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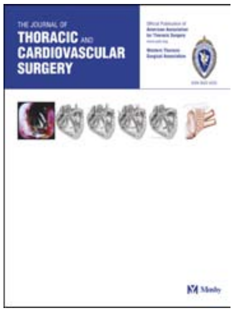

Acute Risk change for Cardio-Thoracic admissions to Intensive Care (The ARCTIC Index): A New Measure of Quality in Cardiac Surgery

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Acute **R**isk change for **C**ardio-**T**horacic admissions to **I**ntensive **C**are (The ARCTIC Index): A New Measure of Quality in Cardiac Surgery

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Abstract

Introduction: Quality of cardiac surgical care may vary between institutions. Mortality is low and large numbers are required to discriminate between hospitals. Measures other than mortality may provide better comparisons.

Objectives: To develop and assess a new performance measure for cardio-thoracic admissions to the Intensive Care Unit (ICU): The ARCTIC index (**A**cute **R**isk change for **C**ardio-**T**horacic admissions to **I**ntensive **C**are).

Methods: The Australian and New Zealand Society of Cardiac and Thoracic Surgeons database and Australian and New Zealand Intensive Care Society Adult Patient Database were linked. Logistic regression was used to generate a predicted risk of death first from preoperative data using the previously validated "Allprocscore" and secondly on admission to ICU using APACHE III score. Change in risk as a percentage (ARCTIC) was calculated for each patient. The validity of ARCTIC as a marker of quality was assessed by comparison with intraoperative variables and postoperative morbidity markers.

Results: 16,687 patients at 21 hospitals from 2008 to 2011 were matched. An increase in ARCTIC was associated with prolonged cardiopulmonary bypass time ($p=0.001$), intra-operative blood product transfusion ($p<0.001$), reoperation ($p<0.0001$), post-operative renal failure ($p<0.0001$), prolonged ventilation ($p<0.0001$) and stroke ($p=0.001$).

Conclusion: The ARCTIC index is associated with known markers of perioperative performance and postoperative morbidity. It may be used as an overall marker of quality for cardiac surgery. Further work is required to assess ARCTIC as a method to discriminate between cardiac surgical units.

Word Count: 233

Ultramini abstract

The ARCTIC index is a new measure of overall quality in cardiac surgery derived from the difference in mortality risk between pre and postoperative phases. ARCTIC was associated with known markers of perioperative performance and postoperative morbidity. In future ARCTIC may help discriminate between cardiac surgical units.

Word Count: 47

Introduction

Cardiac surgical programs in many countries routinely monitor procedures and outcomes. The function of this large-scale monitoring is to maintain and improve the quality of patient care. Despite more than twenty years of experience, the concept of quality of care remains difficult to define and measure[1]. Measures of quality include outcome measures such as risk-adjusted mortality and risk-adjusted major morbidity (eg. renal failure, stroke, deep sternal infection, prolonged ventilation and reoperation) and process measures such as use of internal mammary artery grafts and optimal perioperative medical therapy. Currently the Society of Thoracic Surgeons uses all the above in a composite quality score[2].

The most intuitive measures of quality are outcomes. Mortality rate (adjusted for preoperative risk) was one of the earliest quality measures to be used. Due to advances in surgical and medical knowledge the in hospital mortality rate for the most common cardiac surgical procedure, coronary artery bypass grafting (CABG), has reduced to as little as 1.5%[3].This means that using in hospital mortality to determine significant variation in performance between units requires large numbers[4]. Achieving these numbers in many units takes considerable time, delaying the time to recognition of under or over performing units. Alternative methods may be useful to more effectively monitor and recognise outliers in performance.

The Australian and New Zealand Society of Cardiac and Thoracic Surgeons Cardiac Surgical Database (ANZSCTS-CSD) was developed in 2001 and includes data from public and private hospitals. Patient data from all cardiac surgical procedures occurring at participating hospitals is included. Demographic, pre-, intra- and post-operative data, outcomes and derived scores such as the previously validated 'Allprocscore'[5,6] are recorded. Cardiac surgical risk of death scores typically use pre operative variables that are not under the control of the provider.

The Australian and New Zealand Intensive Care Society Adult Patient Database (ANZICS-APD) is one of four registries run by the ANZICS Centre for Outcome and Resource Evaluation. The ANZICS-APD presently contains de-identified patient data on 1.4 million ICU admissions from 85% of Intensive Care Units (ICUs) in Australia and New Zealand. It contains demographic, diagnostic and physiological data from the first 24 hours of ICU admission for calculation of severity of illness scores such as the Acute Physiological and Chronic Health Evaluation (APACHE) III score. It can therefore provide information on the immediate postoperative period. Both databases are audited to assess reliability of submitted data.[5,7,8] The presence of two databases with data from the same patients provides a rare opportunity to study the entire perioperative episode, giving a more complete picture of procedural risk for each patient.

The aim of our study was to derive a measure of change in mortality risk from pre operative period to the time of ICU admission after coronary artery bypass grafting (CABG) or cardiac valve repair/replacement (VR) surgery (Figure 1) and to attempt to validate this **A**cute **R**isk change for **C**ardio-**T**horacic admissions to **I**ntensive **C**are (The ARCTIC index) as a potential marker of perioperative cardiothoracic performance. Our hypothesis was that ARCTIC would not only correlate with intra-operative measures of surgical performance but also post-operative markers of morbidity already recognised as performance measures for cardiothoracic units.

Methods

Matching of ANZICS and ANZSCTS databases

Probabilistic methodology was used to match individual patient data from 21 sites which contributed to both ANZSCTS databases and the ANZICS-APD between 2008 and 2011[9]. Only CABG and/or cardiac valve operations were included. Patients in each database were considered matched if a minimum of six out of seven of the following variables were identical: ICU admission date, hospital admission date, ICU discharge date, hospital discharge date, age, sex and postcode. Patients admitted to an ICU before cardiac surgery who then proceed to cardiac surgery would have a non operative APACHE diagnosis were excluded as these patients would not have post operative APACHE scores.

Generation of ARCTIC

All Statistical analyses were performed using STATA version 12 (StataCorp., College Station, TX, USA). Pre-operative predicted risk of death (ROD_{pre}) was calculated using logistic regression and 'Allprocscore'[5]. Variables included in 'Allprocscore' include: age, gender, NYHA class, urgency of procedure, ejection fraction, hypercholesterolaemia, preoperative dialysis, previous cardiac surgery, procedure type, inotropic medication, peripheral vascular disease and BMI. Postoperative predicted risk of death (ROD_{post}) was calculated using logistic regression based on APACHEIII score and type of operation ("CABG", "VR" or "CABG & VR"). The APACHE III score is based on age, chronic health conditions and acute physiological variables (eg. blood pressure). Model calibration was checked using the Hosmer-Lemeshow 'goodness-of-fit' test. Model discrimination was assessed using area under the receiver operator characteristic. The ARCTIC index was created by subtraction of ROD_{pre} from ROD_{post}, such that a positive ARCTIC (as a percentage increase in risk of death) denoted an increase in risk of death. Normality of distribution for ARCTIC was assessed.

Relationship of ARCTIC to pre and intra-operative variables

The relationship between the ARCTIC index to pre and intra-operative factors was assessed in the following way: Pre and intraoperative variables (excluding those already used in 'Allprocscore') were identified. Univariate linear regression was carried out to look for association between variables and ARCTIC. Variables with a univariate p-value of less than 0.10 were subjected to stepwise regression (forwards and backwards elimination procedures) to identify factors independently associated with ARCTIC. Two-way interactions between variables were tested. Variables exhibiting co-linearity were removed.

Relationship of the ARCTIC index to postoperative morbidity

The ARCTIC index was compared to other known markers of morbidity[2], including new renal failure (increased creatinine >200umol/l, doubling of baseline creatinine or new need for renal replacement therapy), prolonged ventilation (>24hrs), return to theatre (for complications related to original surgery), deep sternal wound infection (debridement plus antibiotics or positive culture) and new stroke (deficit >72hrs). The mean ARCTIC for groups with and without the complication was compared using t-tests.

Ethical review

The study was reviewed and approved by the Alfred Hospital research ethics committee (Ref 66/13).

Results

27,115 patients were identified in the ANZSCTS-CSD with a valid ICU admission date. 19,304 patients could be matched using at least 6 identical variables. There were differences between matched and unmatched patients that achieved statistical significance (appendix 1). After removal of non-CABG/VR procedures 16,687 patients at 21 centres were left in the database (Figure 2). Demographics and overall outcomes of study patients are shown in table 1.

Logistic regression models generated using 'Allprocscore' and APACHEIII score performed well in predicting ROD_{pre} (area under receiver operating curve 0.78, Hosmer-Lemeshow $chi^2 = 12.56$, $p = 0.13$) and ROD_{post} (area under receiver operating curve 0.84, Hosmer-Lemeshow $chi^2 = 10.4$, $p = 0.24$). ARCTIC (ROD_{post} - $ROD_{pre)}$ assumed a symmetrical distribution.

Twenty three pre- and intra-operative variables were identified as having a significant univariate relationship with ARCTIC including race, diabetes, preoperative creatinine, hypertension, hypercholesterolaemia, preoperative shock, immunosuppressive treatment, infective endocarditis, clopidogrel use, tirofiban use, cardiopulmonary bypass time, cross-clamp time, presence of consultant surgeon, red cell units transfused, fresh frozen plasma units transfused, platelets transfused, antifibrinolytic use, intraoperative transoesophageal echocardiography, intraoperative decision to graft coronary arteries, number of diseased vessels, balloon pump (IABP) use and ventricular assist device (VAD) use. Stepwise regression resulted in the identification of 10 variables independently associated with ARCTIC. All variables were available for 87% of the matched database. Bypass time and cross clamp time exhibited a high degree of collinearity and hence cross clamp time was eliminated from the model. The interaction between shock and red blood cells transfused was found to be significant. The final model is shown in table 2. Seven variables were independently associated with risk increase. Four, including the one interaction variable, were associated with a reduction in risk.

ARCTIC was significantly higher with four of the five post-operative morbidity markers tested: new renal failure (-0.12% (0.03) vs 2.23% (0.43), p<0.0001), prolonged ventilation (-0.19% (0.03) vs 1.47% (0.27), p<0.0001), return to theatre (-0.17% (0.04) vs 2.28% (0.35), p=<0.0001) and new stroke (-0.03% (0.04) vs 1.19% (0.70), p=0.001) (table 3). Deep sternal wound infection was not significantly associated with risk change.

Discussion

In this study we have developed the ARCTIC index, which represents a change in risk of death from the pre-operative to post-operative period for patients having cardiac surgery. We have shown consistent and biologically plausible relationships with known perioperative markers of morbidity. To our knowledge this is the first time a potential overall measure of cardiac performance has been developed which is relevant to the whole perioperative period.

By combining cardiac and ICU databases we were able to calculate both a pre and postoperative risk for patients. Both risk scores performed well and enabled the calculation of change in mortality risk (the ARCTIC index) between the pre and post-operative periods. Although it was not surprising that the previously published 'Allprocscore'[5] was related to mortality, the APACHE III score has not until now been validated for this purpose. Indeed the APACHE III score had better discrimination than the 'Allprocscore' which may relate to the fact it is measured later in the patient's course (i.e. temporally closer to the final outcome). Intraoperative events and preoperative risk factors that are known to be associated with poor outcome were associated with an adverse ARCTIC, (i.e. an increasing postoperative risk of death). These included the number of red cell and plasma units transfused, cardiac bypass time, IABP use, preoperative creatinine and diabetes[10-16]. It is also unsurprising that the requirement for a VAD insertion would be associated with an adverse ARCTIC. Thus the relationship between ARCTIC and these intra-operative events supports consideration for its use as a plausible marker for assessing peri-operative performance.

Similarly some intra-operative variables were associated with a beneficial ARCTIC, or reduction in postoperative risk (i.e. those with negative coefficients), for example, a consultant surgeon operating (as opposed to a more junior member of the team) and the use of any anti-fibrinolytic (previously shown to be associated with reduction in bleeding[17]). Curiously, cardiogenic shock was also associated with a reduction in postoperative risk. This may be due to therapeutic intervention in patients with preoperative cardiogenic shock and a very high preoperative risk of death, or the known over-prediction of cardiac surgical risk models in very high risk patients[18] or unquantifiable aspects of patient selection. It should also be noted that the database records cardiogenic shock at any perioperative point and therefore this variable might include a heterogenous population. A statistical interaction between cardiogenic shock and red cell units transfused was also associated with ARCTIC. The nature of this interaction appears to be a positive effect of red cells transfused when shock is present and a negative effect when shock is absent. While the benefits and adverse effects of transfusion are only partially understood, they are likely to have differential effects according to clinical situation, therefore this finding does seem at least physiologically reasonable. One other study has reported a trend towards increased cardiogenic shock in patients with restrictive transfusion regimes[19].

Patients with higher ARCTIC were more likely to experience postoperative markers of morbidity, including return to theatre, prolonged ventilation, stroke and new renal failure. This further supports the assertion that ARCTIC is associated with an adverse perioperative course leading to postoperative complications. The causes of these adverse events can only be speculated, but given the factors associated with ARCTIC these may include: prolonged surgery, less skilled operators and perioperative bleeding.

Future uses of ARCTIC include as a screening tool to identify near miss scenarios and to potentially quantify the effect of a complication in a more objective way. For example take back to the OR may not have an adverse effect on risk of death if it is timely. Similarly a prolonged operation may not be detrimental if the patient arrives in the ICU in good physiological condition and their post operative risk of death is unchanged compared to their pre op risk. ARCTIC may also be useful in assessing overall comparative performance of cardio-thoracic units. Its consistent relationship with many recognised markers of perioperative morbidity may allow its use to benchmark units with very low mortality rates or with very low case numbers. However, further work will be required to determine its applicability to these situations.

Study limitations

Limitations should be addressed. Not all patients in the database were matched. Appendix 1 shows that there were some small differences between identically matched and unmatched patients that were statistically significant. Matched patients were younger, had lower preoperative risk scores, lower ejection fractions and were more likely to be dialysed. It is unclear why this pattern of matching should occur based on the matching criteria described above. These differences are likely to impact on the generalizability of the findings to the overall population. Future data collection should use unique identifiers to reduce the impact of this limitation.

The APACHE III score is currently not collected by ANZSCTS so additional data or a regular match would be required to use ARCTIC as a quality marker. This is feasible in Australian and New Zealand, however the applicability of this score internationally is unknown. Similar data are collected, for example EUROSCORE, and future work may examine the applicability of ARCTIC to these scores. The time of occurrence of some variables was not recorded, for example cardiogenic shock and transfusion, therefore intraoperative events are harder to isolate. The APACHE III score is calculated from the worst variables in the first 24 hours, therefore change in risk may represent events and treatments within the ICU.

Conclusion

ARCTIC is a new and potentially useful method to measure quality in cardiac surgery. Unlike most other measures it focuses specifically on perioperative care. It is associated with known markers of intraoperative performance and postoperative morbidity. We have demonstrated the feasibility of development of novel performance measures by matching methods across 2 large datasets. Further work is planned to assess ARCTIC as a method to discriminate between cardiac surgical units.

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	Survived (n=16326)	Died (n=325)	All Patients (n=16687)*	*p*-value
Age (mean)	65.8 (12.5)	72.0 (11.3)	65.9 (12.5)	<0.0001
Length of stay (median(IQR))	9 (7-15)	15 (6-32)	9 (7-15)	<0.0001
Male (%)	73.2	60.1	72.9	<0.0001
VR (%)	25.6	29.3	25.7	0.18
CABG (%)	62.6	45.2	62.2	<0.0001
VR/CABG (%)	11.8	25.5	12.1	<0.0001
				<0.0001
Allprocscore (mean(std))	5.21 (4.7)	11.20 (6.1)	5.34 (4.85)	
ROD_{pre} (%)	1.85	6.94	1.95	<0.0001
APACHEIII score (mean(std))	46 (16)	75 (29)	46 (17)	<0.0001
ROD_{post} (%)	1.69	14.1	1.94	<0.0001
ARCTIC (%)	-0.16	7.27	-0.01	<0.0001
Red cell units transfused (median)	0 (0-2)	6 (2-12)	0 (0-2)	<0.0001
Plasma units transfused (median)	0 (0-0)	3 (0-8)	0 (0-0)	<0.0001
Cardiopulmonary Bypass time (median-minutes(IQR))	101 (77-132)	143 (98-201)	101 (77-134)	<0.0001
Diabetes (%)	30.3	38.1	30.4	0.003
Preoperative creatinine (median(IQR))	85 (72-102)	98 (80-129)	85 (72-102)	<0.0001
Ventricular assist device used (%)	0.06	5.64	0.16	<0.001
Balloon pump used (%)	4.0	31.8	4.6	<0.001
Antifibrinolytics used (%)	71.4	80.8	71.6	<0.001
Consultant operating (%)	83.8	88.4	83.9	0.05
Cardiogenic shock (%)	1.03	7.81	1.17	<0.001
New renal failure (%)	4.1	38.6	4.8	<0.001
Prolonged Ventilation (%)	9.6	58.9	10.6	<0.001
New stroke (%)	0.8	13.2	1.1	<0.001
Return to theatre (%)	5.8	41.4	6.5	<0.001
Deep sternal wound infection (%)	0.7	4.1	0.8	<0.001

Table 1. Patient demographics, risk scores and perioperative variables stratified according to survival status. Standard deviation/interquartile range in brackets. Percentages relate to column population.

*Survival data missing for 36 patients

Risk change	Coefficient	Standard error	P value
Red cells transfused*	0.19	0.02	<0.001
FFP transfused*	0.049	0.02	0.032
Bypass time	0.18	0.05	0.001
Diabetic patient	0.31	0.09	0.001
Pre-operative creatinine	0.0039	0.0005	<0.001
Ventricular assist device used*	15.94	0.96	<0.001
Intra aortic balloon pump used*	0.80	0.21	<0.001
Antifibrinolytics used	-0.43	0.10	<0.001
Consultant surgeon operating	-0.52	0.11	<0.001
Cardiogenic shock*	-2.95	0.49	<0.001
Red blood cells/ cardiogenic shock interaction	-0.39	0.05	<0.001

n=14496

Table 2. Regression model: Variables with positive coefficients are associated with an increase in predicted risk of death (positive ARCTIC), those with negative coefficients are associated with a reduction.

* At any perioperative point

Complication (mean (sd))	Risk change if complication absent	Risk change if complication present	p-value
New Renal Failure	-0.12% (0.03)	2.23% (0.43)	<0.0001
Prolonged ventilation	-0.19% (0.03)	1.47% (0.27)	<0.0001
Return to theatre	-0.17% (0.04)	2.28% (0.35)	<0.0001
New stroke	-0.03% (0.04)	1.19% (0.70)	0.001
Deep sternal wound infection	-0.017% (0.04)	0.74% (0.51)	0.053

Table 3. ARCTIC percentage by presence or absence of complications

Appendix 1

	All patients in ANZSCTS database with ICU admission (n=27115)*	Unmatched patients (n=7793)	Matched patients (n=19304)	*p*-value
Age (mean)	68 (58-74)	69 (60-76)	67 (57-75)	<0.0001
Gender**	1 (1-2)	1 (1-2)	1 (1-2)	0.07
VR (%)	38	39	38	0.3
CABG (%)	70	72	69	<0.0001
Other cardiac surgery (%)	10	9	11	<0.0001
Urgency***	1 (1-2)	1 (1-2)	1 (1-2)	<0.0001
NYHA category	2 (1-3)	2 (1-2)	2 (1-3)	<0.0001
Preoperative inotropes (%)	3	3	3	0.45
Ejection fraction (%)	60 (50-65)	60 (50-65)	60 (46-65)	<0.0001
Preoperative dialysis (%)	1.7	1	2	<0.0001
BMI (kg/m^2)	28.7	28.9	28.6	0.06
Allprocscore	6 (2-9)	6 (3-9)	5 (2-9)	<0.0001
Mortality (%)	2	2	2	0.07

Appendix 1. Comparison between matched and unmatched patients. Median/mean/percentage and standard deviation/interquartile range in brackets (as appropriate). Percentages relate to column population.

* Matching data missing for 18 patients

** 1 = male, 2 = female

*** Urgency: 1=Elective, 2=Urgent, 3=Emergency, 4=Salvage

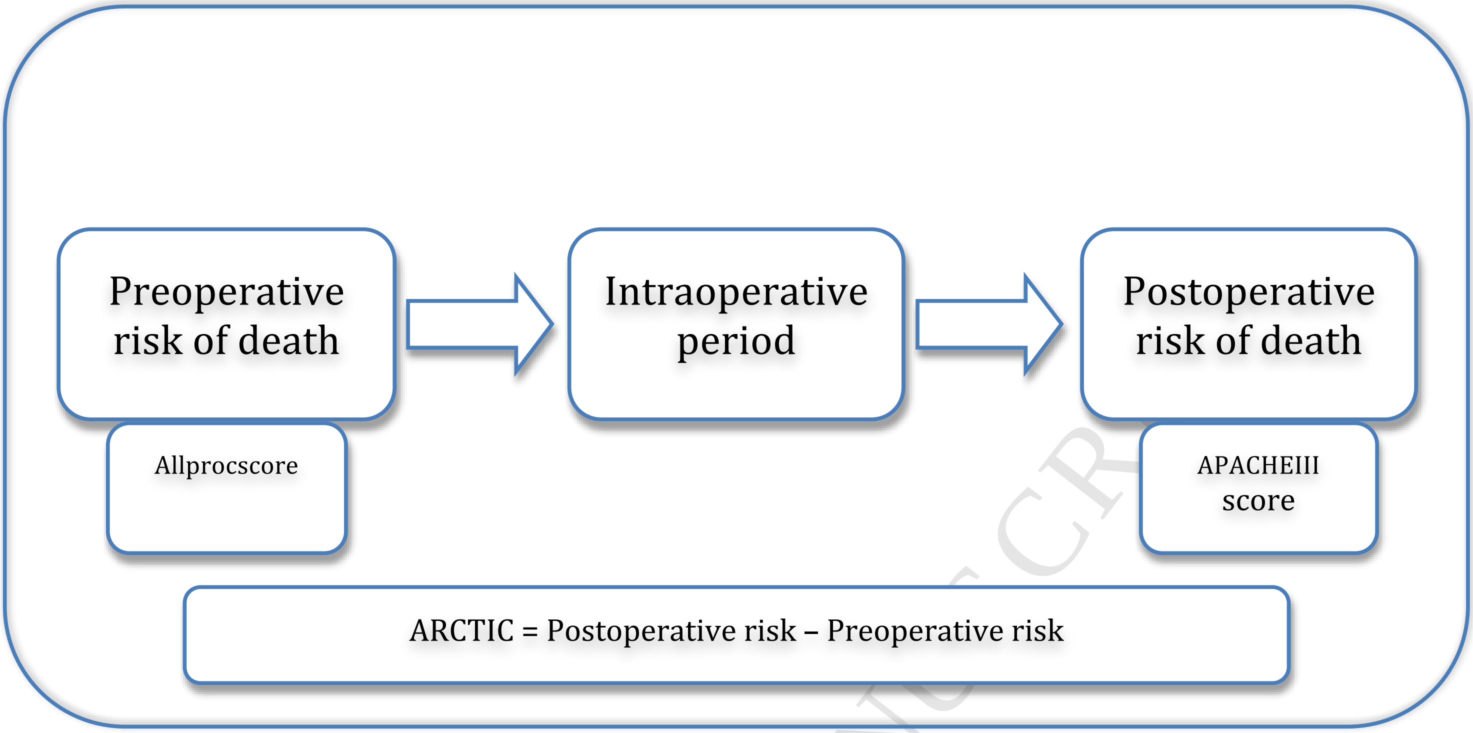

Figure 1. The **A**cute **R**isk change for **C**ardio-**T**horacic admissions to **I**ntensive **C**are (ARCTIC) index. Preoperative risk was calculated using 'Allprocscore', postoperative risk was calculated using APACHEIII score

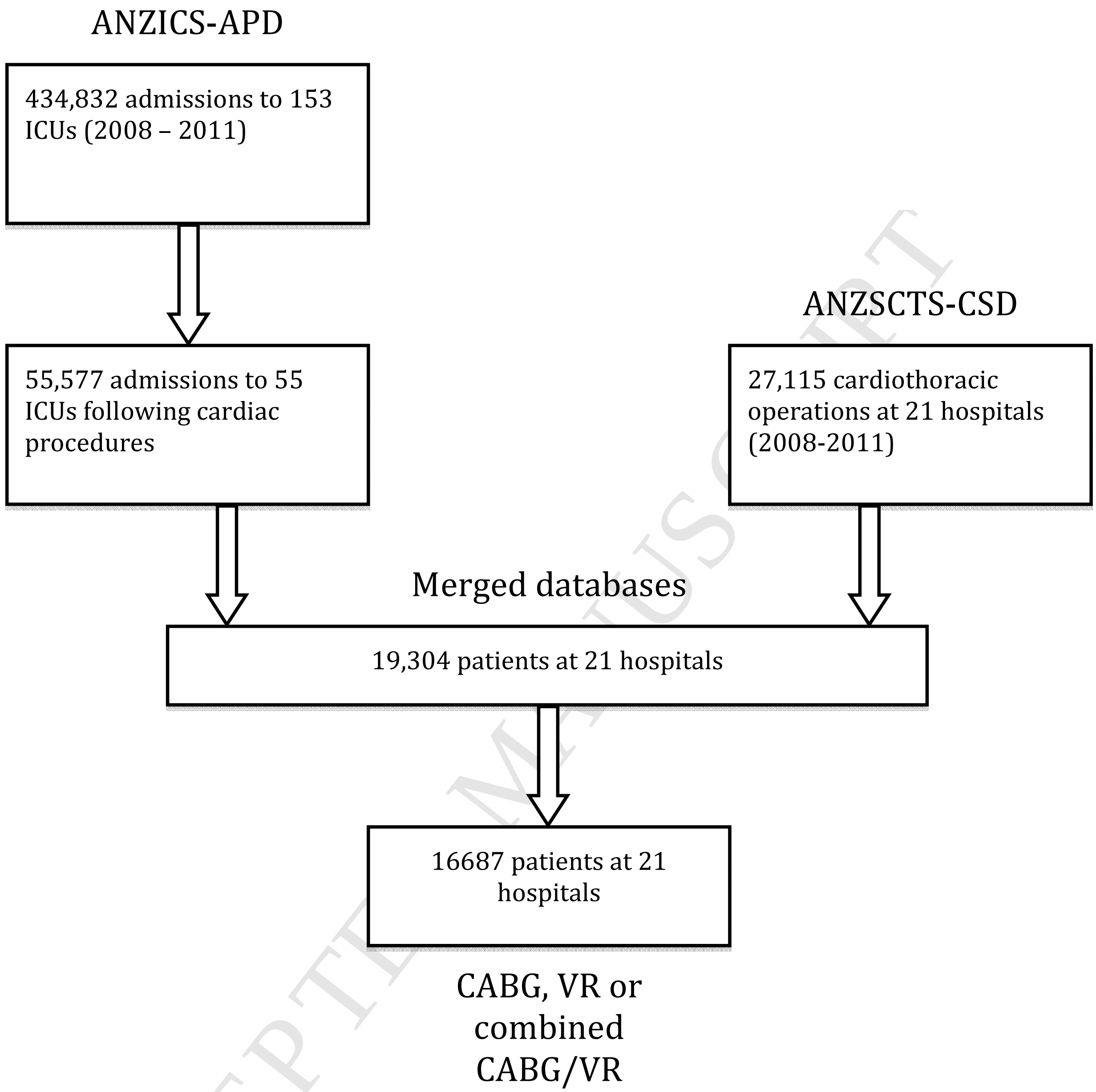

Figure 2. CONSORT diagram showing original databases and final merged database