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Original Article

Acute Risk Change: An Innovative Measure of Operative Adverse Events and Perioperative Team Performance

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Objectives: Cardiac surgical risk models predict mortality preoperatively, whereas intensive care unit (ICU) models predict mortality postoperatively. Finding a large difference between the 2 (an acute risk change [ARC]) may reflect an alteration in the status of the patient related to the surgery. An adverse ARC was associated with morbidity and mortality in an Australian population. The aims of this study were to validate ARC in a UK population and to investigate the possible mechanisms behind ARC.

Design: This was a retrospective case–control study.

Setting: Single, high-volume cardiothoracic hospital.

Participants: Data from 4,842 cardiac surgical patients were collected between 2013 and 2015.

Interventions: None.

Measurements and main results: EuroSCORE was recalibrated to each preceding year's data. ARC was defined as postoperative minus preoperative percentage mortality risk. Association among ARC, morbidity, and mortality was tested. Cases with large adverse ARC (greater than +15%) were compared with cases with large favorable ARC (less than −10%) with regard to intraoperative adverse events, unmeasured patient risk factors, and postoperative events. Adverse ARC was associated with hospital mortality, ICU stay, ICU readmission, renal support, prolonged intubation and return to the operating room ($p < 0.001$). Intraoperative adverse events occurred in 23 of 33 patients with adverse ARC; however, only 2 of 17 patients with favorable ARC reported adverse events ($p < 0.001$). Unmeasured risk factors were present in 48% of patients in the adverse ARC group.

Conclusion: ARC is a readily available and sensitive marker that correlates strongly with morbidity and mortality. The use of ARC in local and national quality monitoring could identify areas for improvement of the quality of cardiac surgical care.

Key Words: cardiac surgery; quality of care; risk assessment; outcomes

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THE RISK FOR DEATH after cardiac surgery can be estimated preoperatively using risk models such as EuroSCORE.[1] The risk for death also can be estimated postoperatively in the intensive care unit (ICU). If a surgery goes as expected, the mortality risk postoperatively in the ICU should be similar to the preoperative prediction. An abrupt postoperative increase or decrease in risk could reflect negative or positive intraoperative events, respectively.

The authors previously developed the measure *acute risk change* (ARC) to quantify this difference in mortality risk.[2] ARC is the arithmetic difference in percentage mortality risk between preoperative and postoperative risk assessments, such that an ARC of +5% denotes a 5% absolute increase in the risk for death sustained during the course of the surgical procedure. ARC may be a useful measure of quality. In previous studies, ARC was more sensitive than mortality in detecting performance outliers and was associated with morbidity including new renal failure, stroke, prolonged ventilation, and return to the operating room (OR), as well as long-term mortality up to 6 years later.[2–4] ARC can be calculated in the first 24 hours after arrival in the ICU, and therefore may be a useful early measure of perioperative events that relates to important postoperative outcomes.

To the authors' knowledge, there have been no studies to date examining the mechanisms associated with ARC. In addition to adverse surgical events, ARC could be caused by chance, by a statistical anomaly and resultant bias, by inaccurate coding, or by the inherent inability of a risk model to account for all possible risk factors.[4] For example, the effects of preoperative right ventricular dysfunction may not be accounted for by some risk models, and the true risk for death may be higher than predicted. Additionally, ARC has not previously been validated in a population external to Australia and New Zealand.

This study aimed to investigate the use of ARC in a UK patient population by comparing ARC with other known morbidity and mortality markers and to investigate the mechanisms associated with ARC. The authors' hypothesis was that extreme high values of ARC would be associated with adverse events (AEs) compared with extreme low values of ARC.

Methods

Study Population

Data were obtained from a large, UK tertiary center between January 2013 and December 2015. Data from 2013 and 2014 were used for calibration. Data from 2015 were used for hypothesis testing. A database of cardiac surgery patients was obtained from the Intensive Care National Audit and Research Centre (ICNARC), a national database comprising demographic and clinical data from all patients admitted to the ICU. Included in the ICNARC is a new national risk for death calculation developed specifically to calculate risk for death in cardiothoracic patients, known here as the ICNARC model.[5,6] Only ICU admissions after cardiac surgery were included. A second database of cardiac surgical data was obtained from hospital records, providing information on preoperative demographics and clinical data including EuroSCORE.[1] Both databases contained a unique patient identifier allowing the datasets to be easily merged. All general cardiac surgery patients were included. Transplantation, ventricular assist device implantation, pulmonary thromboendarterectomy, and percutaneous valve procedures were excluded. In patients with multiple episodes of cardiac surgery, only the first procedure was included.

Generation of ARC

To accurately predict outcomes, data from the immediately preceding year were used to recalibrate EuroSCORE to the local population for the study year. To recalibrate the EuroSCORE, a logistic regression model was generated using the "additive" patient scores and hospital mortality as the outcome (where additive relates to the original integer EuroSCORE based on preoperative variables ranging from 0 to 17). Coefficients from this logistic model were used to calculate preoperative predicted risk for death for patients in subsequent years. Discrimination and calibration were assessed using the area under the receiver operating characteristic curve (AUROC) and the Hosmer-Lemeshow test. The ICNARC model was used to generate postoperative risk for death. ARC was calculated by subtracting preoperative from postoperative percentage risk for death. ARC with a value >0 represented a higher risk for death postoperatively (adverse ARC) and values <0 a lower risk for death (favorable ARC).

Identification ARC Mechanisms: Case Note Review

Possible mechanisms for ARC were investigated by case note review, focusing on patients with extreme values of ARC (either adverse or favorable). Extreme values were chosen to allow maximum potential for documented AEs or favorable events to be discoverable from retrospective case note review and therefore based on percentage ARC rather than population percentiles. Threshold values also were chosen to allow a manageable number of cases for review. The threshold for review was set at adverse ARC greater than +15% and favorable ARC less than −15%. Preliminary analysis showed only 1 patient with a favorable ARC less than −15%, so that threshold was subsequently changed to −10% to give a sufficiently sized comparator group. Two experienced clinicians reviewed all cases and a third provided adjudication where there was disagreement.

Case review examined 3 main areas: accuracy of risk score, the presence of "unmeasured risk," and the occurrence of AEs. Data accuracy was assessed by comparison of the EuroSCORE and ICNARC model variables to the clinical case records. The records also were reviewed for risk factors that were not accounted for in the risk models and classified by reviewers as unmeasured risk. These were separated into patient factors (eg, liver disease) and institutional factors (eg, delayed surgery). Any patient factor that was known or suspected by either of

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