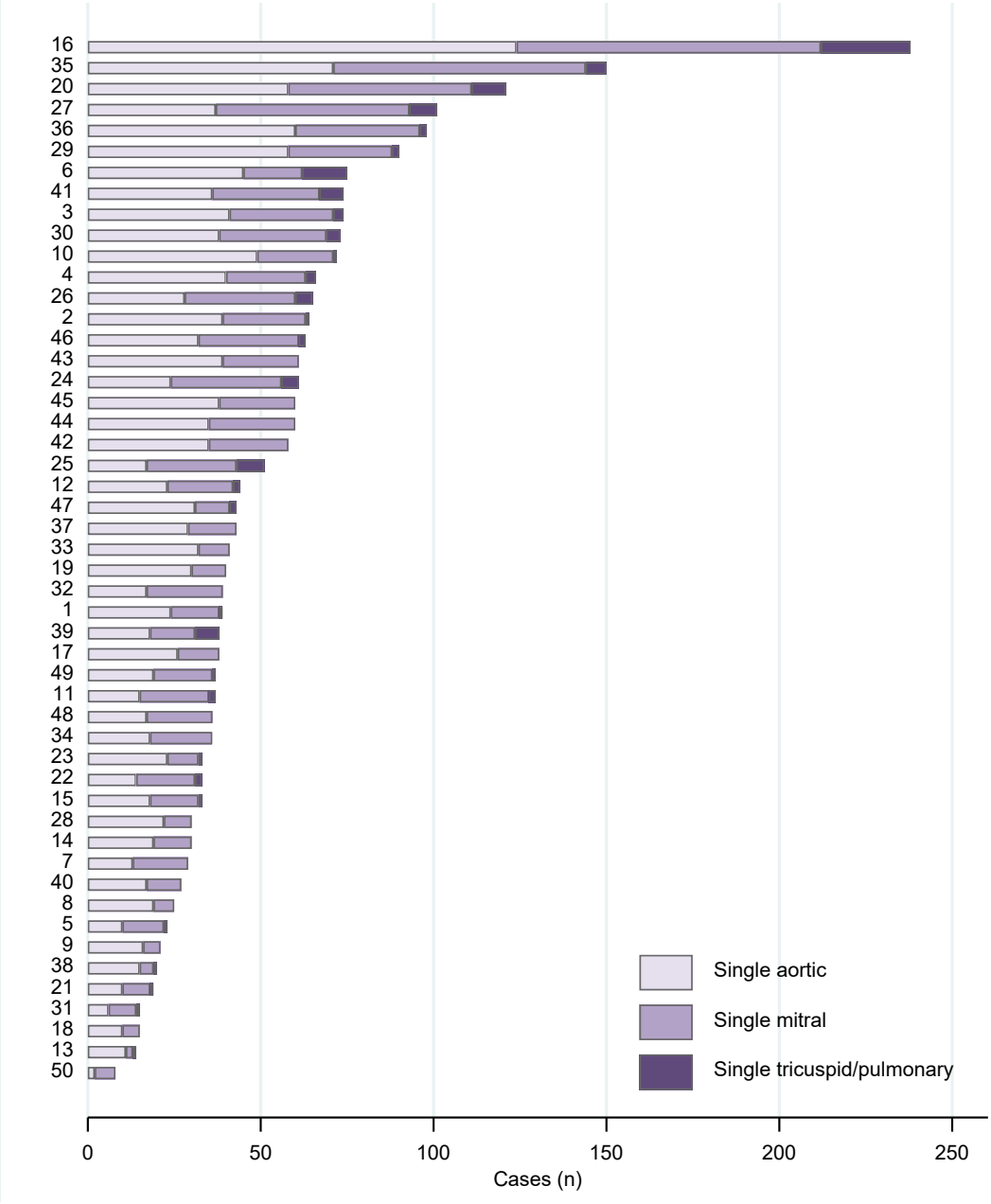
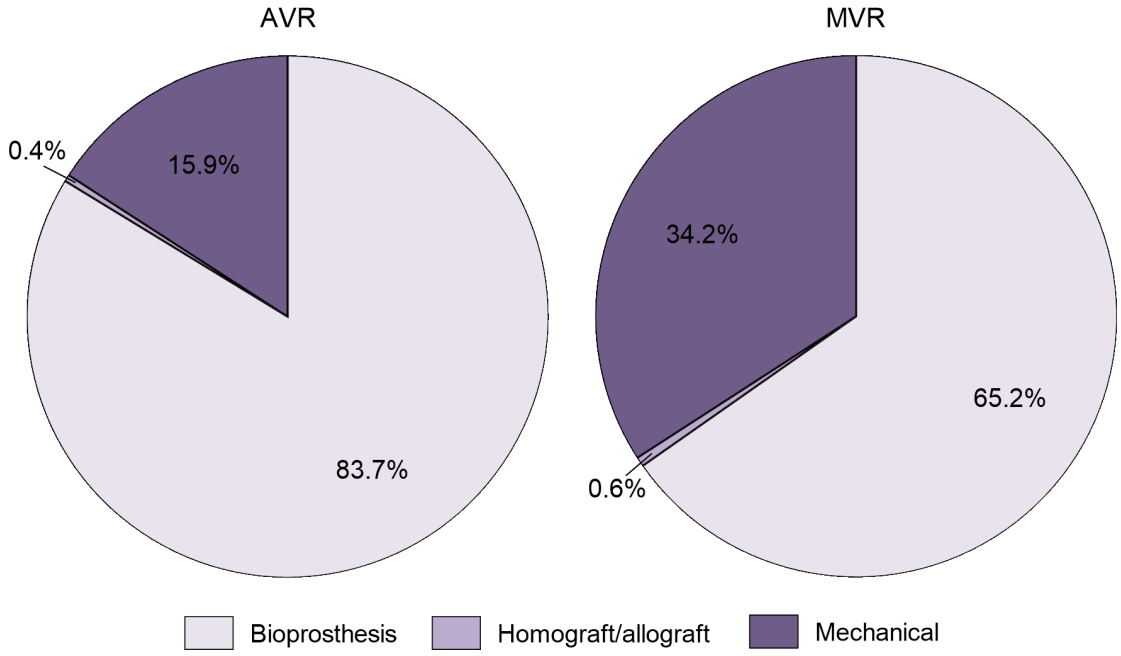


Table 27. Types of isolated single valve surgery performed by year

	2017	2018	2019	2020	2021	Total
Single aortic (%)	61.1	62.2	57.8	56.3	55.2	58.4
Single mitral (%)	34.0	33.6	37.6	38.8	39.9	36.9
Single tricuspid/pulmonary (%)	4.9	4.2	4.6	4.9	4.9	4.7

3.4.1 Prothesis types used

Figure 38. Prosthesis type used for single AVR/MVR surgery, 2021



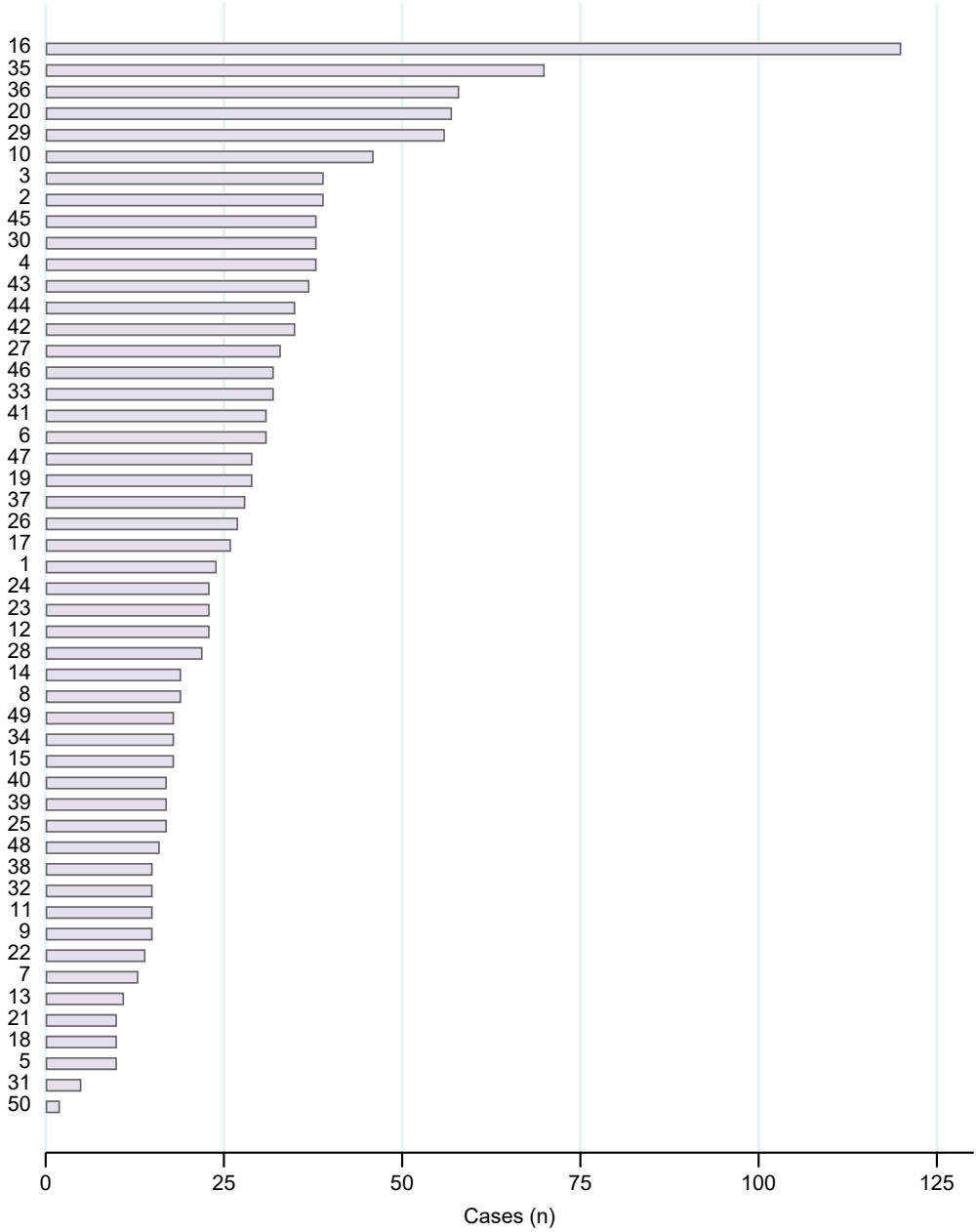
3.5 Influence of patient characteristics on operative mortality

Table 28. OM following the three most common isolated single valve surgeries, by patient demographics and risk factors, 2017 - 2021

	AVR		MVR		MV repair	
	n	OM (%)	n	OM (%)	n	OM (%)
Clinical status						
Elective	5,952	0.9	1,560	1.9	2,168	0.4
Urgent	1,066	2.8	522	4.6	281	1.1
Emergency/salvage	99	9.1	93	10.8	19	0.0
Sex/age						
Male	4,784	1.2	1,078	2.6	1,659	0.2
18 - <50y	487	0.4	190	2.1	336	0.0
50 - <60y	709	0.8	190	1.6	404	0.0
60 - <70y	1,411	0.9	264	3.0	476	0.2
70 - <80y	1,745	1.1	337	2.7	367	0.3
≥80y	432	3.9	97	4.1	76	1.3
Female	2,333	1.6	1,097	3.2	809	1.0
18 - <50y	166	1.8	252	1.6	153	0.0
50 - <60y	277	0.7	166	3.0	166	0.6
60 - <70y	679	0.9	232	3.4	218	0.9
70 - <80y	939	2.0	318	5.0	218	1.4
≥80y	272	2.6	129	1.6	54	3.7
LVF						
EF>45%	6,152	1.1	1,880	2.9	2,301	0.5
EF≥30% - ≤45%	654	2.4	234	2.1	127	0.0
EF<30%	194	4.1	27	7.4	7	0.0
Previous MI						
No MI	6,600	1.3	1,999	2.6	2,408	0.4
NSTEMI	338	2.1	91	5.5	29	3.4
STEMI	71	1.4	58	12.1	14	0.0
Unknown type	108	2.8	26	0.0	16	0.0
Previous surgery						
Initial	6,339	1.1	1,676	2.4	2,396	0.5
Redo	778	2.8	499	4.6	72	0.0
Dialysis						
No	7,028	1.2	2,128	2.7	2,457	0.4
Yes	89	11.2	46	10.9	11	0.0
Pre-operative creatinine						
≤200 µmol/L	6,939	1.2	2,091	2.7	2,450	0.4
>200 µmol/L	178	7.3	81	8.6	18	5.6

3.6 Aortic valve replacement

Figure 39. Isolated AVR surgery by unit, 2021



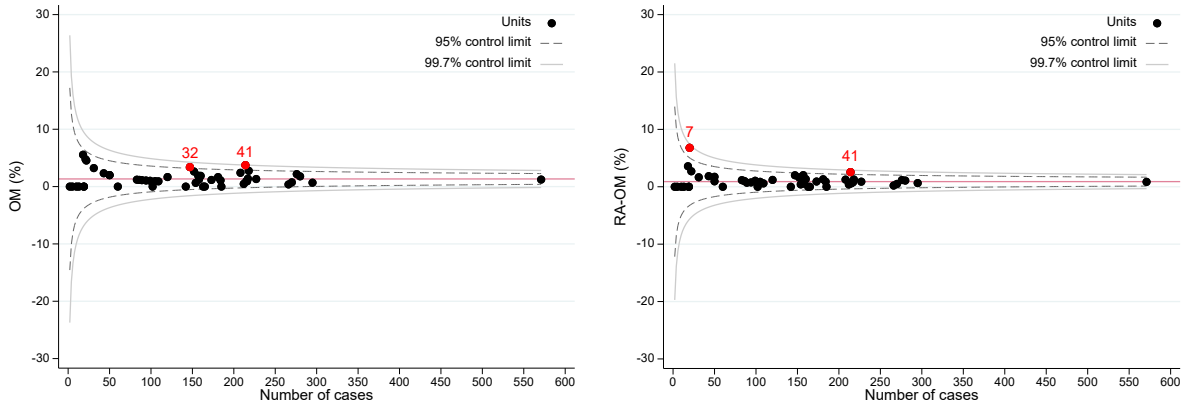
3.6.1 Unit outcomes – mortality, complications and resource utilisation

The data reported in Figures 40-42c have been tabulated in Appendix F (Table F3, pg. 94).

3.6.1.1 Operative mortality

Figure 40. OM following isolated AVR surgery 2017 – 2021, by unit

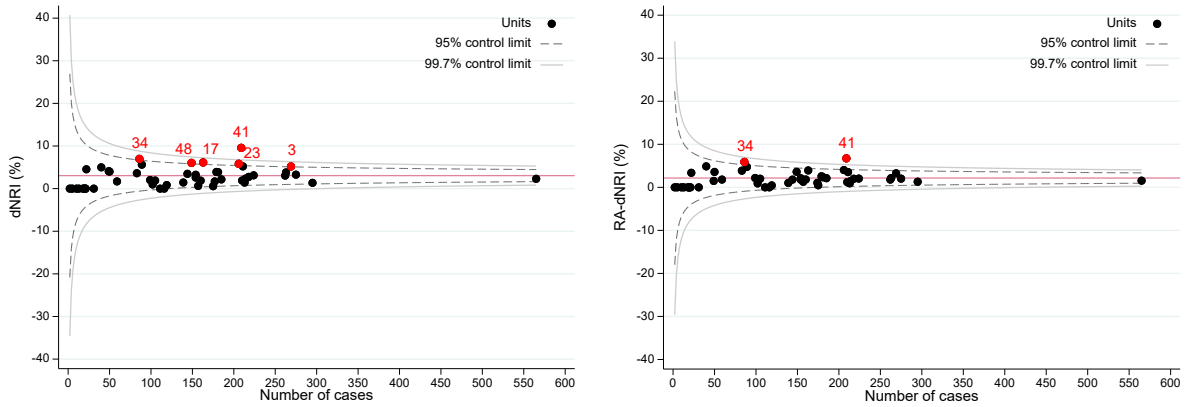
a. OM b. RA-OM



3.6.1.2 Complications

Figure 41. dNRI following isolated AVR surgery 2017 – 2021, by unit

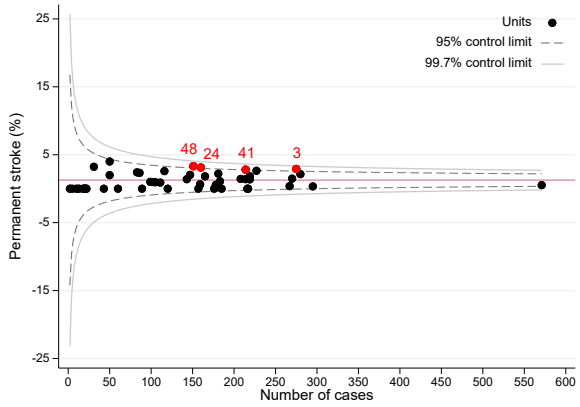
a. dNRI b. RA-dNRI



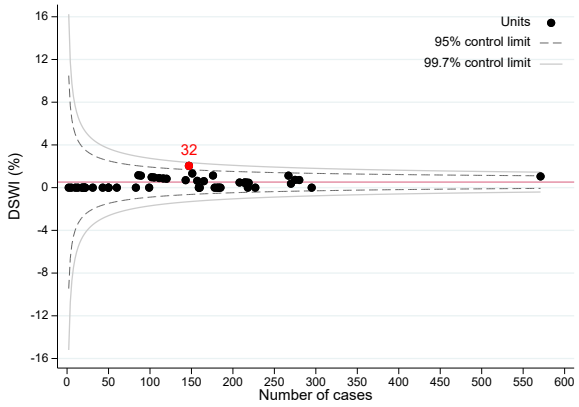
dNRI indicates derived new renal insufficiency.

Figure 42. Complications following isolated AVR surgery 2017 – 2021, by unit

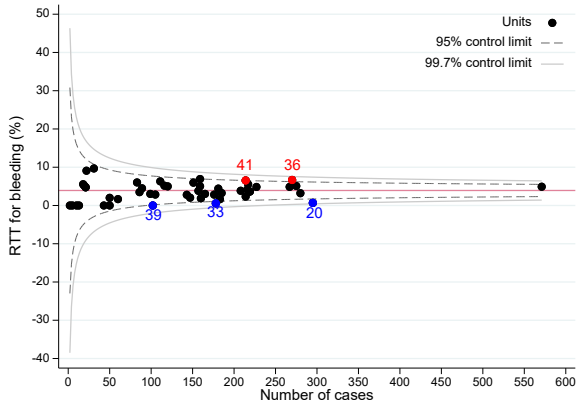
a. Permanent stroke



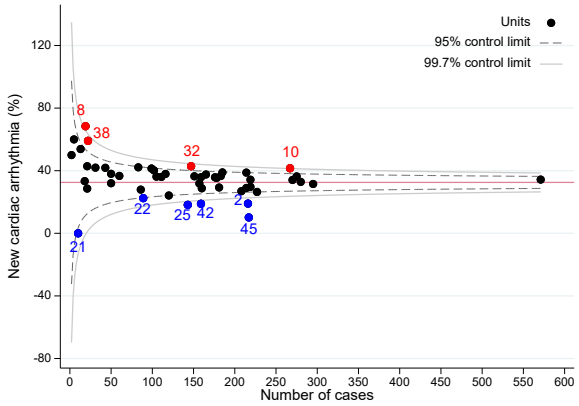
b. DSWI



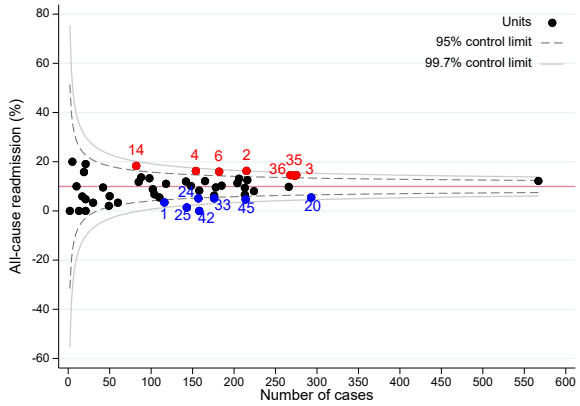
c. RTT for bleeding



d. New cardiac arrythmia



e. All-cause readmission



3.6.1.3 Resource utilisation

Figure 43. Distribution of pre-operative LOS for isolated AVR patients, 2021

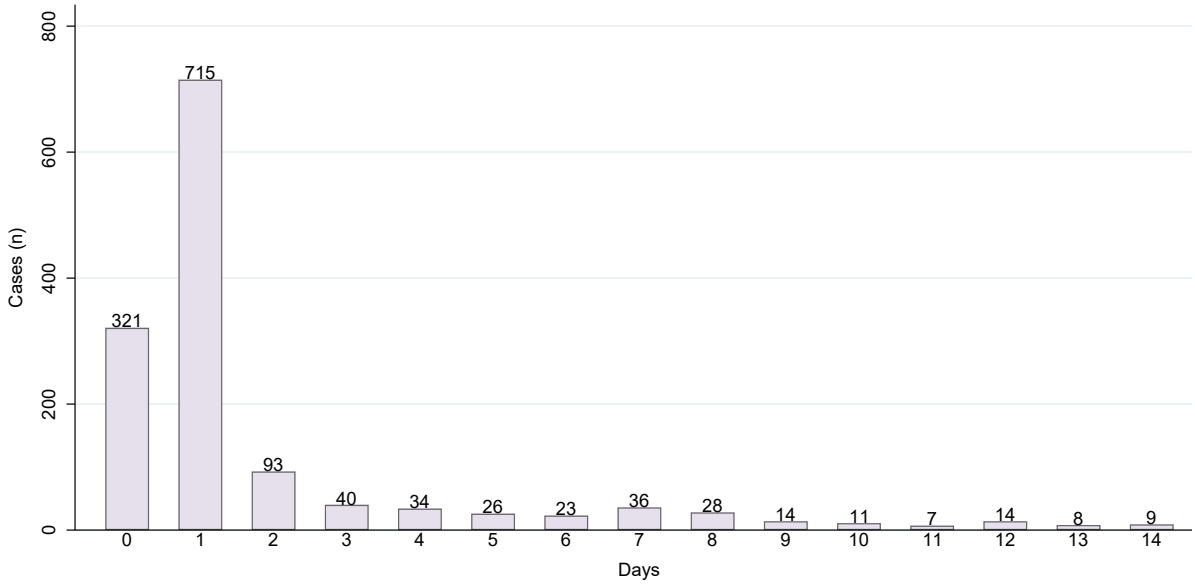


Table 29. Summary of pre-operative LOS for public and private isolated AVR patients, 2021

	Mean (d)	Median (d)	IQR (d)
Public	2.0	1	0 - 2
Private	1.7	1	1 - 1
Total	1.9	1	1 - 1

Cases with a pre-operative LOS of more than 14 days were classified as clinical outliers and excluded from the analysis.

Figure 44. Distribution of post-operative LOS for isolated AVR patients, 2021

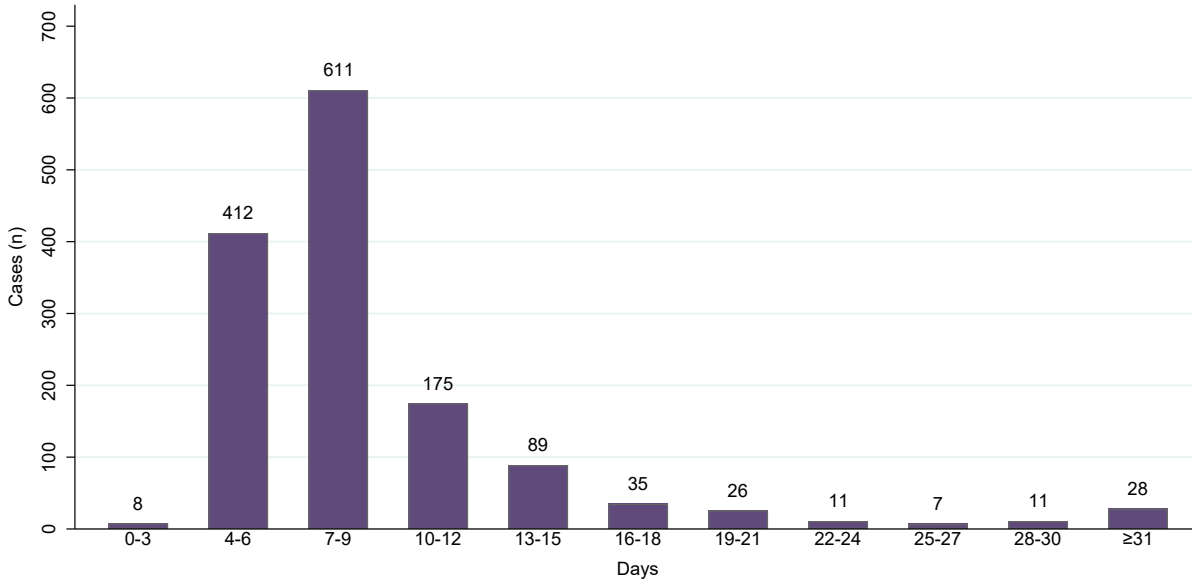


Table 30. Summary of post-operative LOS for public and private isolated AVR patients, 2021

	Mean (d)	Median (d)	IQR (d)
Public	9.4	7	6 - 10
Private	9.0	8	7 - 10
Total	9.3	7	6 - 10

Cases with a post-operative LOS of more than 30 days were classified as clinical outliers and excluded from the analysis.

Figure 45. Distribution of initial post-operative ventilation time for isolated AVR patients, 2021

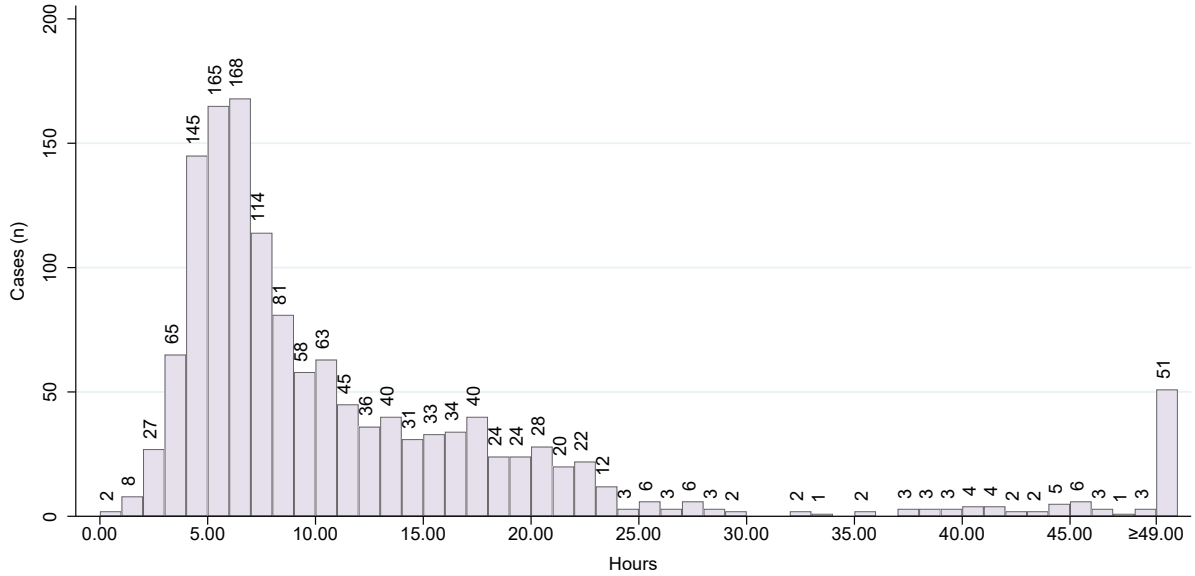


Table 31. Cumulative proportion of patients extubated by hour up to 28 days for isolated AVR surgery, 2021

	6h	12h	24h	48h	96h	192h	384h	672h
Cumulative patients (n)	433	946	1,285	1,349	1,382	1,397	1,402	1,403
Cumulative percentage (%)	30.9	67.4	91.6	96.2	98.5	99.6	99.9	100.0

Table 32. Summary of initial post-operative ventilation time for public and private isolated AVR patients, 2021

	Mean (h)	Median (h)	IQR (h)
Public	15.9	8.0	5.6 - 15.0
Private	12.6	8.2	5.6 - 15.3
Total	14.7	8.0	5.6 - 15.0

Cases with a ventilation time of more than four weeks were classified as clinical outliers and excluded from the analysis.

Figure 46. Distribution of ICU length of stay for isolated AVR patients, 2021

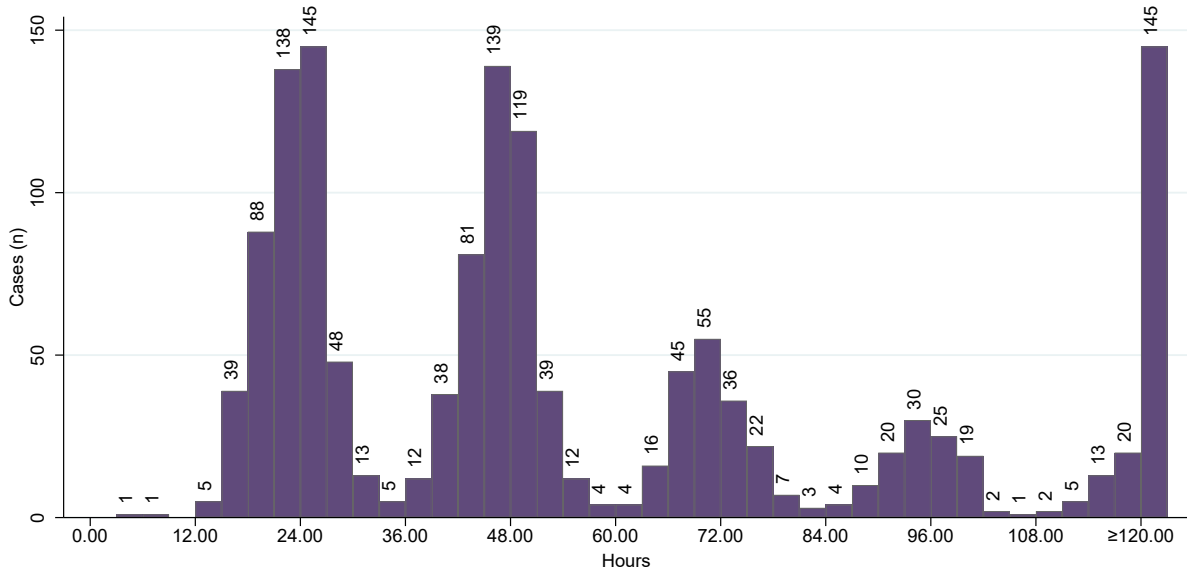


Table 33. Cumulative proportion of patients discharged from ICU by hour up to 42 days for isolated AVR surgery, 2021

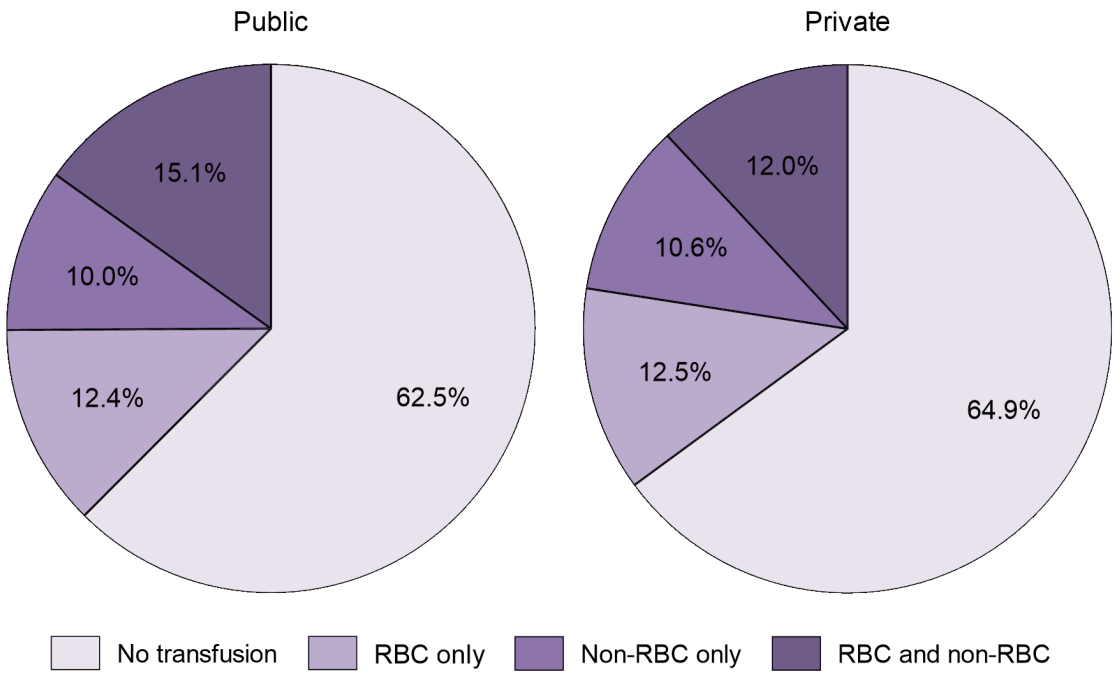
	12h	24h	48h	72h	144h	288h	576h	1008h
Cumulative patients (n)	2	278	758	1,049	1,327	1,390	1,409	1,411
Cumulative percentage (%)	0.1	19.7	53.7	74.3	94.0	98.5	99.9	100.0

Table 34. Summary of ICU length of stay for public and private isolated AVR patients, 2021

	Mean (h)	Median (h)	IQR (h)
Public	59.1	40.7	23.6 - 70.7
Private	68.4	50.0	45.4 - 75.5
Total	62.5	47.0	25.4 - 72.6

Cases with an ICU length of stay of more than six weeks hours were classified as clinical outliers and excluded from the analysis.

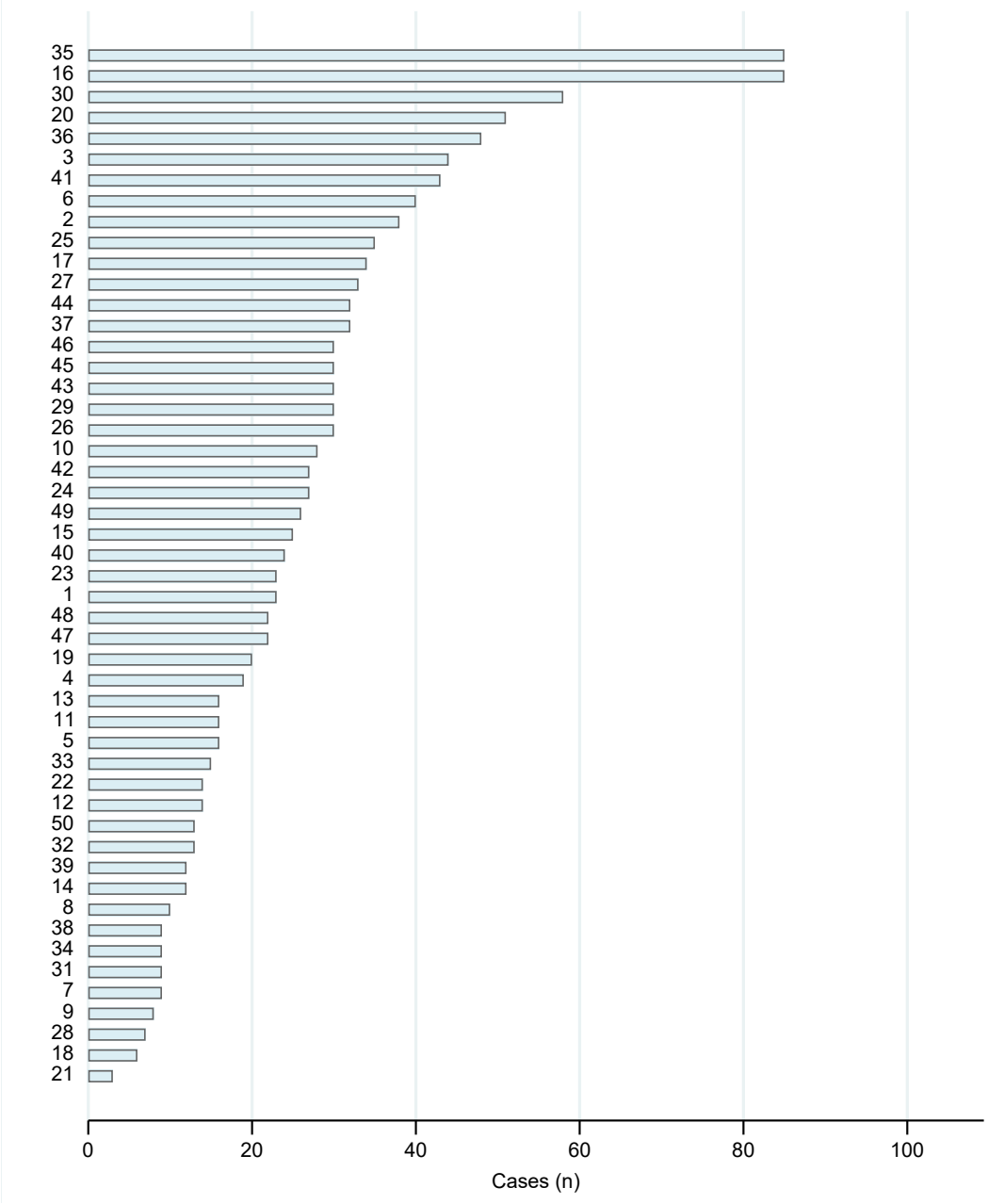
Figure 47. Blood product usage at public and private hospitals for isolated AVR patients, 2021



Note: non-RBC consists of platelets, NovoSeven, cryoprecipitate and FFP

4. Combined Valve and CABG Surgery

Figure 48. Combined valve and CABG cases by unit, 2021



Summary of valve and CABG activity

All valve and CABG procedures: Type and mortality

The most common type of valve and CABG surgery in the last ten years has been AVR and CABG, despite a decrease of approximately 5.5% since 2011. In 2021, the second and third most frequent procedures were MV repair and CABG, followed by MVR and CABG, which each accounted for approximately 12.5% of cases (Figure 56). In-hospital mortality and OM for all valve and CABG patients were 3.4 and 3.8%, respectively, in 2021 (Table 41).

Single valve procedures: Valve choice and mortality

A higher proportion of bioprostheses was used for both AVR and CABG (93.9%) and MVR and CABG (77.8%), compared to isolated valve surgery (Figure 58). The remaining procedures used mechanical valves, except for the 0.1% of AVR and CABG cases that used a homo- or allo-graft.

For the three most common valve and CABG procedures (AVR, MVR and MV repair), higher incidences of OM were observed for urgent and emergency/salvage procedures. OM was also generally higher for patients with lower ejection fraction, having redo surgery or dialysis, or with a high pre-operative creatinine (>200 µmol/L), compared their counterparts (Table 43).

AVR with CABG: Case volume and outcomes

Despite AVR with CABG being the most common valve + CABG procedure, more than 70% of participating units had a case volume of 20 or less procedures in 2021 (Figure 59).

Patients with markers of pre-operative renal dysfunction or diabetes generally had higher incidences of permanent stroke, DSWI and RTT for bleeding (Table 44). As would be expected, these patients also had a higher post-operative incidence of dNRI, as did patients having redo surgery (Table 46 and Table 47). There was increasing incidence of new cardiac arrythmias with increasing age, but age did not show any trends with permanent stroke, DSWI or RTT for bleeding or dNRI (Table 45 and Table 47).

The majority of units performed comparably in 2021, and units with outcomes outside the 99.7% control limit on funnel plot analyses were engaged by the ANZSCTS Database Steering Committee, in line with the Special Cause Variation Management Policy. Data for the last five years was pooled to provide sufficient case numbers for analysis of outcomes.

The OM for AVR and CABG patients was 2.6% in 2017-21 (Figure 60a), which is lower than the OM reported by the STS for 2020 (3.6%) and in-hospital mortality reported by the registry of the German Society for Thoracic and Cardiovascular Surgery (5.0%) (2, 4). The risk-adjusted OM calculated using the Database's ANZSCORE model was 2.2% for 2017-21 (Figure 60b) The incidences of the other key performance indicators were dNRI (5.1%), risk-adjusted dNRI (2.2%), permanent stroke (1.9%), DSWI (1.1%) and RTT for bleeding (4.8%; Figure 61 and Figure 62).

Resource utilisation

Most patients (64.6%) were admitted the day before or day of their surgery, and the median pre-PLOS was one day at public and private hospitals (Figure 63 and Table 48). The majority of patients (58.9%) were discharged less than ten days following their surgery, with a median post-PLOS at public and private hospitals of nine days (Figure 64 and Table 49).

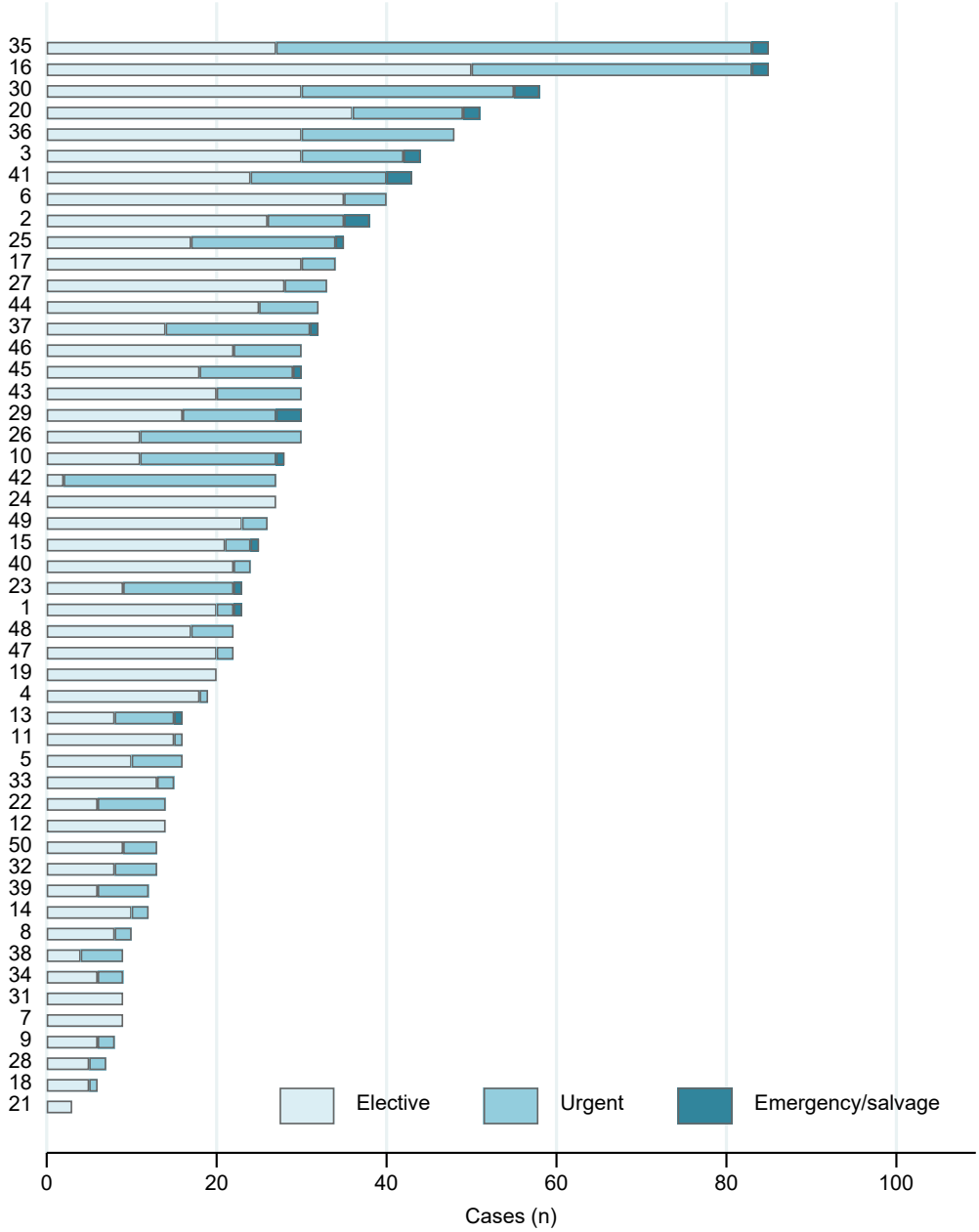
One patient out of every ten was ventilated for more than 48 hours and patients at public hospitals had a higher mean duration of ventilation (27.1 hours), compared to private hospitals (16.4 hours; Table 50 and Table 51). As was also seen with the other major procedure types, ICU length of stay showed a cyclical pattern with patients often discharged at 24-hour intervals (Figure 66). Only 40.3% of patients were discharged in less than 48 hours and the mean length of stay was similar between public (84.7 hours) and private (81.7 hours) hospitals (Table 52 and Table 53).

There was increased use of blood transfusions for AVR and CABG patients at public hospitals (62.5%), compared to private hospitals (47.8%), with the most common type of transfusion including both RBC and non-RBC products (Figure 67).

4.1 Patient characteristics

4.1.1 Clinical status

Figure 49. Clinical status of combined valve and CABG patients by unit, 2021



It should be noted that clinical status is a reported variable, therefore variation can occur due to the interpretation of the Database's data definition (Appendix C, pg. 88).

Table 35. Clinical status of combined valve and CABG patients by year

	2017	2018	2019	2020	2021	Total
Elective (%)	75.4	77.4	72.0	68.3	65.4	71.6
Urgent (%)	22.8	21.1	24.9	30.0	32.5	26.4
Emergency/salvage (%)	1.8	1.5	3.1	1.8	2.2	2.1

4.4.2 Sex and age

Figure 50. Sex of combined valve and CABG patients by unit, 2021

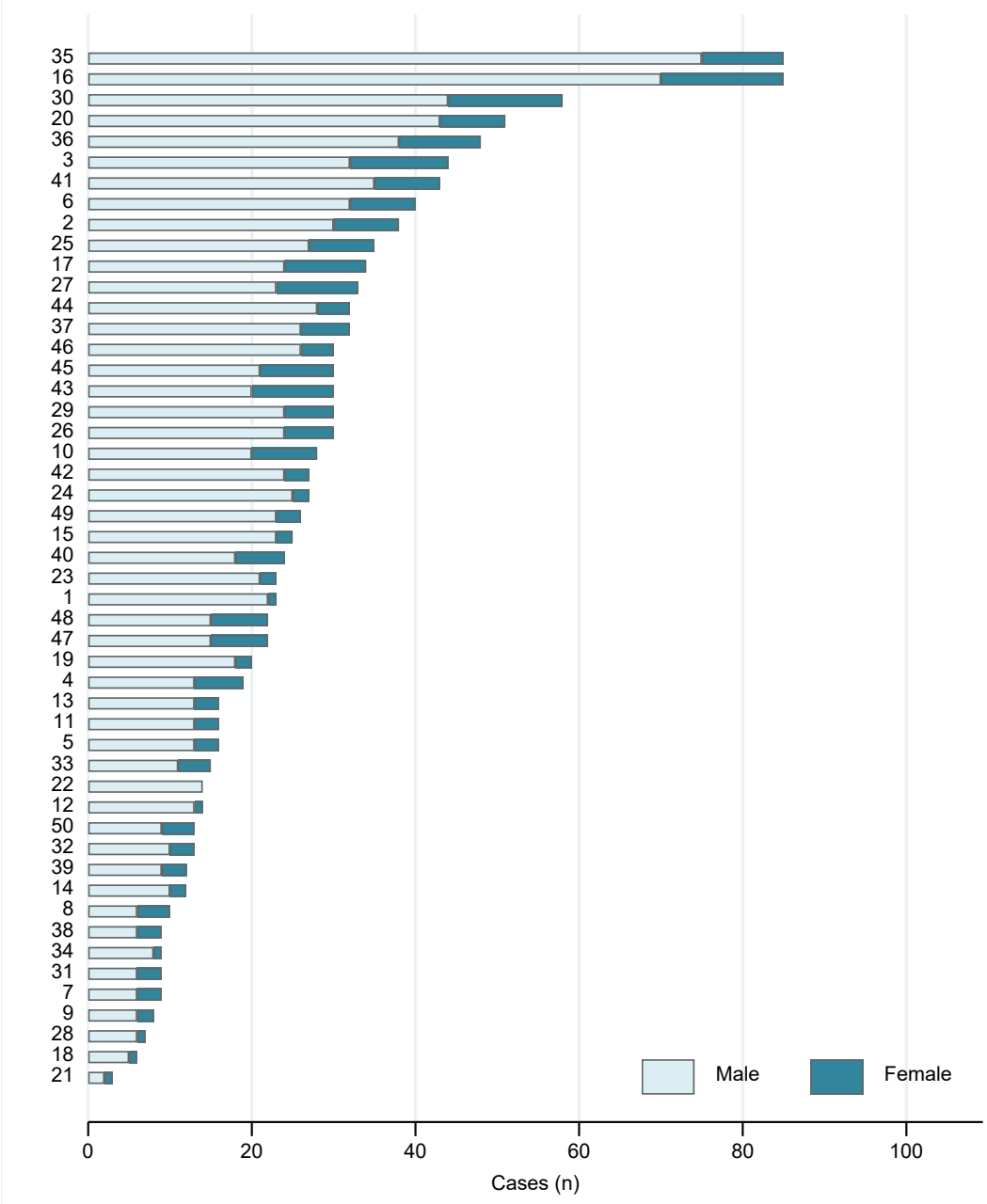
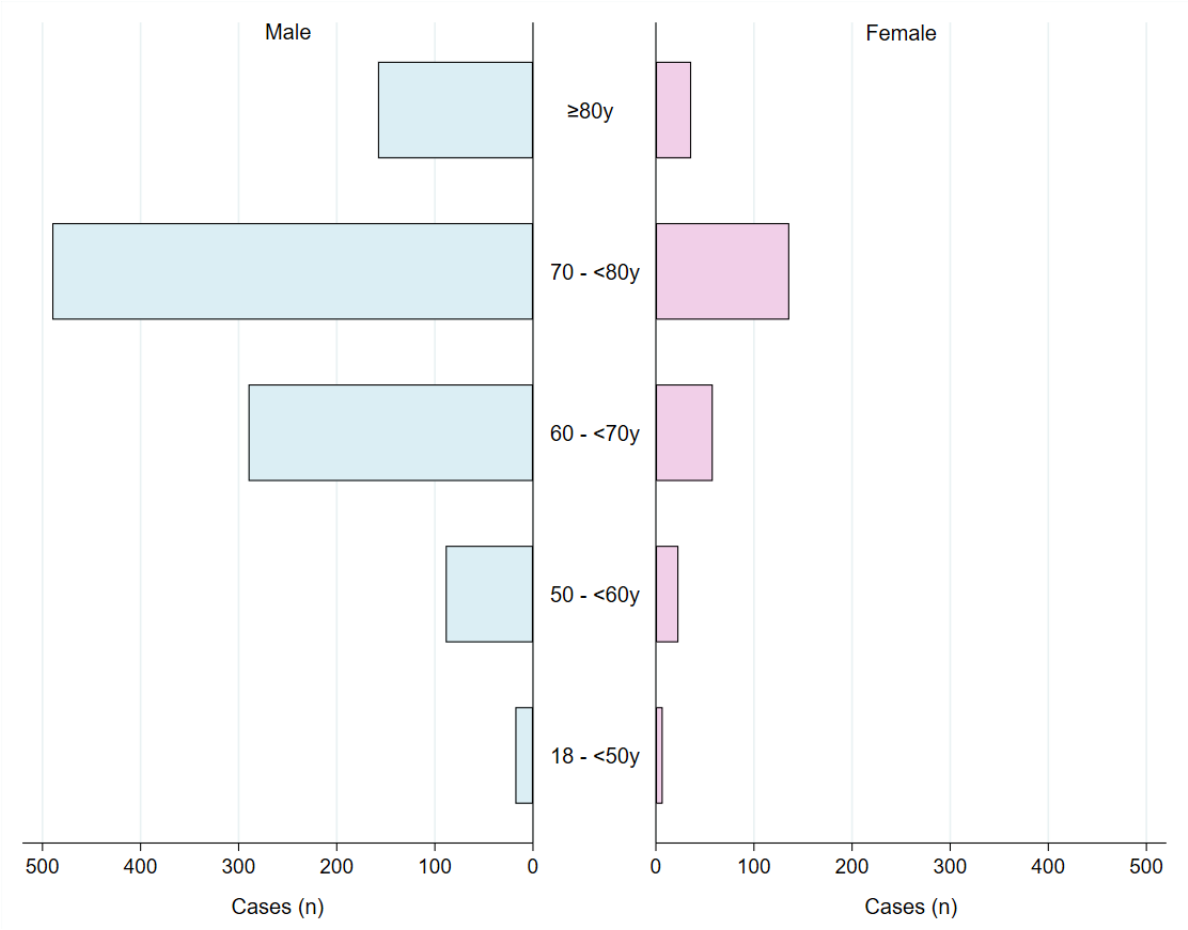


Table 36. Sex of combined valve and CABG patients by year

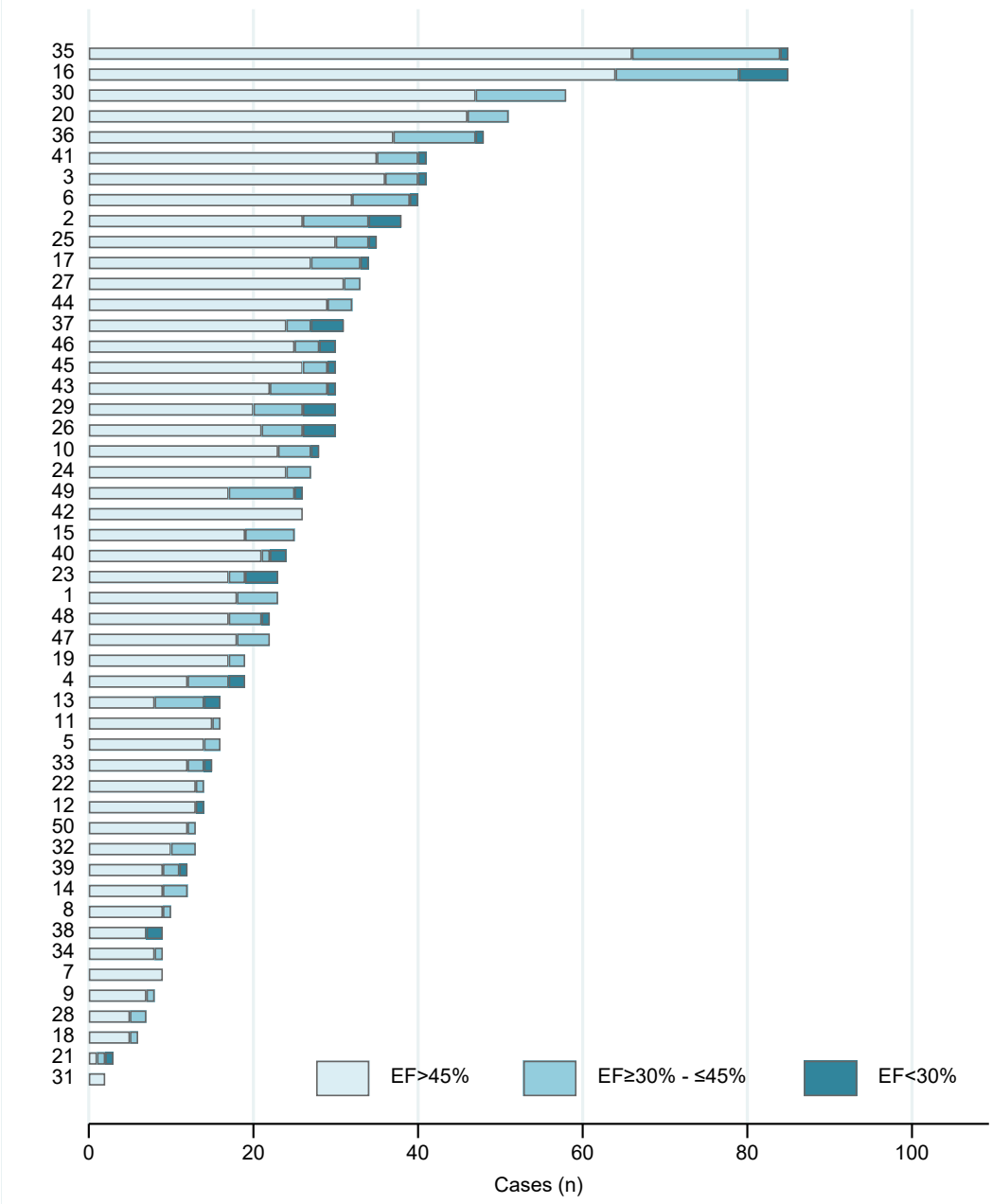
	2017	2018	2019	2020	2021	Total
Male (%)	77.8	80.0	81.4	80.7	80.1	80.0
Female (%)	22.2	20.0	18.6	19.3	19.9	20.0

Figure 51. Age of combined valve and CABG patients by sex, 2021



4.1.3 Left ventricular function

Figure 52. Pre-operative LVF of combined valve and CABG patients by unit, 2021



The ANZSCTS Database classifies an EF>45% as normal or mildly reduced, an EF≥30% - ≤45% as moderately reduced and an EF<30% as severely reduced LVF, respectively (Appendix C, pg. 88).

Table 37. Pre-operative LVF of combined valve and CABG patients by year

	2017	2018	2019	2020	2021	Total
EF>45% (%)	80.8	80.1	79.8	79.7	80.7	80.2
EF≥30% - ≤45% (%)	14.4	15.4	16.4	15.9	15.3	15.5
EF<30% (%)	4.8	4.5	3.8	4.4	4.0	4.3

4.1.4 Previous myocardial infarction

Figure 53. Previous MI in combined valve and CABG patients by unit, 2021

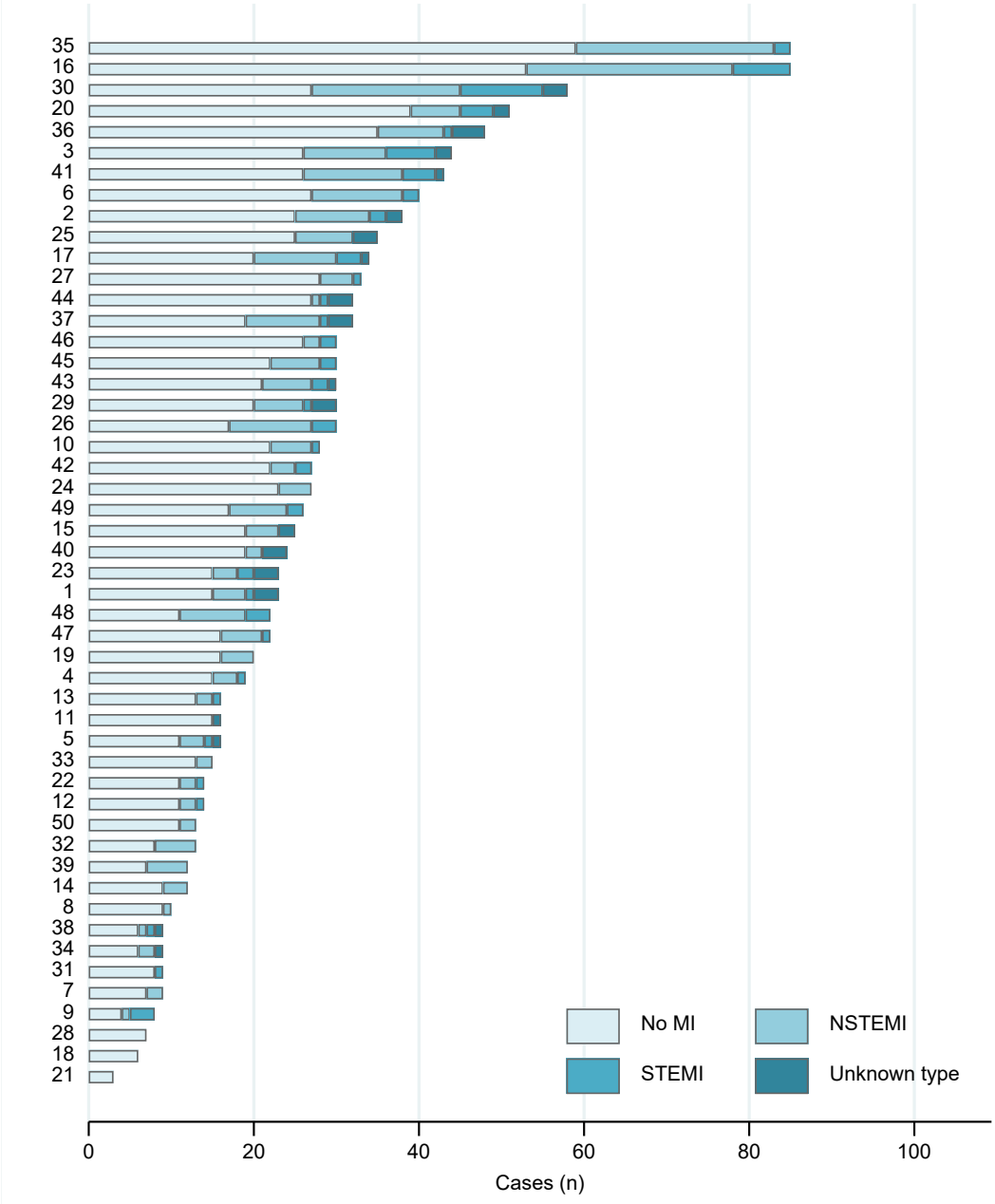


Table 38. Previous MI in combined valve and CABG patients by year

	2017	2018	2019	2020	2021	Total
No MI (%)	69.2	70.8	73.1	71.5	70.3	71.0
NSTEMI (%)	22.0	19.6	19.7	21.2	20.6	20.6
STEMI (%)	4.7	5.7	3.7	3.8	5.8	4.7
Unknown type (%)	4.1	4.0	3.5	3.5	3.3	3.7

4.1.5 Timing of previous myocardial infarction

Figure 54. Timing of previous MI in combined valve and CABG patients by unit, 2021

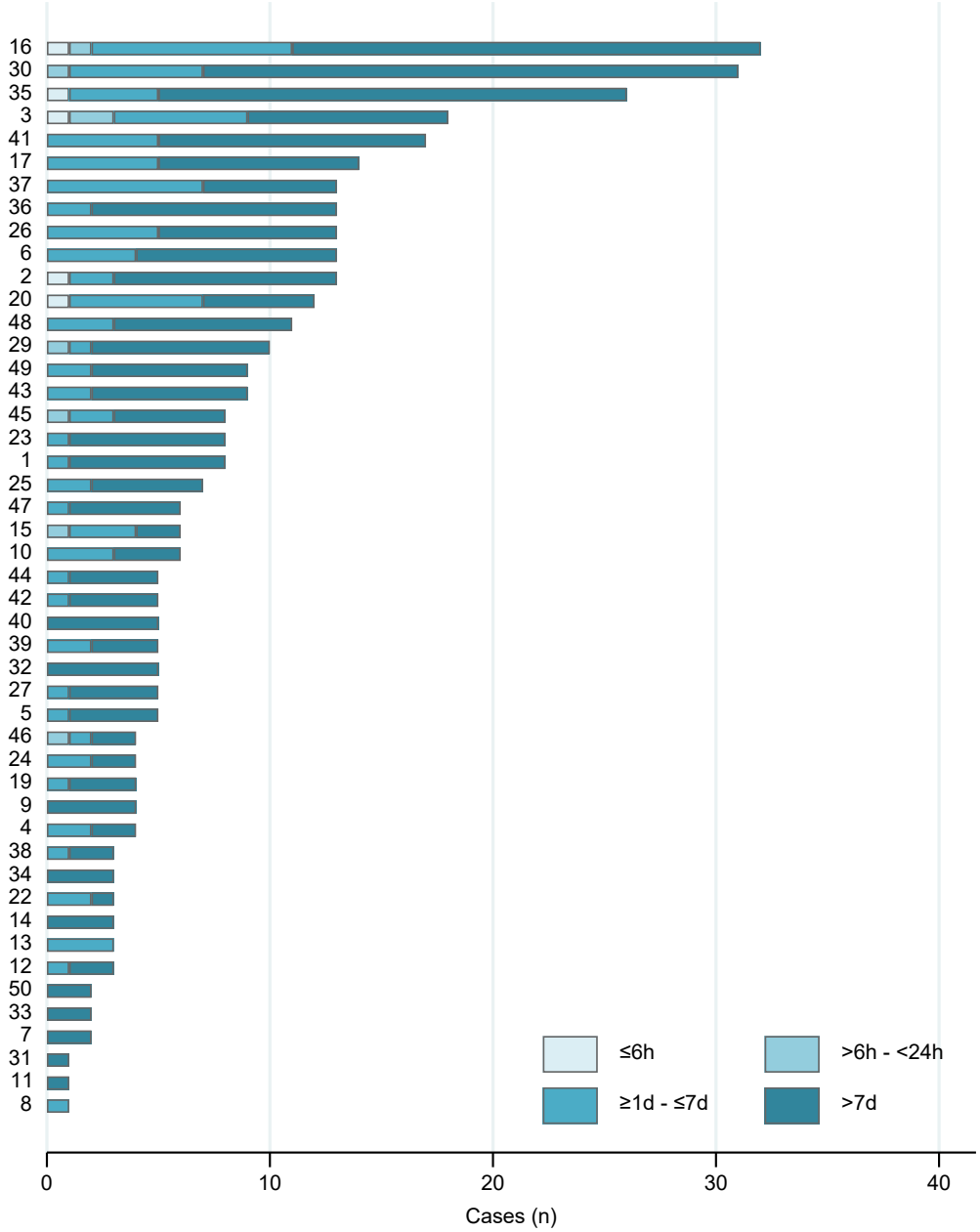


Table 39. Timing of previous MI in combined valve and CABG patients by year

	2017	2018	2019	2020	2021	Total
≤6hr (%)	0.3	0.9	1.2	0.6	1.3	0.8
>6hr - <24hr (%)	1.6	1.7	0.9	1.4	2.1	1.5
≥1d - ≤7d (%)	16.8	19.9	22.1	24.1	26.5	21.9
>7d (%)	81.4	77.5	75.8	73.9	70.1	75.7

4.2 Previous cardiac surgery

Figure 55. Initial vs redo surgery in combined valve and CABG patients by unit, 2021

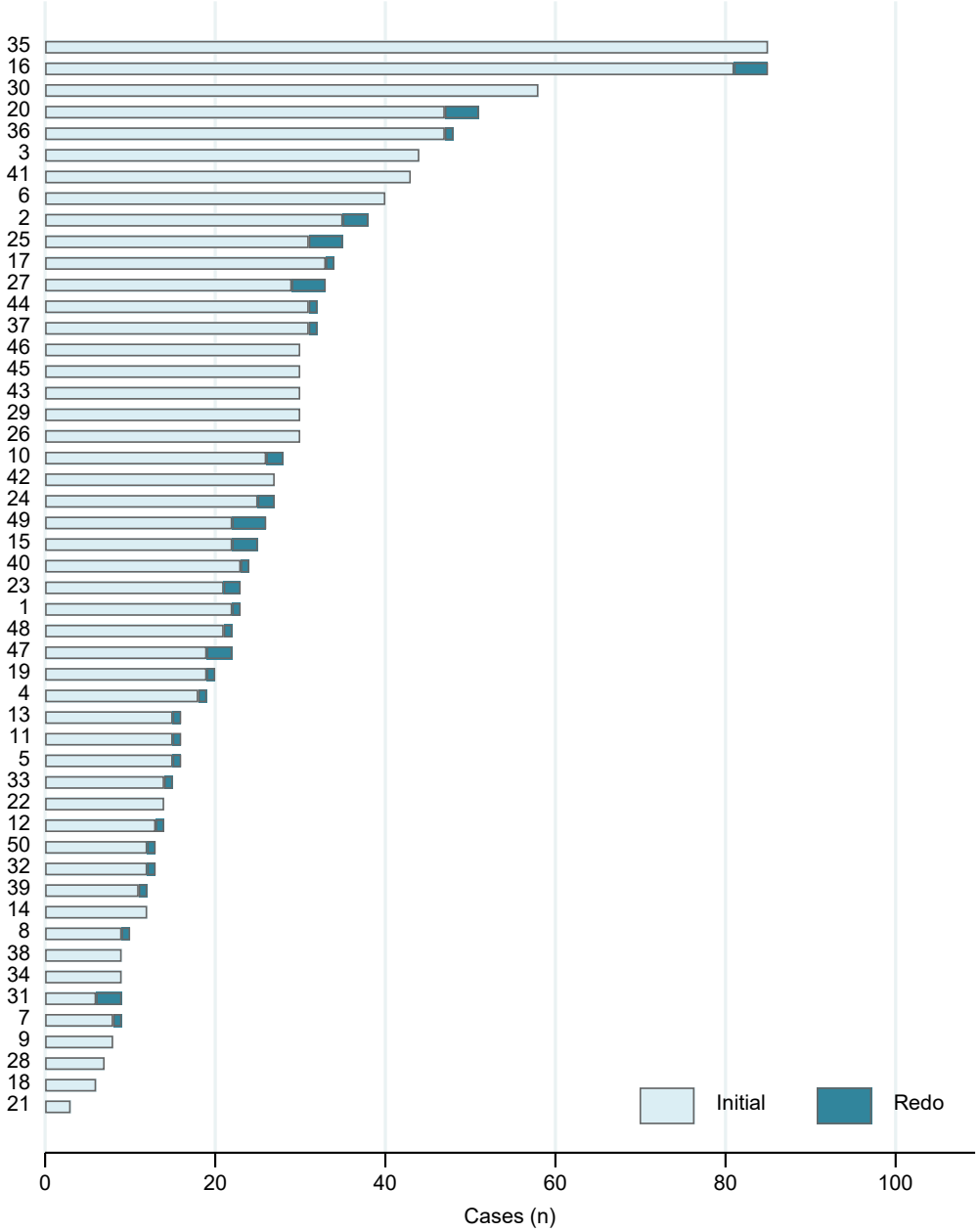
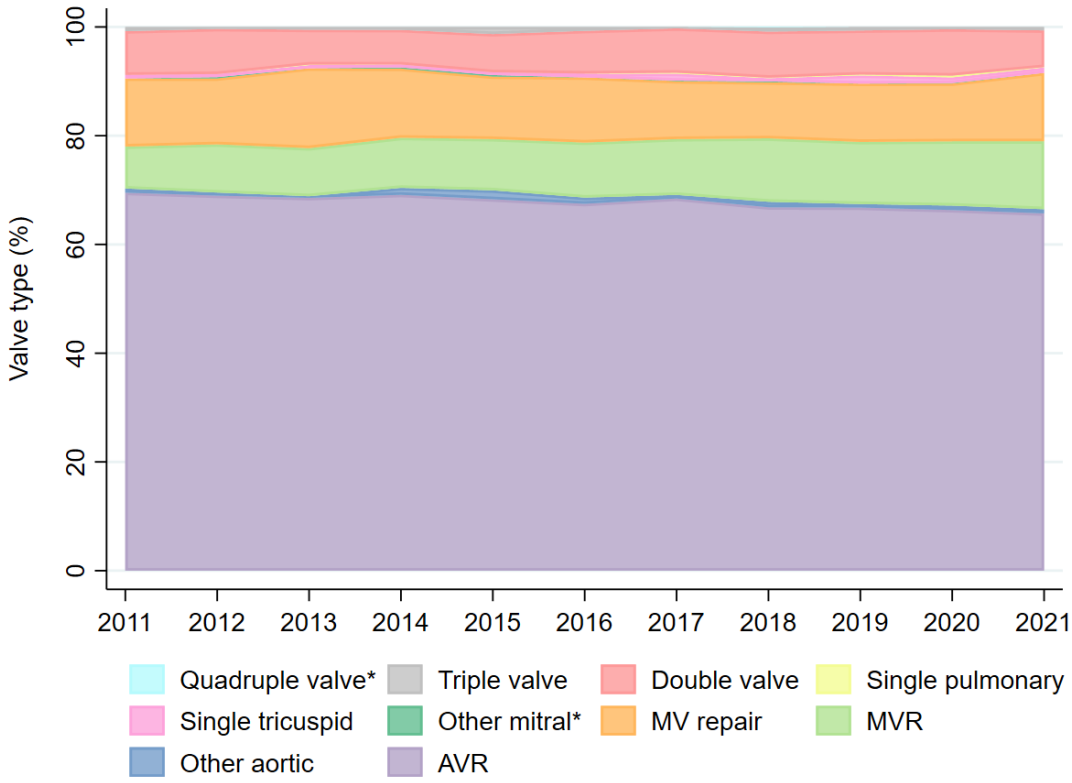


Table 40. Initial vs redo surgery in combined valve and CABG patients by year

	2017	2018	2019	2020	2021	Total
Initial (%)	94.1	95.0	95.5	94.5	95.6	95.0
Redo (%)	5.9	5.0	4.5	5.5	4.4	5.0

4.3 Overview of all valve combined with CABG surgery

Figure 56. Combined valve and CABG surgery by year, 2011 – 2021



*Not visible on figure as these categories represent a total of 12 out of 12,333 cases, combined, between 2011 and 2021

Table 41. In-hospital mortality and total OM in combined valve and CABG patients, 2021

	Total cases		In-hospital mortality		Total OM	
Valve surgery type	n	%	n	%	n	%
Single aortic	867	66.4	17	2.0	21	2.4
AVR	857	65.7	16	1.9	20	2.3
Other aortic	10	0.8	1	10.0	1	10.0
Single mitral	328	25.1	21	6.4	22	6.7
MVR	163	12.5	12	7.4	12	7.4
MV repair	164	12.6	8	4.9	9	5.5
Other mitral	1	0.1	1	100	1	100
Single tricuspid	13	1.0	0	0.0	0	0.0
Single pulmonary	1	0.1	0	0.0	0	0.0
Aortic and mitral	50	3.8	3	6.0	3	6.0
Mitral and tricuspid	31	2.4	1	3.2	1	3.2
Aortic and tricuspid	6	0.5	1	16.7	1	16.7
Other double valve	1	0.1	0	0.0	0	0.0
Triple valve	8	0.6	1	12.5	2	25.0
Quadruple valve	0	-	0	-	0	-
Total valve surgery	1,305	100	44	3.4	50	3.8

4.4 Combined single valve and CABG surgery

Figure 57. Types of combined single valve and CABG surgery performed by unit, 2021

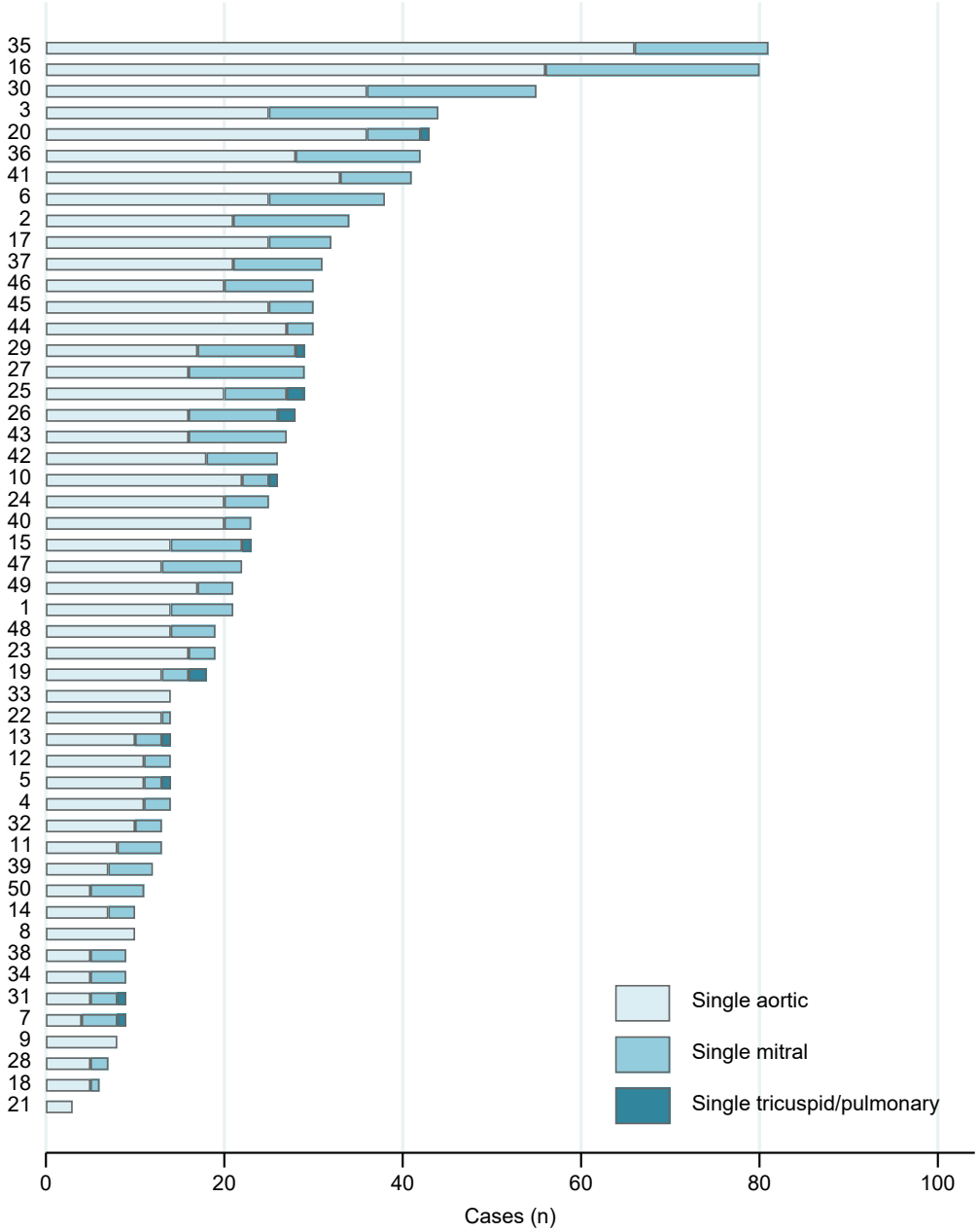
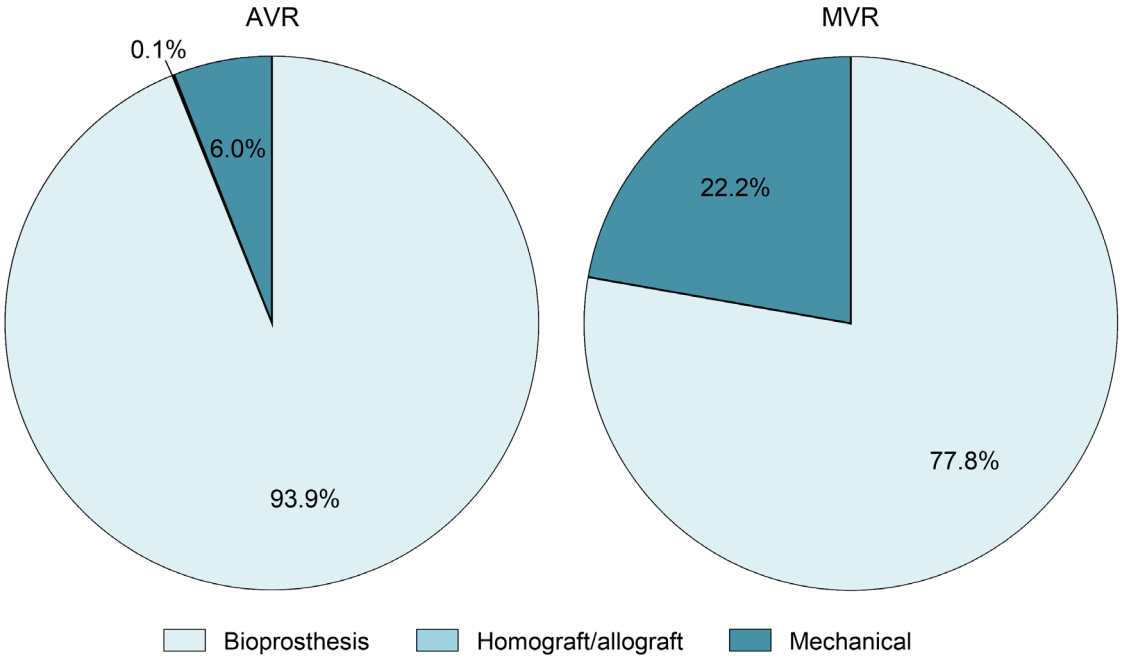


Table 42. Types of combined single valve and CABG surgery performed by year

	2017	2018	2019	2020	2021	Total
Single aortic (%)	75.5	74.8	73.9	73.7	71.7	73.9
Single mitral (%)	22.9	24.4	24.3	24.8	27.1	24.7
Single tricuspid/pulmonary (%)	1.6	0.7	1.8	1.5	1.2	1.4

4.4.1 Prothesis types used

Figure 58. Prosthesis type used for combined AVR/MVR and CABG surgery, 2021



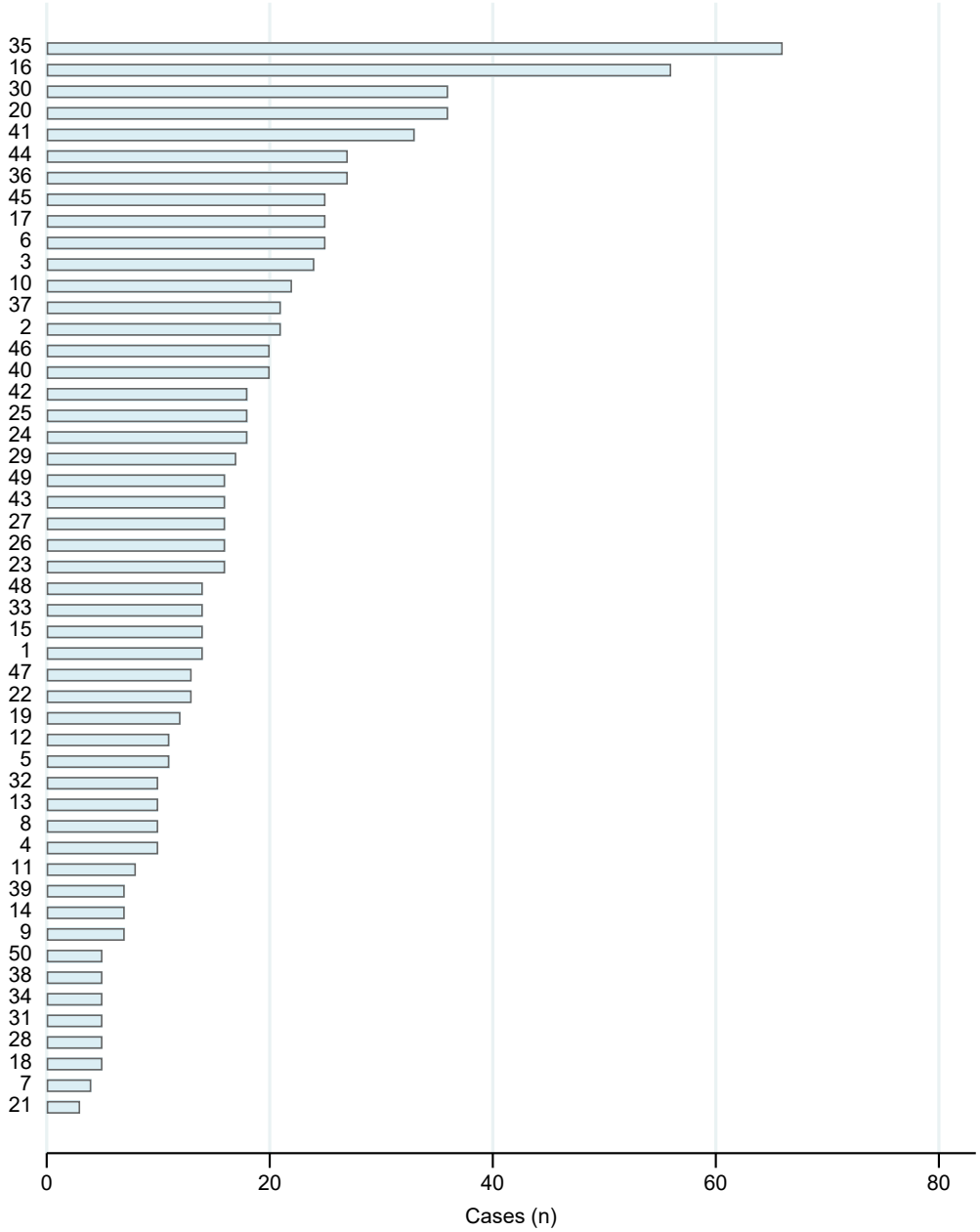
4.5 Influence of patient characteristics on operative mortality

Table 43. OM following the three most common combined single valve and CABG operations, by patient demographics and risk factors

	AVR and CABG		MVR and CABG		MV repair and CABG	
	n	OM (%)	n	OM (%)	n	OM (%)
Clinical status						
Elective	3,100	1.8	435	2.5	466	1.5
Urgent	1,015	4.1	259	11.2	199	4.0
Emergency/salvage	57	15.8	27	33.3	22	4.5
Sex/age						
Male	3,432	2.2	498	7.0	562	1.6
18 - <50y	42	0.0	19	5.3	22	0.0
50 - <60y	214	2.3	58	5.2	80	2.5
60 - <70y	910	1.6	146	5.5	176	0.6
70 - <80y	1,737	2.5	206	9.2	220	2.7
≥80y	529	2.3	69	5.8	64	0.0
Female	740	4.2	223	6.3	125	5.6
18 - <50y	16	0.0	13	0.0	5	0.0
50 - <60y	37	2.7	26	3.8	17	5.9
60 - <70y	160	3.8	53	13.2	29	6.9
70 - <80y	377	4.0	93	5.4	57	7.0
≥80y	150	6.0	38	2.6	17	0.0
LVF						
EF>45%	3,478	2.0	508	5.1	492	1.6
EF≥30% - ≤45%	531	5.1	153	10.5	135	4.4
EF<30%	123	7.3	48	12.5	55	3.6
Previous MI						
No MI	3,056	1.6	454	3.5	438	1.6
NSTEMI	851	5.5	161	9.3	153	2.6
STEMI	125	5.6	79	20.3	63	6.3
Unknown type	139	2.2	27	7.4	33	3.0
Timing of previous MI						
≤6hr	7	28.6	5	60.0	2	0
>6hr - <24hr	12	0.0	7	28.6	5	0
≥1d - ≤7d	247	6.9	58	17.2	55	5.5
>7d	847	4.4	196	9.2	186	3.2
Previous surgery						
Initial	4,065	3.9	674	6.2	670	2.4
Redo	107	6.5	47	14.9	17	0.0
Dialysis						
No	4,094	2.4	701	6.6	678	2.4
Yes	77	9.1	20	15.0	9	0.0
Pre-operative creatinine						
≤200 µmol/L	4,053	2.4	676	5.8	667	2.1
>200 µmol/L	118	8.5	45	22.2	20	10.0

4.6 Combined AVR and CABG

Figure 59. Combined AVR and CABG surgery by unit, 2021



4.6.1 Influence of co-morbidities on complications

4.6.1.1 Pre-existing diabetes and renal impairment

Table 44. Complications following combined AVR and CABG surgery, by pre-operative diabetes and renal function

		Insulin dependent diabetes		Pre-operative creatinine		Pre-operative eGFR	
		No	Yes	≤200 µmol/L	>200 µmol/L	>60mL /min/1.73m^2	≤60mL /min/1.73m^2
n	2021	778	79	832	25	640	217
	2017-2020	2,997	313	3,217	93	2,421	889
Permanent stroke (%)	2021	2.4	2.5	2.4	4.0	2.2	3.2
	2017-2020	1.7	2.6	1.7	4.3	1.6	2.4
DSWI (%)	2021	0.8	6.3	1.2	0.1	1.3	1.4
	2017-2020	1.1	1.3	1.1	2.2	1.1	1.0
New cardiac arrythmia (%)	2021	42.2	38.0	41.8	40.0	41.9	41.5
	2017-2020	37.8	37.7	37.7	41.9	36.8	40.4
RTT for bleeding (%)	2021	4.1	7.6	4.0	20.0	3.6	6.9
	2017-2020	4.9	4.8	4.8	6.5	4.7	5.2

4.6.1.2 Age

Table 45. Complications following combined AVR and CABG surgery, by age group

		Age				
		18 - <50y	50 - <60y	60 - <70y	70 - <80y	≥80y
n	2021	12	56	218	438	133
	2017-2020	46	195	852	1,674	545
Permanent stroke (%)	2021	0.0	1.8	3.2	2.1	3.0
	2017-2020	2.2	0.5	1.3	2.0	2.4
DSWI (%)	2021	0.0	1.8	1.4	1.1	1.5
	2017-2020	2.2	1.0	1.5	0.8	1.1
New cardiac arrythmia (%)	2021	16.7	42.9	38.5	42.5	46.6
	2017-2020	23.9	26.3	35.1	39.8	41.3
RTT for bleeding (%)	2021	8.3	1.8	5.0	3.7	6.8
	2017-2020	10.9	4.1	4.7	5.0	4.4

4.6.1.3 Surgical history

Table 46. Complications following combined AVR and CABG surgery, by redo

		Initial	Redo
n	2021	826	31
	2017-2020	3,178	134
Permanent stroke (%)	2021	2.3	6.5
	2017-2020	1.8	2.2
DSWI (%)	2021	1.3	0.0
	2017-2020	1.0	2.2
New cardiac arrythmia (%)	2021	41.9	38.7
	2017-2020	37.9	36.6
RTT for bleeding (%)	2021	4.5	3.2
	2017-2020	4.8	6.0

4.6.1.4 Influence of comorbidities on derived new renal insufficiency

Table 47. Incidence of dNRI following combined AVR and CABG surgery, by pre-operative demographics and risk factors

	2021		2017 - 2020	
	n	dNRI (%)	n	dNRI (%)
Insulin dependent diabetes				
No	767	5.5	2,942	4.4
Yes	76	7.9	303	10.9
Pre-operative creatinine				
≤200 µmol/L	832	5.4	3,201	4.7
>200 µmol/L	11	27.3	44	22.7
Pre-operative eGFR				
>60mL/min/1.73m^2	640	3.6	2,412	3.2
≤60mL/min/1.73m^2	203	12.3	833	10.0
Age				
18 - <50y	11	9.1	41	4.9
50 - <60y	52	9.6	189	2.1
60 - <70y	213	7.0	833	5.3
70 - <80y	434	3.9	1,642	4.6
≥80y	133	7.5	540	6.5
Previous surgery				
Initial	813	5.5	3,116	4.8
Redo	30	10.0	129	8.5

dNRI indicates derived new renal insufficiency.

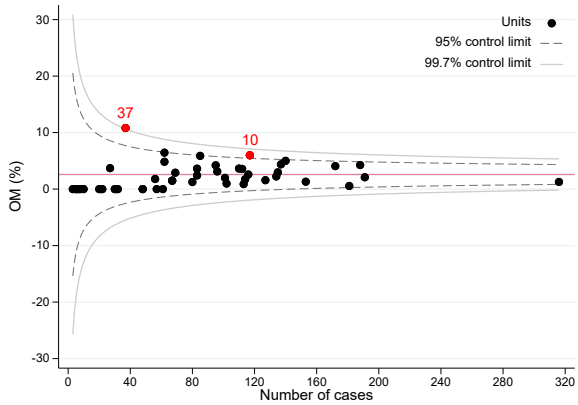
4.6.2 Unit outcomes – mortality, complications and resource utilisation

The data reported in Figures 60-62c have been tabulated in Appendix F (Table F4, pg. 95).

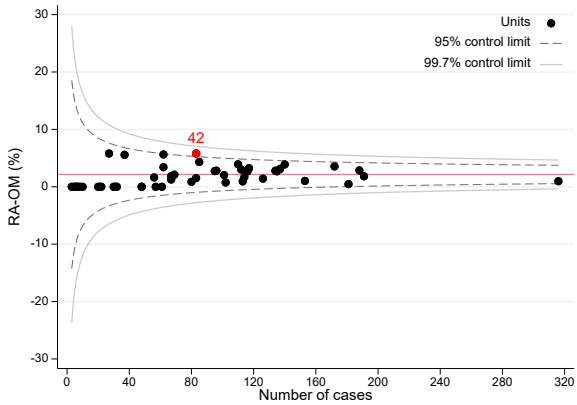
4.6.2.1 Operative mortality

Figure 60. OM following combined AVR and CABG surgery 2017 – 2021, by unit

a. OM



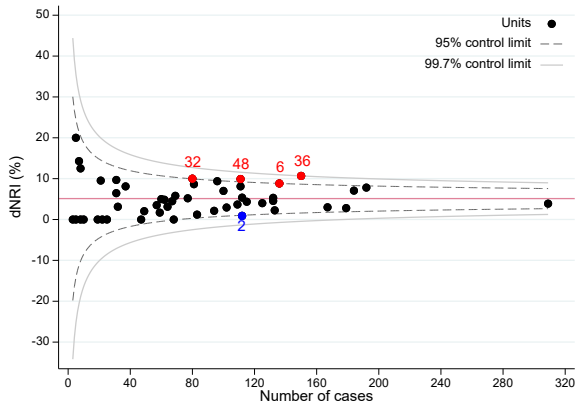
b. RA-OM



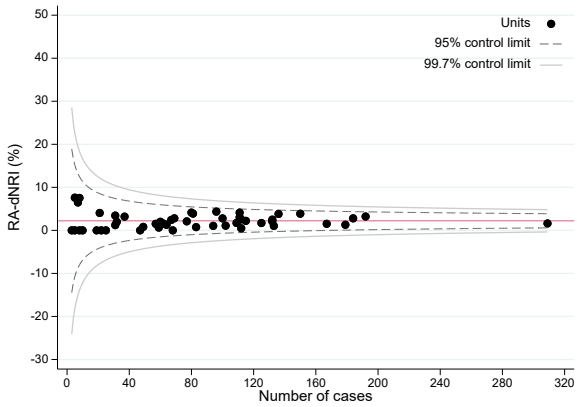
4.6.2.2 Complications

Figure 61. dNRI following combined AVR and CABG surgery 2017 – 2021, by unit

a. dNRI



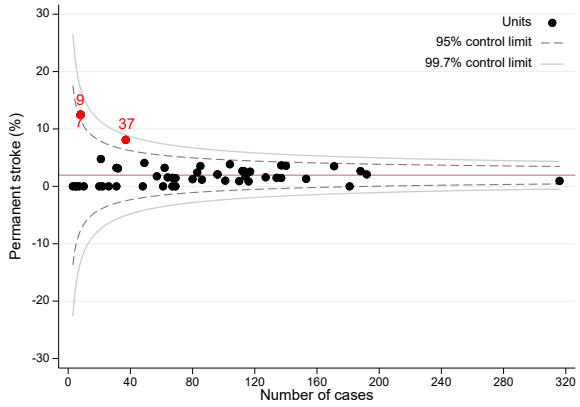
b. RA-dNRI



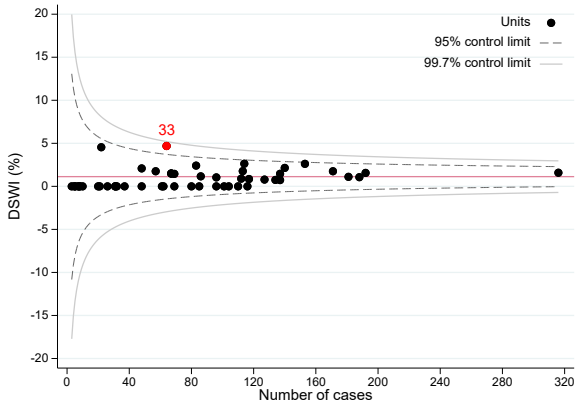
dNRI indicates derived new renal insufficiency.

Figure 62. Complications following combined AVR and CABG surgery 2017 – 2021, by unit

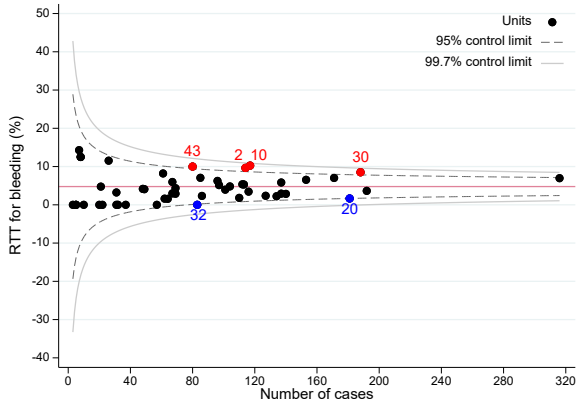
a. Permanent stroke



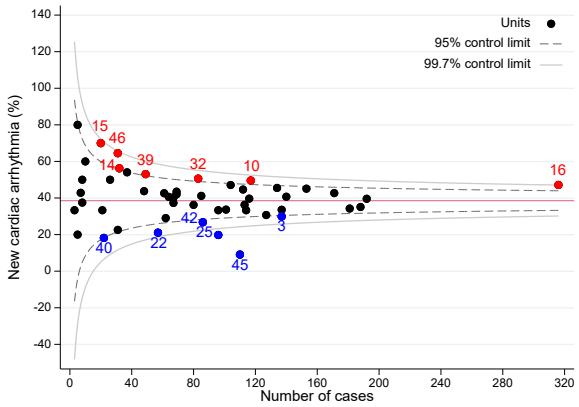
b. DSWI



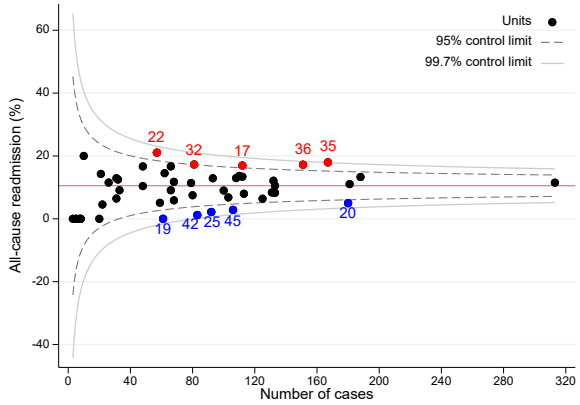
c. RTT for bleeding



d. New cardiac arrythmia



e. All-cause readmission



4.6.2.3 Resource utilisation

Figure 63. Distribution of pre-operative LOS for combined AVR and CABG patients, 2021

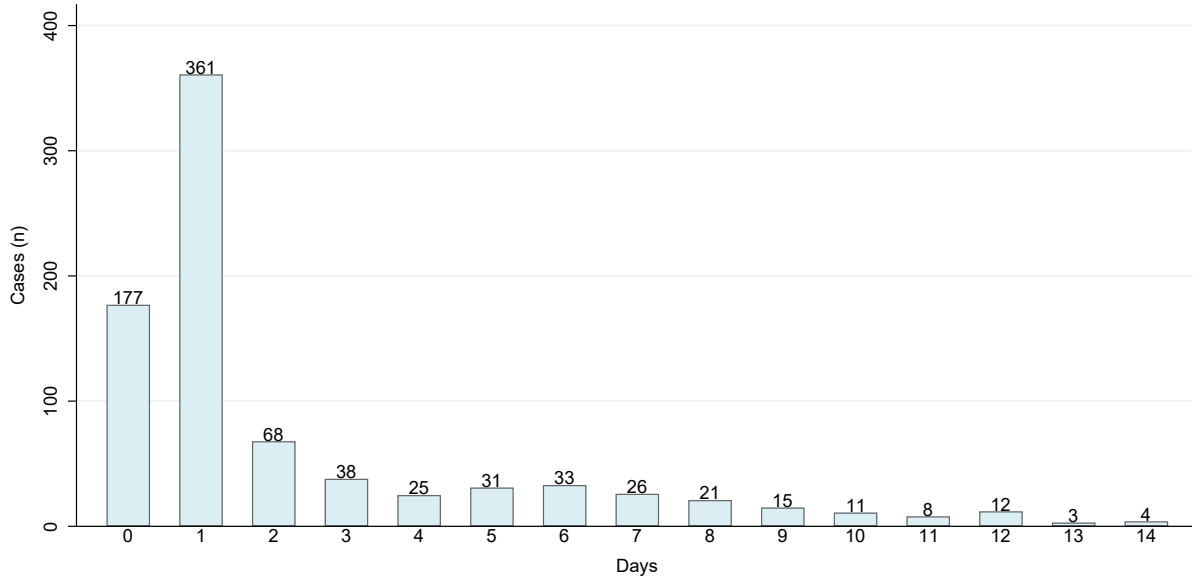


Table 48. Summary of pre-operative LOS for public and private combined AVR and CABG patients, 2021

	Mean (d)	Median (d)	IQR (d)
Public	2.7	1	0 - 4
Private	1.9	1	1 - 2
Total	2.4	1	1 - 3

Cases with a pre-operative LOS of more than 14 days were classified as clinical outliers and excluded from the analysis.

Figure 64. Distribution of post-operative LOS for combined AVR and CABG patients, 2021

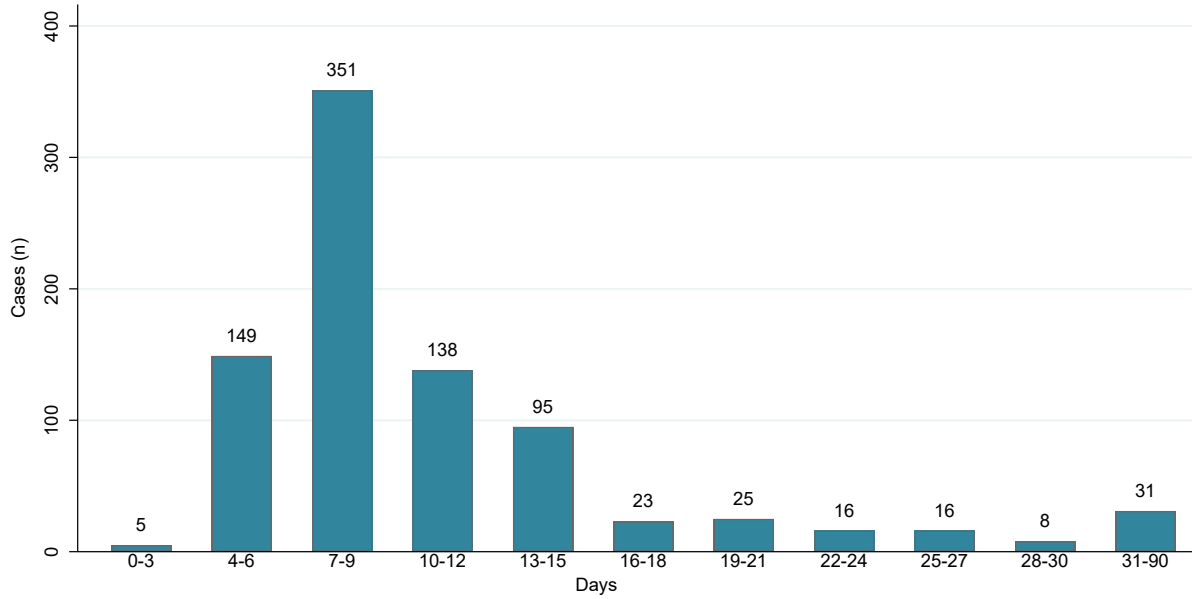


Table 49. Summary of post-operative LOS for public and private combined AVR and CABG patients, 2021

	Mean (d)	Median (d)	IQR (d)
Public	11.7	9	7 - 13
Private	10.7	9	7 - 11
All	11.4	9	7 - 12

Cases with a post-operative LOS of more than 30 days were classified as clinical outliers and excluded from the analysis.

Figure 65. Distribution of initial post-operative ventilation time for combined AVR and CABG patients, 2021

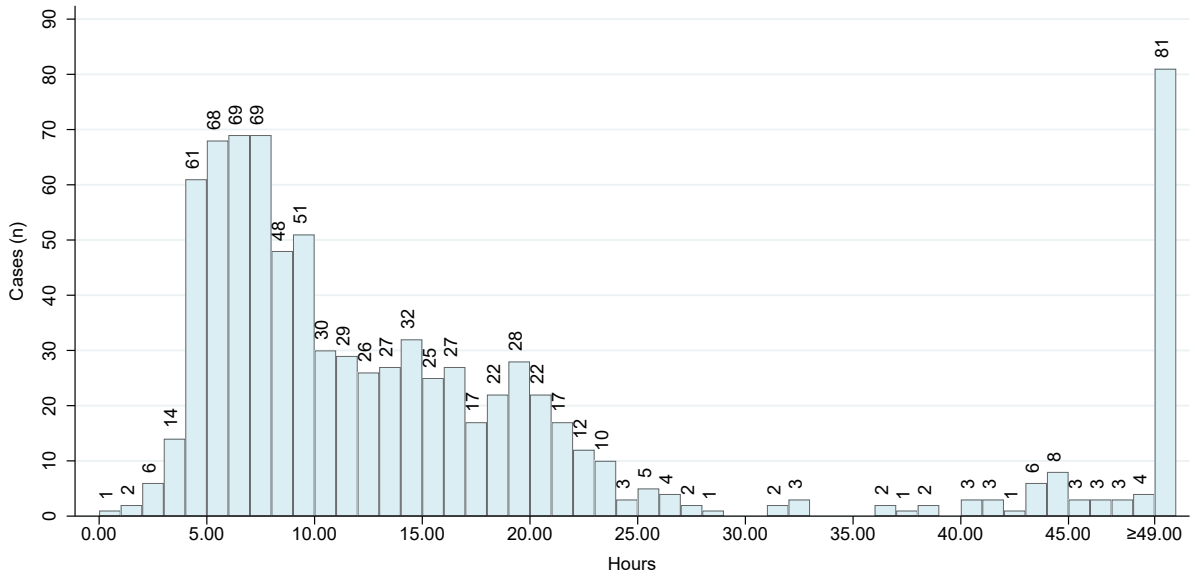


Table 50. Cumulative proportion of patients extubated by hour up to 28 days for combined AVR and CABG surgery, 2021

	6h	12h	24h	48h	96h	192h	384h	672h
Cumulative patients (n)	160	450	713	768	825	841	851	853
Cumulative percentage (%)	18.8	52.8	83.6	90.0	96.7	98.6	99.8	100.0

Table 51. Summary of initial post-operative ventilation time for public and private combined AVR and CABG patients, 2021

	Mean (h)	Median (h)	IQR (h)
Public	27.1	12.4	7.1 - 22.2
Private	16.4	10.2	6.5 - 16.6
All	23.2	11.3	6.8 - 19.6

Cases with a ventilation time of more than four weeks were classified as clinical outliers and excluded from the analysis.

Figure 66. Distribution of ICU length of stay for combined AVR and CABG patients, 2021

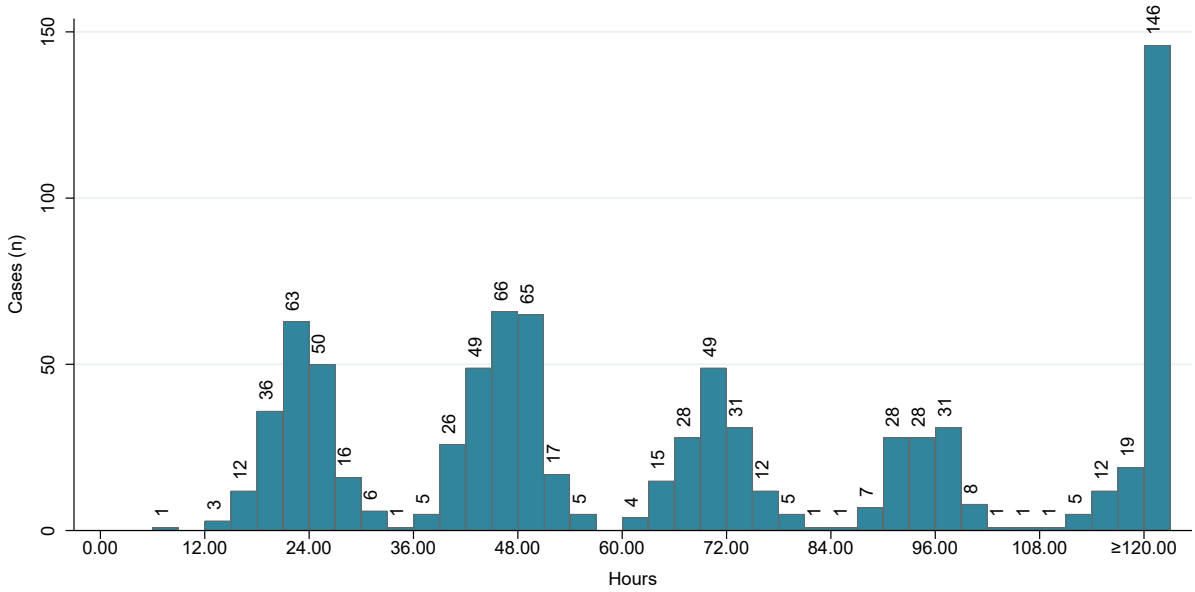


Table 52. Cumulative proportion of patients discharged from ICU by hour up to 42 days for combined AVR and CABG surgery, 2021

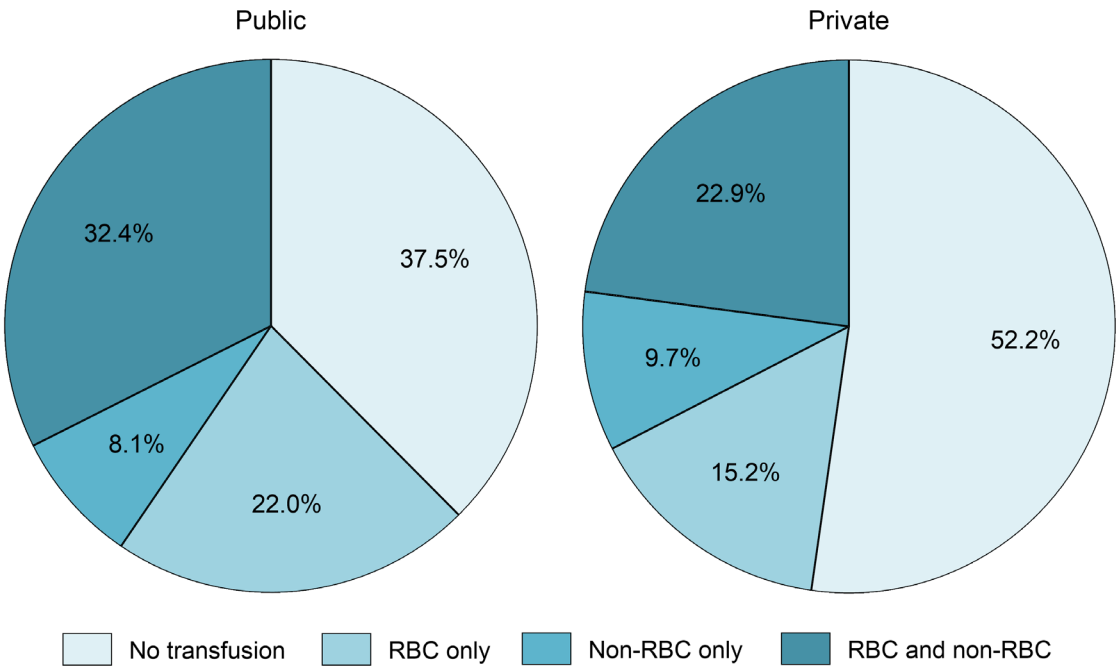
	12h	24h	48h	72h	144h	288h	576h	1008h
Cumulative patients (n)	1	117	344	518	759	830	847	854
Cumulative percentage (%)	0.1	13.7	40.3	60.7	88.9	97.2	99.2	100.0

Table 53. Summary of ICU length of stay for public and private combined AVR and CABG patients, 2021

	Mean (h)	Median (h)	IQR (h)
Public	84.7	56.1	26.1 - 98.0
Private	81.7	65.0	46.2 - 95.8
All	83.6	63.5	41.3 - 97.0

Cases with an ICU length of stay of more than six weeks hours were classified as clinical outliers and excluded from the analysis.

Figure 67. Blood product usage at public and private hospitals for combined AVR and CABG patients, 2021



Note: non-RBC consists of platelets, NovoSeven, cryoprecipitate and FFP

5. Other Cardiac Surgery

The following section describes the frequency of the other types of cardiac procedures submitted to the ANZSCTS Database. Outcome data is not included due to the small sample sizes.

Table 54. Case numbers for aortic surgery, 2021

Surgery Type (not mutually exclusive)	n
Aortic replacement	1,339
Ascending only	1,023
Ascending + arch	240
Arch only	18
Descending	17
Thoraco-abdominal	4
Arch + descending	2
Descending + thoraco-abdominal	4
Ascending + arch + descending	15
Arch + descending + thoraco-abdominal	3
Other	12
Aortic repair	294
Endarterectomy	13
Patch repair	143
Endarterectomy + patch repair	4
Indication for aortic procedure	
Aneurysm	998
Dissection	369
Traumatic transection (<2 weeks)	2
Calcification	74
Other	189

Table 55: Case numbers for other uncommon cardiac surgery, 2021

Surgery Type (not mutually exclusive)	n
LV aneurysm	31
Acquired ventricular septal defect	36
Atrial septal defect	216
Other congenital	128
Cardiac trauma	8
LV outflow tract myectomy	143
LV rupture repair	14
Pericardiectomy	33
Pulmonary thrombo-endarterectomy	22
LV reconstruction	14
Pulmonary embolectomy	12
Cardiac tumour	108
Permanent LV epicardial lead	23
Left atrial appendage closure	517
Atrial arrhythmia surgery	409
Carotid endarterectomy	8
Other	378

LV indicates left ventricular.

Table 56: Case numbers and OM for transplants, 2021

Surgery type (performed in isolation)	n	OM (%)
Cardiac transplant	82	0.0
Cardiopulmonary transplant	53	5.7

Table 57: Case numbers for other aortic valve surgery performed without and with CABG

Valve Surgery		Without CABG (n)	With CABG (n)
Aortic root replacement with valved conduit	2021	291	58
	2017-2020	1,119	218
Pulmonary autograft aortic root replacement (Ross)	2021	24	0
	2017-2020	153	5
Aortic root reconstruction with valve sparing (David)	2021	52	7
	2017-2020	248	24
Total other valve surgery	2021	367	65
	2017-2020	1,520	247

6. The ANZSCTS Database Research Program

Introduction from Professor Julian Smith, Research Committee Chair

Since its inception, and in addition to its role in cardiac surgical quality assurance, the ANZSCTS Database has been an important source of data for a broad range of research projects. These have been conducted by ANZSCTS surgeons, surgical trainees, junior doctors and members of various other specialty groups.

The Database encourages collaborative research and the Research Program focuses on three broad themes of research pertaining to:

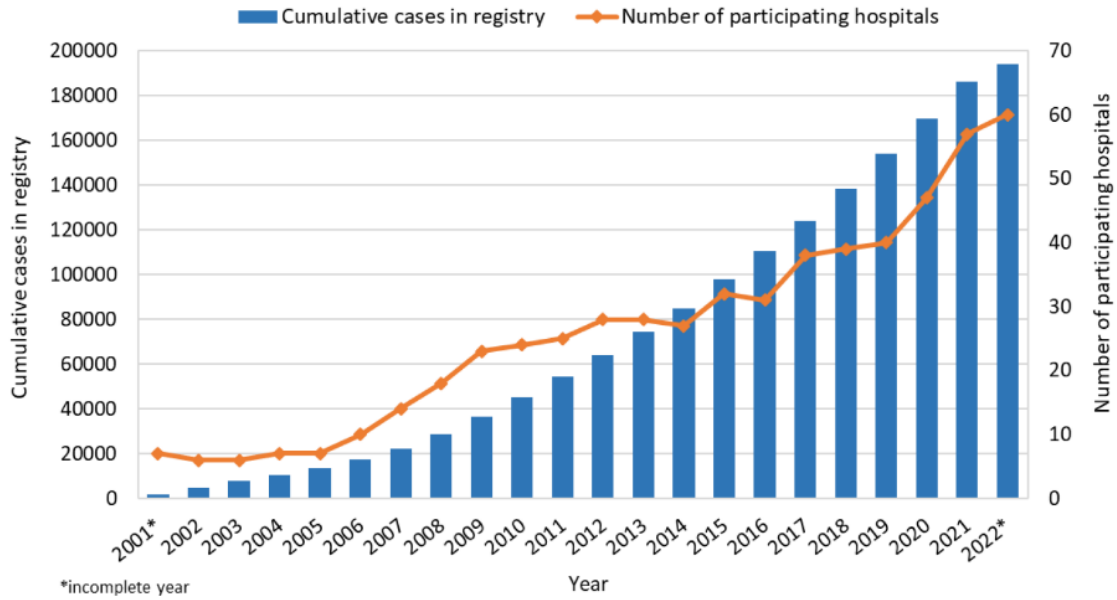
a) risk prediction;
b) intra-operative procedural factors; and
c) improvement of clinical outcomes following cardiac surgery.

To facilitate this work, the ANZSCTS Database has established links to a number of datasets including the Australian Institute of Health and Welfare's National Death Index. All projects must have Human Research Ethics Committee approval prior to the release of research data. Below is a summary of how research is governed within the Database along with an outline of some recent projects and a list of peer-reviewed publications in the last five years.

The Database

Since 2001, more than 190,000 cases from 60 participating hospitals and 203 surgeons have been entered into the Database (Figure 68). Data completeness is excellent at greater than 99% and data accuracy has been consistently over 90% for the past few years. The high quality of the data is a testament to the hard work and dedication of the valued Data Managers at each participating hospital. The maturation of the Database also highlights its addition benefit as a rich dataset for the ANZSCTS Database Research Program.

Figure 68: Summary of ANZSCTS Database data collection



The Research Committee

The ANZSCTS Database Research Program is managed by the Data Management and Analysis Centre at the Centre of Cardiovascular Research and Education in Therapeutics at Monash University and is set up to encourage collaborative research by providing expert clinical and analysis advice for researchers requesting access to the ANZSCTS Database. The Research Program activities are guided and supported by the Research Committee, which reviews research applications and provides support through data interpretation and clinical input.

The Research Committee in 2021 was comprised of surgeons and academics with a wide range of knowledge and expertise. The members of the Research Committee are:

Prof Julian Smith
Chair ANZSCTS Research Committee / ANZSCTS Surgeon

Prof Christopher Reid
Research Program Director

Mr Gil Shardey
Former ANZSCTS Steering Committee Chair / ANZSCTS Surgeon

A/Prof Dion Stub
Cardiologist

Prof Robert Baker
Perfusionist

Mr Bruce Davis
ANZSCTS Surgeon

Prof Alistair Royse
ANZSCTS Surgeon

Mr Andrew Newcomb
ANZSCTS Surgeon

Dr Jenni Williams-Spence
ANZSCTS Database Program Manager - Operations

Dr Lavinia Tran
ANZSCTS Database Program Manager - Research

Ms Angela Brennan
Program Manager - Cardiac Registries; Senior Research Fellow – CCRET

Research Committee operations

Potential researchers are invited to submit research project applications to the Research Committee. The Research Committee meet and review applications quarterly and assesses the purpose, methodology, potential value, and impact of all applications. The Research Committee also assists with fostering collaborations where appropriate, especially in highly topical research areas. The Research Committee oversees the procedures for access to data and approves the authorship of all manuscripts utilising the ANZSCTS Database.

Key Research Committee responsibilities:

Research Project Applications	• Review applications for data access for the purpose of research, in line with ANZSCTS Database policies and procedures, and provide feedback for applicants • Foster collaborations between researchers when projects may overlap • Review project progress and provide advice and guidance to researchers if required.
Data Access	• Propose, review and implement data access, publication and reporting policies • Provide guidance on the release of data for linkage projects • Ensure research data integrity and security provided to researchers through a secure research platform
Outputs	• Review all manuscript for publications • Ensure appropriate authorship and/or acknowledgement of the ANZSCTS Database on all publications and presentations according to the Data Access Policy

Data access

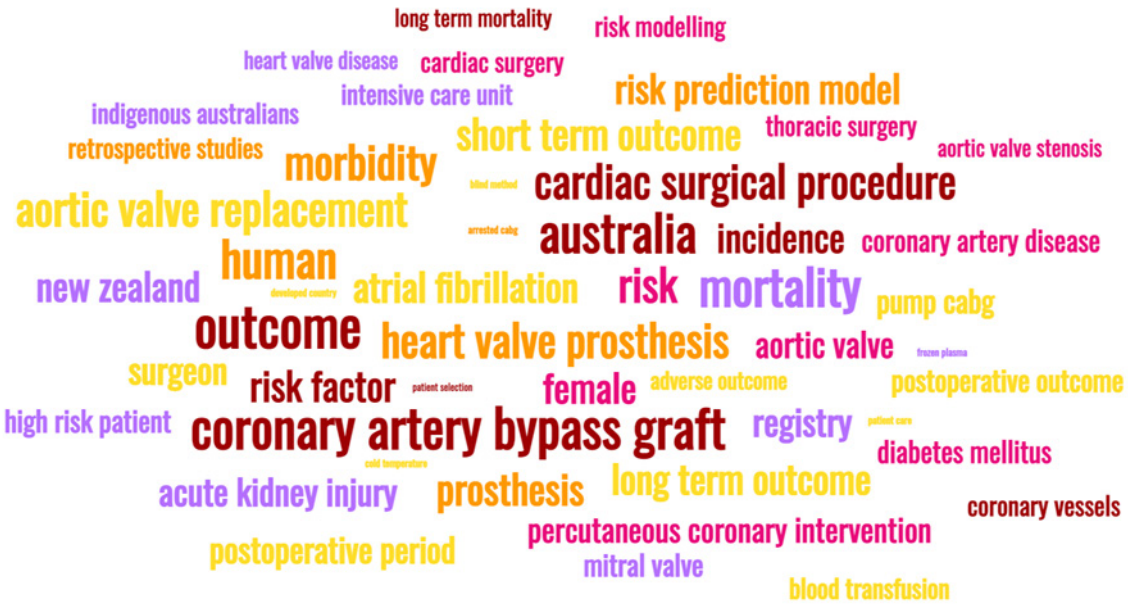
Upon approval by the Research Committee, researchers are provided with a restricted dataset to complete the research. All identifying information that the Database captures (patient, hospital, and surgeon) are removed from the restricted dataset. Only information required for the project is provided. Data security is ensured through the use of the Monash University's Secure eResearch Platform (SeRP).

The SeRP allows users to analyse data on secure virtual machines from any location (with an internet connection), and the resulting research outputs can be exported from the server while the data file remains locked. Set-ups can be customised to meet the specific software and user configurations required for each project. For more information, please visit https://www.monash.edu/researchinfrastructure/eresearch/capabilities/collaborate/monash-serp

The research

The breadth of research in recent years has encompassed a wide array of topics within cardiac surgery, and the infographic below describes some examples of these topics through keywords. The Database has also been successfully linked to other clinical registries and the Australian Institute of Health and Welfare's National Death Index. Linkage studies are highly valued as they are a cost-effective way to allow a "deeper dive" into the data and utilisation of additional clinical information not collected by the ANZSCTS Database. Requests for linkage to the ANZSCTS Database from other registries and datasets demonstrates the value of the Database in supplementing research from other domains.

Figure 69: Key research themes extracted from submitted projects



Summary of research outputs

The following pages shine a spotlight on some of the high-quality research outputs that have been generated from projects in the Research Program. It includes examples of a registry linkage study, machine learning methodologies, clinical and economic evaluations, a registry-embedded randomised trial, and quality improvement initiatives and outcomes research.

27 projects in progress

80 completed projects

100+ published articles

Linkages with other key registries and datasets

Currently (at time of print), there are 27 active projects in progress, 80 completed projects and over 100 published articles in highly regarded journals spanning across multiple disciplines. Researchers have also had their work accepted for presentation at national and international conferences with prizes and awards being received.

Research summaries

A registry linkage study

Project title - Data linkage to Australia and New Zealand Dialysis and Transplant (ANZDATA) registry

Principal Investigator:
Professor Stephen McDonald
ANZDATA Executive Officer

Multiple common risk factors link chronic kidney disease (CKD) and cardiovascular disease (CVD) needing surgery – diabetes, hypertension and obesity among others. For CKD patients, CVD is more common and advances more quickly. Cardiac deaths are the leading cause among people receiving dialysis. However, we are yet to establish the incidence patterns of cardiac surgery for those presumed to be most at risk - patients with kidney failure requiring dialysis or kidney transplant. Data linkage between ANZSCTS Cardiac Surgery Database and another clinical quality registry, the Australia and New Zealand Dialysis and Transplant (ANZDATA) Registry, enables us to quantify these trends nationally. This data linkage project involves collaboration across the disciplines of nephrology and cardiac surgery to answer the following questions:

What are the rates and types of cardiac surgeries among the population receiving chronic kidney replacement therapy at the time of cardiac surgery (either dialysis or kidney transplant), compared with the general surgery population?

What is the short-term post-cardiac-surgery mortality risk for dialysis and kidney transplant patients compared with the general surgery population? How does this risk vary by the presence/absence of post-operative acute kidney injury (AKI)?

What is the risk of AKI post-cardiac surgery for patients at different stages of CKD and for transplant patients, compared with the general surgery population?

What is the risk for developing kidney failure (treated with dialysis or kidney transplant) post-cardiac surgery, for patients at different stages of CKD pre-operatively and with/without post-operative AKI?

Initial findings will be presented at the 57th Australian & New Zealand Society of Nephrology Annual Scientific Meeting (ASM) in October 2022 and the Australian Registry ASM in November 2022. Manuscripts are being prepared for publication in peer reviewed journals.

Dr Dominic Keuskamp
Post-doctoral research fellow
South Australian Health and Medical Research Institute

Machine learning methodologies

Project title - Machine Learning Algorithms for Predicting Cardiac Surgery-Associated Acute Kidney Injury (CSA-AKI)

Principal Investigator:
Associate Professor Andrew Cochrane
Monash Health Cardiothoracic Surgery

The role of machine learning to assist clinicians in peri-operative decision making is relatively understudied in cardiac surgery. Our research has focused on developing and applying machine learning methods to predict nine different adverse post-operative outcomes.

- Readmission to ICU
- Reintubation
- Return to theatre
- Acute kidney injury
- Renal replacement therapy
- New arrhythmia
- Deep sternal wound infection
- 30-day mortality
- Long term mortality

Our overall goals are to benchmark existing models and engineer new solutions to improve upon existing tools such as the commonly used EuroSCORE or AusSCORE models.

We have published our results predicting post-operative acute kidney injury(6), and have upcoming submissions including the application of machine learning-based survival analysis to overall mortality and developing an attention-based neural network architecture designed to bring deep learning methods to cardiac surgery risk prediction.

This work resulted in one publication at the time of the writing of this report.

Dr Jahan Penny-Dimri
Adjunct Research Associate
Monash University

Clinical and economic evaluation

Project title - The effects of blood pricing and clinical guidelines on the use of blood in cardiac surgery

Principal Investigator:
Professor Anthony Harris
Director of the Centre for Health Economics
Monash University

In March 2012, the National Blood Authority (NBA) published a set of clinical guidelines designed to reduce inappropriate blood transfusions before, during, and after surgery by promoting patient blood management techniques. Despite their widespread use, the effectiveness of interventions such as clinical guidelines at achieving their objectives is rarely assessed, possibly due to insufficient outcome data in the period before the intervention. The NBA funded this research project to evaluate the impact of their guidelines. We used the ANZSCTS Database, which began collecting detailed data on blood use during cardiac surgery in Australia well before the guidelines were published.

There were three outputs of this research project – a clinical evaluation, an economic evaluation, and an analysis of variation in care. The clinical evaluation found a significant reduction in red blood cell, platelet, and fresh-frozen plasma transfusions. There was also a significant reduction in hospital length of stay but no significant impact on cryoprecipitate, 30-day mortality, 30-day readmissions, or intensive care unit length of stay. The economic evaluation estimated that the indexed cost of implementing the guidelines of A$1.5 million (2018-2019 financial year prices) was outweighed by the predicted blood products resource saving of A$5.1 million. The variation analysis found a 48% reduction in the variance across surgeons driven by a more consistent number of units transfused, rather than a reduction in the number of patients transfused.

The clinical and economic evaluations have both been published in peer-reviewed journals and presented at health economic conferences. The variation study is currently under peer-review. This project demonstrated to the NBA that given a high-quality data source it is possible to perform retrospective evaluations of interventions designed to improve the quality and consistency of care such as clinical guidelines(7, 8).

This work resulted in two publications at the time of the writing of this report.

Dr Adam Irving
Research Fellow
Monash University

Registry-embedded randomised control trial

Project title - Prophylactic INtra-aortic BALLoon Counterpulsation in High-Risk Cardiac Surgery

Undertaken in conjunction with the ANZSCTS Database and supported by competitive grants from the Heart Foundation and Intensive Care Foundation, the registry-embedded Prophylactic INtra-aortic BALLoon Counterpulsation in High-Risk Cardiac Surgery (PINBALL) program of research included an observational study (ACTRN12613000293763) and a pilot randomised clinical trial (RCT) (ACTRN12614000712606). The aim was to investigate the use of prophylactic intra-aortic balloon counterpulsation as a therapy to improve outcomes for high risk patients undergoing cardiac surgery.

Registry embedding was highly beneficial. Data collection was enhanced by the use of an established, high quality, database and the associated data collection tools managed by experienced data custodians. Study efficiency was enhanced by avoiding duplicate data collection and allowing a minimal, study-specific case report form via REDCap. Embedding provided access to a network of potential study sites and site-specific data to inform the study design. The registry created capacity to undertake a stepwise program of research whilst maintaining infrastructure with ongoing measurement and reporting of translation of research into practice. Both studies have subsequently been published in the peer-reviewed literature and have informed further registry-embedded research opportunities(9, 10).

This work resulted in two publications at the time of the writing of this report.

Associate Professor Ed Litton
Research Fellow and PINBALL Principal Investigator
The University of Western Australia Medical School

Quality improvement initiatives and outcomes research

Summary of research using a hospital-specific ANZSCTS Database data: Melbourne Health

Being involved in clinical cardiothoracic patient care since 1995, as a Division 1 Registered Nurse, provides unique longitudinal insights into the multidisciplinary development of this cognate area of specialist practice. There is no doubt that technical and technological advancement underpin patient outcomes aligned with cardiothoracic surgery and the development of clinical quality registries for specific patient populations assists clinicians in benchmarking best practice. In the last decade there has been a greater emphasis on multidisciplinary contributions to patient care, and advances in implementation science to facilitate effective and efficient translation of evidence into practice. Continuous quality improvement initiatives and practice evaluation is frequently led by nurses in the clinical context and the ANZSCTS Database provides an avenue to support these activities at a local and national level. Research that utilises registry data as a means of determining the impact of clinical variation also enables clinicians to realise the value of capturing and reporting registry data.

Site specific data from local ANZSCTS Database repositories has informed practice improvement at the 'coalface' in relation to the post-operative management of chest tubes, indwelling urinary catheters, sternal wound dressings, post-operative pain management, factors associated with respiratory dysfunction and pneumonia, the presentation and treatment of new onset post-operative atrial fibrillation, blood product use and patient preferences for discharge planning. Multisite and national Registry data has provided crucial insights into trends associated with frailty, obesity, the impact of COVID-19, surgical techniques, and factors that influence representation or readmission after cardiac surgery in adults. Importantly, Registry data provides a mechanism for clinicians to create programs of research that generate research capability, provide an avenue for sharing cross-disciplinary clinical academic initiatives globally and support innovative patient-focused initiatives*.

**This summarises the work across 52 publications. Please contact the ANZSCTS Database for a full list of references*

Professor Rochelle Wynne
Clinical Nurse Consultant
Melbourne Health

List of publications 2018-2022

Research Committee members are in bold.

Irving AH, Harris A, Petrie D, Higgins A, **Smith JA, Tran L, Reid CM**, McQuilten ZK. Economic Evaluation of National Patient Blood Management Clinical Guidelines in Cardiac Surgery. Value Health. 2022 Mar;25(3):419-426. doi: 10.1016/j.jval.2021.07.014.

Schmidt AF, Haitjema S, Sartipy U, Holzmann MJ, Malenka DJ, Ross CS, van Gilst W, Rouleau JL, Meeder AM, Baker RA, Shiomi H, Kimura T, **Tran L, Smith JA, Reid CM**, Asselbergs FW, den Ruijter HM. Unravelling the Difference Between Men and Women in Post-CABG Survival. Front Cardiovasc Med. 2022 Apr 13;9:768972. doi: 10.3389/fcvm.2022.768972

Surman TL, Abrahams JM, **Williams-Spence J**, Edwards J, Worthington MG, Beltrame J, **Smith J**. Clinical Outcomes in Surgical and Transcatheter Aortic Valve Replacement: An ANZSCTS Database Review 2001-2019. Heart Lung Circ. 2022 Aug;31(8):1153-1165. doi: 10.1016/j.hlc.2022.04.047

Coulson TG, Bailey M, **Reid C, Shardey G, Williams-Spence J**, Huckson S, Chavan S, Pilcher D. Linkage of Australian national registry data using a statistical linkage key. BMC Med Inform Decis Mak. 2021 Feb 2;21(1):37. doi: 10.1186/s12911-021-01393-1

Bradshaw PJ, Tohira H, Marangou J, Newman M, Reményi B, Wade V, **Reid C**, Katzenellenbogen JM. The use of cardiac valve procedures for rheumatic heart disease in Australia; a cross-sectional study 2002-2017. Ann Med Surg (Lond). 2020 Nov 25;60:557-565. doi: 10.1016/j.amsu.2020.11.055

Coulson T, Bailey M, Pilcher D, **Reid CM**, Seevanayagam S, **Williams-Spence J**, Bellomo R. Predicting Acute Kidney Injury After Cardiac Surgery Using a Simpler Model. J Cardiothorac Vasc Anesth. 2021 Mar;35(3):866-873. doi: 10.1053/j.jvca.2020.06.072

Farag J, Summerhayes R, Shen R, Bailey M, **Williams-Spence J, Reid CM**, Marasco SF. Post Cardiotomy Extra Corporeal Membrane Oxygenation: Australian Cohort Review. Heart Lung Circ. 2020 Dec;29(12):1865-1872. doi: 10.1016/j.hlc.2020.05.092

Flint AWJ, Bailey M, **Reid CM, Smith JA, Tran L**, Wood EM, McQuilten ZK, Reade MC. Preoperative identification of cardiac surgery patients at risk of receiving a platelet transfusion: The Australian Cardiac Surgery Platelet Transfusion (ACSePT) risk prediction tool. Transfusion. 2020 Oct;60(10):2272-2283. doi: 10.1111/trf.15990

Irving AH, Harris A, Petrie D, Higgins A, **Smith J,** McQuilten ZK. Impact of patient blood management guidelines on blood transfusions and patient outcomes during cardiac surgery. J Thorac Cardiovasc Surg. 2020 Aug;160(2):437-445.e20. doi: 10.1016/j.jtcvs.2019.08.102

Litton E, Bass F, Dickson C, Hillis G, Inskip D, Jacques T, McGiffin D, McGuiness S, Miller J, Parke R, Playford H, **Reid C, Smith J,** Solman N, **Tran L,** Yarad E, Delaney A; ANZICS Clinical Trials Group. Prophylactic Intra-Aortic Balloon Counterpulsation in High Risk Cardiac Surgery: The PINBALL Pilot Multicentre, Registry-Linked, Randomised, Controlled Feasibility Trial. Heart Lung Circ. 2020 May;29(5):710-718. doi: 10.1016/j.hlc.2019.04.006

Penny-Dimri JC, Bergmeir C, **Reid CM, Williams-Spence J,** Cochrane AD**, Smith JA.** Machine Learning Algorithms for Predicting and Risk Profiling of Cardiac Surgery-Associated Acute Kidney Injury. Semin Thorac Cardiovasc Surg. 2021 Autumn;33(3):735-745. doi: 10.1053/j.semtcvs.2020.09.028

Alramadan MJ, Karim MN, Hossain MN**, Smith JA,** Cochrane A**, Reid CM,** Billah B. Renal Disease Is Associated With Poor Outcomes Following Isolated Coronary Artery Bypass Grafting. Glob Heart. 2019 Dec;14(4):347-353. doi: 10.1016/j.gheart.2019.08.002

Nag N, Tran L, Fotis K, **Smith JA, Shardey GC, Baker RA, Reid CM**. Structured Feedback: Acceptability and Feasibility of a Strategy to Enhance the Role of a Clinical Quality Registry to Drive Change in Cardiac Surgical Practice. Heart Lung Circ. 2019 Aug;28(8):1253-1260. doi: 10.1016/j.hlc.2018.07.005

Si S, Hillis GS, Sanfilippo FM, **Smith J, Tran L, Reid CM**, Briffa T. Surgical aortic valve replacement in Australia, 2002-2015: temporal changes in clinical practice, patient profiles and outcomes. ANZ J Surg. 2019 Sep;89(9):1061-1067. doi: 10.1111/ans.15370

Tran L, Williams-Spence J, Shardey GC, Smith JA, Reid CM. The Australian and New Zealand Society of Cardiac and Thoracic Surgeons Database Program - Two Decades of Quality Assurance Data. Heart Lung Circ. 2019 Oct;28(10):1459-1462. doi: 10.1016/j.hlc.2019.03.002

Zhu MZL, Huq MM, Billah BM, **Tran L, Reid CM,** Varatharajah K, Rosenfeldt FL. On-Pump Beating Heart Versus Conventional Coronary Artery Bypass Grafting Early After Myocardial Infarction: A Propensity-Score Matched Analysis From the ANZSCTS Database. Heart Lung Circ. 2019 Aug;28(8):1267-1276. doi: 10.1016/j.hlc.2018.06.1051

Ariyaratne TV, Ademi Z, Huq M, Rosenfeldt F, Duffy SJ, Parkinson B, Yap CH, **Smith J,** Billah B, Yan BP, **Brennan AL, Tran L, Reid CM**. The Real-World Cost-Effectiveness of Coronary Artery Bypass Surgery Versus Stenting in High-Risk Patients: Propensity Score-Matched Analysis of a Single-Centre Experience. Appl Health Econ Health Policy. 2018 Oct;16(5):661-674. doi: 10.1007/s40258-018-0407-5

Buratto E, Shi WY, Wynne R, Poh CL, Larobina M, O'Keefe M, Goldblatt J, Tatoulis J, Skillington PD. Improved Survival After the Ross Procedure Compared With Mechanical Aortic Valve Replacement. J Am Coll Cardiol. 2018 Mar 27;71(12):1337-1344. doi: 10.1016/j.jacc.2018.01.048

Karim MN, **Reid CM**, Huq M, Brilleman SL, Cochrane A, **Tran L,** Billah B. Predicting long-term survival after coronary artery bypass graft surgery. Interact Cardiovasc Thorac Surg. 2018 Feb 1;26(2):257-263. doi: 10.1093/icvts/ivx330

Kilpin M, Talwar A, Meneguzzi J, **Tran L, Reid C**, Hayward P. Two Long-Term Mortality Risk Models For Coronary Artery Bypass Graft Surgery Produced in American Populations Validated in an Australian Population. Heart Lung Circ. 2018 Jan;27(1):79-88. doi: 10.1016/j.hlc.2017.02.008

Litton E, Bass F, Delaney A, Hillis G, Marasco S, McGuinness S, Myles PS, **Reid CM, Smith JA;** PINBALL study investigators and the ANZICS CTG. Six-Month Outcomes After High-Risk Coronary Artery Bypass Graft Surgery and Preoperative Intra-aortic Balloon Counterpulsation Use: An Inception Cohort Study. J Cardiothorac Vasc Anesth. 2018 Oct;32(5):2067-2073. doi: 10.1053/j.jvca.2018.01.005

Meneguzzi J, Kilpin M, Zhu YY, Doi A, **Reid C, Tran L,** Hayward P, **Smith J**. Impact of Discontinuation of Antiplatelet Therapy Prior to Isolated Valve and Combined Coronary Artery Bypass Graft and Valve Procedures on Short and Intermediate Term Outcomes. Heart Lung Circ. 2018 Jul;27(7):878-884. doi: 10.1016/j.hlc.2017.06.734

O'Brien J, Saxena A, **Reid CM, Tran L**, Baker RA, **Newcomb A**, **Smith J,** Huq MM, Duffy SJ. Thirty-day outcomes in Indigenous Australians following coronary artery bypass grafting. Intern Med J. 2018 Jul;48(7):780-785. doi: 10.1111/imj.13790

Royse A, Pawanis Z, Canty D, Ou-Young J, Eccleston D, Ajani A, **Reid CM**, Bellomo R, Royse C. The effect on survival from the use of a saphenous vein graft during coronary bypass surgery: a large cohort study. Eur J Cardiothorac Surg. 2018 Dec 1;54(6):1093-1100. doi: 10.1093/ejcts/ezy213

7. Concluding Remarks

The mortality and morbidity incidences for the major procedure groups presented in this report are low and comparable to cardiac registries around the world. The Program is committed to update and broaden its quality assurance and research activities to include new statistics of relevance to practice, including procedural details (grafting strategy and valve selection) and long-term survival.

Specific projects underway in 2022 and in focus for 2023 include:

- The addition of unit-level cumulated sum (CUSUM) chart reports for lower volume procedures (AVR, and AVR and CABG) to the routine peer review and feedback activities.
- Strengthening relationships with surgeons and the ANZSCTS, to maximise surgeon input on registry activities and guide the outputs and strategic direction of the Program.
- Introduction of confidential (not public-facing) surgeon-level reporting to maintain control over analysis of surgeon outcomes in the face of increasing interest from external bodies in monitoring clinician performance across a range of domains.
- Publishing the newest ANZSCORE risk-adjustment models for OM, dNRI and long-term mortality.
- Analysis of the COVID-19-related data collected by the Database, including changes in state-level and public/private case volumes and outcomes.
- Completion of the review of the Data Definitions Manual, which will include additions, subtractions, and definition clarifications for difficult variables.
- Implementation of the ANZSCORE long-term mortality models for inclusion in Annual Reports.
- Recruitment of the remaining public hospitals in New Zealand, and the few non-participating private hospitals in Australia.
- Continued support of external researchers through access to the collated dataset, and linkage activities with other registries (ANZDATA, ANZICS) and administrative datasets (AIHW NDI, admitted episodes).

The ANZSCTS Database currently has 60 participating sites and more than 190,000 cases. The 2022 Annual Report will be expanded to accommodate these additional sites and present the increasing amount of data being received from private hospitals.

Appendix A
Key performance indicator definitions

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

In-hospital and 30-day mortality or operative mortality (OM)

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

Return to Theatre (RTT) for bleeding

Did the patient return to theatre for bleeding/tamponade?

Derived new renal insufficiency (dNRI)^

- *This indicator is derived from reported renal data*
  a. Acute post-operative renal insufficiency is characterised by one of the following: 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).
- *Risk-adjusted derived new renal insufficiency (RA-dNRI)*
  The observed outcome is adjusted based on the ANZSCTS Database Program's risk model (Appendix B), and used to account for the degree of risk associated with the surgery and patient profile.

^Where this measure is reported patients on dialysis pre-operatively are excluded from analysis.

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

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

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 (RBC) 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 (NRBC) 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 B

ANZSCORE OM and dNRI models

Table B1. Variables that define risk in the ANZSCORE isolated CABG models

ANZSCORE (RA-OM, isolated CABG) model variables	ANZSCORE (dNRI, isolated CABG) model variables
*Age^*	*Age^*
Timing of previous myocardial infarction	*Previous myocardial infarction*
Clinical status	*Clinical status*
*Estimated glomerular filtration rate^*	*Estimated glomerular filtration rate^*
NYHA class*	*NYHA* class*
Medicare	*Medicare*
Cerebrovascular disease	*Cerebrovascular disease*
Previous surgery	*Previous surgery with cardiopulmonary bypass*
Ejection fraction grade	*Ejection fraction grade*
Direct transfer from catheter lab/ICU to theatre	*Direct transfer from catheter lab/ICU to theatre*
Cardiogenic shock at the time of procedure	*Cardiogenic shock at the time of procedure*
IV nitrates at time of surgery	*IV nitrates at time of surgery*
Peripheral vascular disease	*Peripheral vascular disease*
Race	*Number of diseased vessels*
Pre-operative dialysis	*Body mass index^*
Resuscitation within one hour prior to operation	*Hypertension*
Lung disease	*Permanent pacemaker in situ*
Pre-operative arrhythmia	*History of diabetes*
Left main disease	*Congestive heart failure at the current admission*
Inotropes at time of surgery	*Sex*
	Previous catheterisation

*New York Heart Association
^data for continuous variables has an upper limit, any data that exceeds this upper limit for a case will not generate a risk score for that patient – the upper limits for age, eGFR and BMI are 130, 200mL/min/1.73m² and 60kg/m², respectively

Table B2. Variables that define risk in the ANZSCORE isolated AVR surgery models

ANZSCORE (RA- OM, isolated AVR surgery) model variables	ANZSCORE (dNRI, isolated AVR surgery) model variables
*Age^*	*Sex*
*Estimated glomerular filtration rate^*	*Body mass index^*
Arrhythmia	*NYHA* class*
Ejection fraction grade	*Estimated glomerular filtration rate^*
Clinical status	*Arrhythmia*
Previous surgery	*Previous CABG*
Diabetes	*IV-Nitrates at time of surgery*
Respiratory disease	*Medicare*
Active endocarditis	*Infective endocarditis*
Shock	
Sex	
Anticoagulants at time of surgery	

*New York Heart Association
^data for continuous variables has an upper limit, any data that exceeds this upper limit for a case will not generate a risk score for that patient – the upper limits for age, eGFR and BMI are 130, 200mL/min/1.73m² and 60kg/m² respectively

Table B3. Variables that define risk in the ANZSCORE combined AVR and CABG models

ANZSCORE (RA- OM, combined AVR and CABG surgery) model variables	ANZSCORE (dNRI, combined AVR and CABG surgery) model variables
*Age^*	*Sex*
*Estimated glomerular filtration rate^*	*Body mass index^*
Arrhythmia	*NYHA* class*
Ejection fraction grade	*Estimated glomerular filtration rate^*
Clinical status	*Arrhythmia*
Previous surgery	*Smoking*
Diabetes on med/Insulin	
Number of diseased vessels	
Active endocarditis	

*New York Heart Association
^data for continuous variables has an upper limit, any data that exceeds this upper limit for a case will not generate a risk score for that patient – the upper limits for age, eGFR and BMI are 130, 200mL/min/1.73m² and 60kg/m² respectively

Appendix C

Data preparation and key variable definitions

Data preparation and presentation

Data includes operative details and outcomes of cardiac surgery performed in 50 participating units in 2021, and from 2017-2020 (Sections 2 and 5) or 2017-2021 (Sections 3 and 4) for pooled analyses.

Final data related to this report was received by the ANZSCTS Database Program Data Management and Analysis Centre in the Centre of Cardiovascular Research and Education in Therapeutics (CCRET) of the School of Public Health and Preventive Medicine, Monash University, on May 9th, 2022. 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 May 9th, 2022 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 Data Definitions Manual 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.*

- Ejection fraction (EF)

Record the percentage of blood emptied from the left ventricle at the end of the contraction. Use the most recent determination prior to intervention. If unknown enter EF estimate.

This data is converted to a measure of left ventricular function (LVF) as follows:

EF (%)	Measure of function
EF > 60%	Normal LVF
EF 46-60%	Mild LV dysfunction
EF 30-45%	Moderate LV dysfunction
EF <30%	Severe LV dysfunction

- All-cause readmission ≤ 30 days 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 any prior cardiac surgery.

Appendix D

Units included in 2021 Annual Report

Table D. Summary of units included in the Annual Report, 2021

Contributing hospitals	Hospital type	Contributing hospitals	Hospital type
VICTORIA		**AUSTRALIAN CAPITAL TERRITORY**	
Alfred Hospital	Public	Canberra Hospital	Public
Austin Hospital	Public	National Capital Private Hospital	Private
Cabrini Private Hospital	Private	**QUEENSLAND**	
Epworth Eastern	Private	Gold Coast Private Hospital	Private
Epworth Richmond	Private	Gold Coast University Hospital	Public
Jessie McPherson Private Hospital	Private	Greenslopes Private Hospital	Private
Knox Hospital	Private	John Flynn Private Hospital	Private
Melbourne Private Hospital	Private	Mater Hospital	Private
Monash Medical Centre	Public	Prince Charles Hospital	Public
Mulgrave Private Hospital	Private	Princess Alexandra Hospital	Public
Peninsula Private Hospital	Private	St Vincent's Private Hospital, Northside	Private
Royal Melbourne Hospital	Public	Sunshine Coast University Private Hospital	Private
St John of God, Geelong	Private	The Wesley Hospital	Private
St Vincent's Hospital, Melbourne	Public	Townsville Hospital	Public
St Vincent's Private Hospital, Melbourne	Private	**SOUTH AUSTRALIA**	
University Hospital Geelong	Public	Ashford Hospital	Private
Warringal Private Hospital	Private	Flinders Hospital	Public
NEW SOUTH WALES		Flinders Private Hospital	Private
John Hunter Hospital	Public	Royal Adelaide Hospital	Public
Lake Macquarie Private Hospital	Private	**WESTERN AUSTRALIA**	
Liverpool Hospital	Public	Fiona Stanley Hospital	Public
Newcastle Private Hospital	Private	Sir Charles Gairdner Hospital	Public
Royal North Shore Hospital	Public	St John of God Hospital, Subiaco	Private
Royal Prince Alfred Hospital	Public	**TASMANIA**	
St George Hospital	Public	Royal Hobart Hospital	Public
St George Private Hospital	Private	**NEW ZEALAND**	
St Vincent's Hospital, Sydney	Public	Auckland City Hospital	Public
Westmead Hospital	Public		
Westmead Private Hospital	Private		

Appendix E

Interpretation of funnel plots

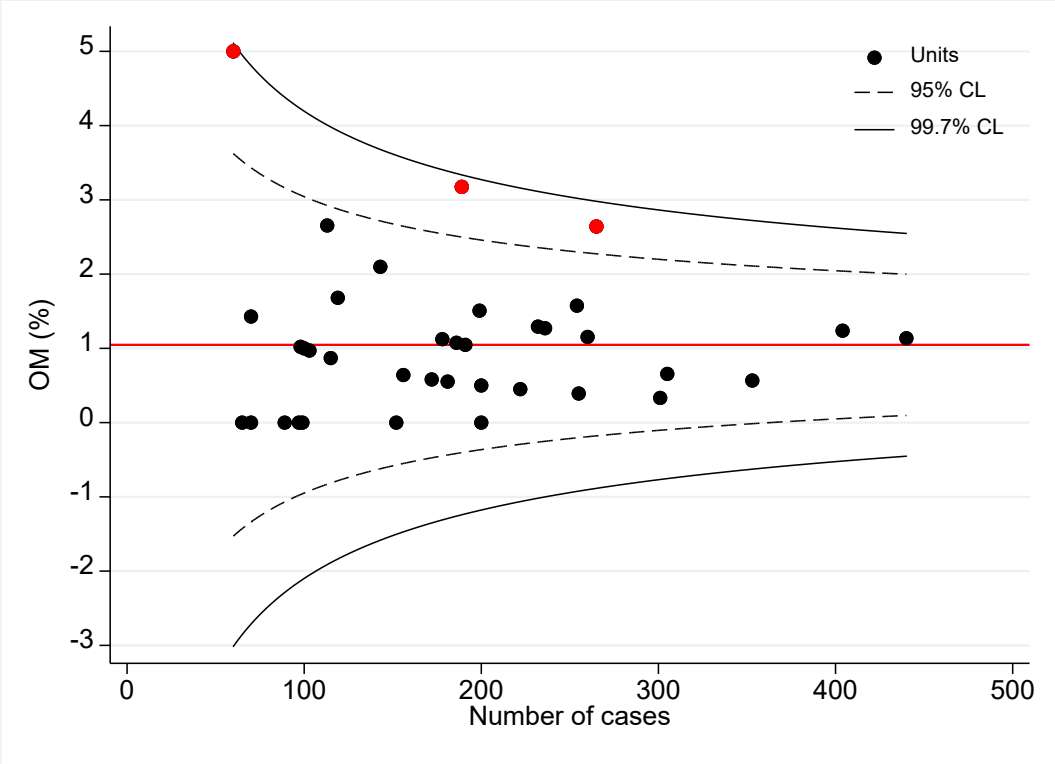
Funnel plots are an established benchmarking tool used to compare performance between healthcare providers. The plots include a single datapoint for each unit with the coordinates based on unit case number (x-axis) and aggregate outcome data (y-axis) for the specified time period.

The mean and standard deviation for all units, combined, are used to plot two sets of control limits (the 'funnels') which correspond to 95% (approximately two standard deviations) and 99.7% (approximately three standard deviations) from the mean. These cut-offs equate to the probability with which a unit performing at the expected level would be expected to fall within the control limits. Statistically, the selected limits impose a probability of false positive identification of an outlier of five or 0.3% for units outside the 95 or 99.7% control limits, respectively.

An advantage of funnel plots is that case number is factored into the control limits due to the reduced standard deviation for units with higher case volumes. This ensures that smaller volume units that are more susceptible to higher variation in outcomes are not evaluated using the lower thresholds associated with the larger volume units.

Figure E below illustrates operative mortality (OM) after isolated CABG in Australia in 2018. The solid red line represents the OM for all units, the two-dashed lines are the 95% control limits and the solid black lines are the 99.7% control limits. The funnel plot demonstrates how the control limits narrow as the number of cases increases. This representation illustrates the invalidity of ranking all of those units from "best" to "worst" as only three were worse than the majority, all of which had statistically similar outcomes.

Figure E. OM following isolated CABG by unit



Appendix F

Supplementary data - outcomes by unit

Table F1. Outcomes by unit in isolated CABG by unit, 2021

	n	OM (%)	RA-OM (%)	dNRI (%)	RA-dNRI (%)	Permanent Stroke (%)	DSWI (%)	RTT for bleeding (%)
Unit 1	96	0.0	0.0	0.0	0.0	1.0	1.0	4.2
Unit 2	199	2.5	1.7	1.0	0.8	0.5	2.5	3.0
Unit 3	302	1.3	1.2	2.7	2.8	0.7	1.7	2.6
Unit 4	122	2.5	1.8	5.0	4.2	0.8	0.8	2.5
Unit 5	144	0.0	0.0	2.1	1.6	0.0	1.4	1.4
Unit 6	217	0.9	0.6	0.9	0.9	0.0	0.0	2.3
Unit 7	71	0.0	0.0	2.9	2.5	1.4	2.8	5.6
Unit 8	75	0.0	0.0	1.3	1.6	0.0	1.3	0.0
Unit 9	62	1.9	1.1	0.0	0.0	0.0	0.0	0.0
Unit 10	254	1.2	0.9	1.2	1.0	2.0	0.0	2.0
Unit 11	76	0.0	0.0	2.6	3.0	0.0	0.0	1.3
Unit 12	97	1.0	1.3	1.0	1.4	2.1	2.1	1.0
Unit 13	100	0.0	0.0	3.0	2.9	1.0	0.0	1.0
Unit 14	59	0.0	0.0	0.0	0.0	0.0	1.7	3.4
Unit 15	100	0.0	0.0	2.0	2.6	0.0	1.0	0.0
Unit 16	471	0.2	0.1	2.6	2.1	0.6	0.8	2.1
Unit 17	240	0.8	0.5	3.4	2.4	1.7	2.1	2.9
Unit 18	41	0.0	0.0	2.5	3.6	2.5	0.0	0.0
Unit 19	117	0.0	0.0	1.7	1.9	0.9	1.7	2.6
Unit 20	219	0.0	0.0	0.5	0.5	0.5	0.9	2.3
Unit 21	27	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unit 22	104	0.0	0.0	1.9	1.6	0.0	1.9	2.9
Unit 23	229	0.4	0.3	3.2	2.5	1.3	0.4	2.2
Unit 24	148	0.0	0.0	1.4	1.9	0.7	0.7	1.4
Unit 25	195	0.0	0.0	2.1	1.6	2.6	0.0	3.1
Unit 26	268	0.7	0.4	2.7	2.0	1.9	1.9	1.9
Unit 27	195	0.5	0.6	3.6	4.6	0.5	0.0	2.1
Unit 28	108	0.0	0.0	2.9	2.1	0.0	0.9	0.0
Unit 29	212	2.0	0.8	3.4	2.5	0.9	1.0	0.5
Unit 30	250	1.6	0.9	4.3	2.8	0.0	1.6	5.3^
Unit 31	78	0.0	0.0	1.7	2.4	0.0	0.0	0.0
Unit 32	172	0.6	0.3	3.0	2.3	3.5^	0.0	0.0
Unit 33	75	2.8	3.0	1.4	1.3	2.7	0.0	1.3
Unit 34	65	0.0	0.0	4.7	8.3^	1.5	0.0	6.2
Unit 35	453	2.4^	2.0^	3.2	2.5	1.3	1.3	2.2
Unit 36	328	1.2	1.0	1.5	1.3	0.9	0.3	2.4
Unit 37	116	0.0	0.0	3.5	2.6	0.0	0.9	1.7
Unit 38	77	1.3	1.2	0.0	0.0	0.0	1.3	3.9
Unit 39	131	0.0	0.0	0.8	0.7	0.0	0.0	3.1
Unit 40	164	0.6	0.7	3.1	3.6	0.0	0.6	0.0
Unit 41	313	1.0	0.8	2.6	2.0	0.3	0.6	1.3
Unit 42	123	0.0	0.0	0.0	0.0	0.0	0.0	3.3
Unit 43	176	1.1	1.1	1.1	1.2	0.6	2.3	1.7
Unit 44	128	0.8	0.8	1.6	2.1	0.8	2.3	0.0
Unit 45	177	0.0	0.0	1.2	0.7	0.0	0.6	1.1
Unit 46	83	0.0	0.0	6.2	6.3	1.2	1.2	2.4
Unit 47	167	1.8	1.5	4.3	4.5	0.0	1.2	3.0
Unit 48	177	2.3	1.6	5.2	4.5	1.7	0.0	4.0
Unit 49	246	3.3^	2.3	2.9	2.9	1.2	0.0	0.4
Unit 50	72	1.4	1.4	2.8	2.9	2.8	1.4	1.4

^ unit is above the upper 99.7% control limit on funnel plot for the associated KPI

ˇ unit is below the lower 99.7% control limit on funnel plot for the associated KPI

Table F2. Outcomes by unit in isolated CABG by unit, 2017 – 2020

	n	OM (%)	RA-OM (%)	dNRI (%)	RA-dNRI (%)	Permanent Stroke (%)	DSWI (%)	RTT for bleeding (%)
Unit 1	410	0.3	0.3	0.5	0.5	0.5	1.2	2.0
Unit 2	820	1.5	1.3	2.4	2.1	0.5	2.68^	4.0
Unit 3	1143	1.9	1.6	2.8	2.6	1.0	1.7	3.1
Unit 4	709	1.1	1.1	2.6	2.3	2.1	0.4	2.0
Unit 5	38	0.0	0.0	0.0	0.0	0.0	0.0	5.3
Unit 6	952	0.5	0.4	3.3	2.8	1.2	0.7	1.7
Unit 7	23	5.0	1.6	9.5	9.5	0.0	0.0	4.5
Unit 8	-	-	-	-	-	-	-	-
Unit 9	18	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unit 10	1183	1.1	0.9	2.2	1.9	1.4	1.1	3.0
Unit 11	333	0.3	0.5	1.8	2.3	0.3	0.9	2.1
Unit 12	378	1.1	1.7	0.8	1.0	1.3	2.1	2.1
Unit 13	367	0.5	0.6	1.7	2.2	0.3	0.0	1.1
Unit 14	195	1.5	1.7	2.6	2.6	1.0	1.5	6.2^
Unit 15	35	0.0	0.0	5.7	11.4^	2.9	0.0	2.9
Unit 16	1941	0.8	0.6	2.0	1.6	0.9	2.0^	3.6^
Unit 17	797	1.8	1.0	4.4^	3.3	0.8	1.9	3.8
Unit 18	212	1.9	1.5	1.4	1.7	0.5	1.4	1.4
Unit 19	296	1.0	1.4	1.4	1.6	0.0	0.7	1.4
Unit 20	901	0.4	0.5	0.7ᵛ	0.7ᵛ	0.3	0.6	1.0
Unit 21	-	-	-	-	-	-	-	-
Unit 22	320	0.9	0.6	3.1	2.7	0.3	0.6	1.3
Unit 23	1089	0.9	0.9	2.2	1.8	1.9	0.7	1.9
Unit 24	575	1.0	1.5	2.8	4.0	1.2	0.5	1.2
Unit 25	634	1.4	1.2	1.8	1.6	0.9	0.2	2.7
Unit 26	1265	1.3	0.9	1.1ᵛ	0.8ᵛ	1.3	0.9	2.1
Unit 27	818	1.1	1.4	3.0	3.8	0.6	0.2	1.6
Unit 28	600	1.5	1.4	3.0	2.3	1.0	1.3	2.0
Unit 29	768	1.1	0.8	1.7	1.8	0.5	0.5	3.4
Unit 30	1135	1.6	1.0	3.9	2.6	1.7	0.9	4.5^
Unit 31	-	-	-	-	-	-	-	-
Unit 32	860	1.4	0.9	3.7	3.4	1.5	0.9	1.2
Unit 33	323	1.0	0.7	3.5	2.7	0.6	1.2	1.9
Unit 34	307	0.3	0.4	2.0	2.5	1.3	0.0	1.6
Unit 35	905	2.7^	2.1^	2.0	1.6	1.1	1.3	2.9
Unit 36	1356	0.9	0.7	1.7	1.3	1.0	1.9	2.4
Unit 37	109	1.8	0.9	1.9	1.2	1.9	0.0	2.8
Unit 38	31	0.0	0.0	6.5	4.3	0.0	3.2	9.7
Unit 39	377	0.3	0.3	1.3	1.3	0.8	1.4	2.9
Unit 40	33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unit 41	1517	1.2	1.1	5.7^	4.5^	1.0	1.3	1.5
Unit 42	392	0.3	0.3	1.3	1.4	0.3	0.8	4.1
Unit 43	495	0.6	0.5	1.7	1.4	0.8	0.8	2.6
Unit 44	421	0.8	0.9	0.5	0.5	0.7	2.4	0.7
Unit 45	732	0.8	0.8	2.4	1.6	0.3	1.0	3.3
Unit 46	53	1.9	2.0	3.8	4.0	1.9	1.9	3.8
Unit 47	738	1.4	1.1	4.2	4.1^	1.4	0.5	2.2
Unit 48	803	1.1	1.1	3.8	3.2	0.9	1.6	2.4
Unit 49	1008	1.4	1.3	2.2	2.0	1.7	0.9	1.7
Unit 50	-	-	-	-	-	-	-	-

^unit is above the upper 99.7% control limit on funnel plot for the associated KPI

ᵛunit is below the lower 99.7% control limit on funnel plot for the associated KPI

Table F3. Outcomes by unit in isolated AVR surgery by unit, 2017 – 2021

	n	OM (%)	RA-OM (%)	dNRI (%)	RA-dNRI (%)	Permanent Stroke (%)	DSWI (%)	RTT for bleeding (%)
Unit 1	117	1.1	0.8	0.0	0.0	2.6	0.9	5.2
Unit 2	216	0.9	0.8	1.4	0.9	0.0	0.5	4.2
Unit 3	276	2.2	1.2	5.2	3.3	2.9	0.7	5.1
Unit 4	157	1.9	2.0	2.6	1.8	0.0	0.6	3.8
Unit 5	13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unit 6	184	1.1	0.9	3.9	2.6	1.1	0.0	1.6
Unit 7	21	4.8	6.8	0.0	0.0	0.0	0.0	4.8
Unit 8	19	0.0	0.0	0.0	0.0	0.0	0.0	5.3
Unit 9	21	0.0	0.0	0.0	0.0	0.0	0.0	4.8
Unit 10	267	0.4	0.2	3.1	1.8	0.4	1.1	4.9
Unit 11	99	1.0	1.0	2.0	2.2	1.0	0.0	3.0
Unit 12	105	1.0	0.9	1.9	2.0	1.0	1.0	2.9
Unit 13	60	0.0	0.0	1.7	1.8	0.0	0.0	1.7
Unit 14	83	1.2	1.2	3.6	3.9	2.4	0.0	6.0
Unit 15	31	3.2	1.7	0.0	0.0	3.2	0.0	9.7
Unit 16	571	1.2	0.9	2.3	1.5	0.5	1.1	4.9
Unit 17	165	0.0	0.0	6.1	3.9	1.8	0.6	3.0
Unit 18	43	2.3	1.8	5.0	4.9	0.0	0.0	0.0
Unit 19	111	0.9	0.6	0.0	0.0	0.9	0.9	6.3
Unit 20	295	0.7	0.6	1.4	1.3	0.3	0.0	0.7
Unit 21	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unit 22	89	1.1	0.7	5.6	4.7	0.0	1.1	4.5
Unit 23	208	2.4	1.2	5.8	4.0	1.4	0.5	3.8
Unit 24	160	1.9	1.3	1.9	1.8	3.1	0.0	1.9
Unit 25	143	0.0	0.0	1.4	1.0	1.4	0.7	2.8
Unit 26	219	2.8	1.3	1.9	1.2	1.8	0.5	3.7
Unit 27	185	0.0	0.0	2.2	2.1	0.0	0.0	3.2
Unit 28	120	1.7	1.2	0.8	0.5	0.0	0.8	5.0
Unit 29	219	0.9	0.6	2.8	2.0	1.4	0.0	3.7
Unit 30	228	1.3	0.9	3.1	2.0	2.6	0.0	4.8
Unit 31	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unit 32	147	3.4	2.0	3.5	1.8	2.0	2.0	2.0
Unit 33	178	1.2	0.9	1.7	1.0	0.6	0.0	0.6
Unit 34	86	1.2	1.0	7.0	5.9	2.3	1.2	3.5
Unit 35	280	1.8	1.1	3.3	2.0	2.1	0.7	3.2
Unit 36	270	0.7	0.5	3.8	2.1	1.5	0.4	6.7
Unit 37	50	2.0	0.9	4.1	1.5	4.0	0.0	2.0
Unit 38	22	4.5	2.7	4.5	3.4	0.0	0.0	9.1
Unit 39	102	0.0	0.0	1.0	0.9	1.0	1.0	0.0
Unit 40	18	5.6	3.6	0.0	0.0	0.0	0.0	5.6
Unit 41	214	3.7	2.6	9.6^	6.7^	2.8	0.5	6.5
Unit 42	159	0.6	0.4	0.6	1.3	0.6	0.0	5.0
Unit 43	159	1.3	0.6	3.2	2.1	0.6	0.0	6.9
Unit 44	176	0.0	0.0	0.6	0.5	0.0	1.1	2.8
Unit 45	217	1.4	0.8	2.3	1.4	0.0	0.5	5.5
Unit 46	50	2.0	1.7	4.0	3.6	2.0	0.0	0.0
Unit 47	214	0.5	0.4	5.2	3.5	1.4	0.5	2.3
Unit 48	152	2.6	1.6	6.0	3.6	3.3	1.3	6.0
Unit 49	181	1.7	1.3	3.9	2.3	2.2	0.0	4.4
Unit 50	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

^unit is above the upper 99.7% control limit on funnel plot for the associated KPI

ˇunit is below the lower 99.7% control limit on funnel plot for the associated KPI

Table F4. Outcomes by unit in combined AVR and CABG surgery by unit, 2017 – 2021

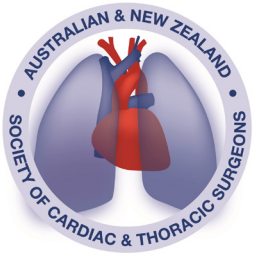
	n	OM (%)	RA-OM (%)	dNRI (%)	RA-dNRI (%)	Permanent Stroke (%)	DSWI (%)	RTT for bleeding (%)
Unit 1	69	1.8	1.6	0.0	0.0	0.0	1.4	4.3
Unit 2	114	1.8	1.7	0.9	0.5	1.8	2.6	9.6
Unit 3	137	4.4	3.1	5.3	2.1	1.5	1.5	2.9
Unit 4	67	1.5	1.3	3.1	1.3	0.0	1.5	6.0
Unit 5	21	0.0	0.0	9.5	4.0	4.8	0.0	4.8
Unit 6	140	5.0	3.9	8.8	3.8	3.6	2.1	2.9
Unit 7	8	0.0	0.0	12.5	7.5	12.5	0.0	12.5
Unit 8	10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unit 9	8	0.0	0.0	0.0	0.0	12.5	0.0	12.5
Unit 10	118	6.0	3.2	8.1	3.0	2.6	0.9	10.3
Unit 11	48	0.0	0.0	0.0	0.0	0.0	0.0	4.2
Unit 12	67	1.5	1.9	4.5	2.4	1.5	1.5	3.0
Unit 13	69	2.9	2.1	5.8	2.8	1.4	0.0	2.9
Unit 14	32	0.0	0.0	3.1	2.0	3.1	0.0	0.0
Unit 15	20	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unit 16	316	1.3	1.0	3.9	1.6	0.9	1.6	7.0
Unit 17	113	0.9	0.9	5.4	2.6	2.7	1.8	5.3
Unit 18	27	3.7	5.8	0.0	0.0	0.0	0.0	11.5
Unit 19	61	0.0	0.0	1.7	0.6	0.0	0.0	8.2
Unit 20	181	0.6	0.5	2.8	1.3	0.0	1.1	1.7
Unit 21	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unit 22	57	0.0	0.0	3.5	1.5	1.8	1.8	0.0
Unit 23	85	5.9	4.3	8.6	3.9	3.5	0.0	7.1
Unit 24	127	1.6	1.4	4.0	1.7	1.6	0.8	2.4
Unit 25	96	4.2	2.7	2.1	1.0	2.1	0.0	6.3
Unit 26	137	3.0	2.7	2.3	1.0	3.6	0.7	5.8
Unit 27	134	2.2	2.8	4.5	2.5	1.5	0.7	2.2
Unit 28	62	6.5	5.6	5.0	2.0	3.2	0.0	1.6
Unit 29	97	3.1	2.8	9.4	4.4	2.1	1.0	5.2
Unit 30	188	4.3	2.9	7.1	2.8	2.7	1.1	8.5
Unit 31	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unit 32	83	2.4	1.5	10.0	4.1	2.4	2.4	0.0
Unit 33	64	4.8	3.4	4.8	1.6	1.6	4.7	1.6
Unit 34	31	0.0	0.0	9.7	3.4	0.0	0.0	0.0
Unit 35	172	4.1	3.5	3.0	1.5	3.5	1.8	7.0
Unit 36	153	1.3	1.0	10.7	3.9	1.3	2.6	6.5
Unit 37	37	10.8^	5.6	8.1	3.2	8.1	0.0	0.0
Unit 38	7	0.0	0.0	14.3	6.5	0.0	0.0	14.3
Unit 39	49	0.0	0.0	2.0	0.8	4.1	2.1	4.1
Unit 40	22	0.0	0.0	0.0	0.0	0.0	4.5	0.0
Unit 41	192	2.1	1.8	7.8	3.2	2.1	1.6	3.6
Unit 42	86	3.6	5.8	1.2	0.8	1.2	1.2	2.3
Unit 43	80	1.3	0.9	5.2	2.1	1.3	0.0	10.0
Unit 44	104	1.0	0.7	2.9	1.1	3.8	0.0	4.8
Unit 45	110	3.6	3.9	3.7	1.7	0.9	0.0	1.8
Unit 46	31	0.0	0.0	6.5	1.2	3.2	0.0	3.2
Unit 47	101	2.0	2.0	7.0	2.8	1.0	0.0	4.0
Unit 48	112	3.6	3.0	9.9	4.1	2.7	0.9	5.4
Unit 49	116	2.6	2.7	4.3	2.2	0.9	0.0	3.4
Unit 50	5	0.0	0.0	20.0	7.6	0.0	0.0	0.0

^unit is above the upper 99.7% control limit on funnel plot for the associated KPI

ˇunit is below the lower 99.7% control limit on funnel plot for the associated KPI

References

1. Statistics ABo. Australian National Accounts: National Income, Expenditure and Product. Canberra: ABS; 2022 March 2022.
2. Beckmann A, Meyer R, Lewandowski J, Markewitz A, Blassfeld D, Boning A. German Heart Surgery Report 2021: The Annual Updated Registry of the German Society for Thoracic and Cardiovascular Surgery. Thorac Cardiovasc Surg. 2022;70(5):362-76.
3. SWEDEHEART Annual report 2021. 2022.
4. Bowdish ME, D'Agostino RS, Thourani VH, Schwann TA, Krohn C, Desai N, et al. STS Adult Cardiac Surgery Database: 2021 Update on Outcomes, Quality, and Research. Ann Thorac Surg. 2021;111(6):1770-80.
5. Programme NCA. National Adult Cardiac Surgery Audit (NACSA) 2021 Summary Report. 2021.
6. Penny-Dimri JC, Cochrane AD, Perry LA, Smith JA. Characterising the Role of Perioperative Erythropoietin for Preventing Acute Kidney Injury after Cardiac Surgery: Systematic Review and Meta-Analysis. Heart Lung Circ. 2016;25(11):1067-76.
7. Irving AH, Harris A, Petrie D, Higgins A, Smith J, McQuilten ZK. Impact of patient blood management guidelines on blood transfusions and patient outcomes during cardiac surgery. J Thorac Cardiovasc Surg. 2020;160(2):437-45 e20.
8. Irving AH, Harris A, Petrie D, Higgins A, Smith JA, Tran L, et al. Economic Evaluation of National Patient Blood Management Clinical Guidelines in Cardiac Surgery. Value Health. 2022;25(3):419-26.
9. Litton E, Bass F, Delaney A, Hillis G, Marasco S, McGuinness S, et al. Six-Month Outcomes After High-Risk Coronary Artery Bypass Graft Surgery and Preoperative Intra-aortic Balloon Counterpulsation Use: An Inception Cohort Study. J Cardiothorac Vasc Anesth. 2018;32(5):2067-73.
10. Litton E, Bass F, Dickson C, Hillis G, Inskip D, Jacques T, et al. Prophylactic Intra-Aortic Balloon Counterpulsation in High Risk Cardiac Surgery: The PINBALL Pilot Multicentre, Registry-Linked, Randomised, Controlled Feasibility Trial. Heart Lung Circ. 2020;29(5):710-8.



MONASH University

Health and Human Services

CLINICAL EXCELLENCE COMMISSION

Queensland Government

Contact Details

Postal Address:
ANZSCTS Database
Monash University
Level 4, 553 St Kilda Road
Melbourne 3004

Web: www.anzscts.org/database
Email: anzscts@monash.edu
Telephone: +61 3 9903 0518
Facsimile: +61 3 9903 0556