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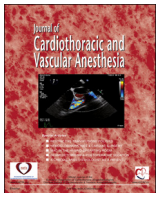

Original Article

Right Ventricular Function After Cardiac Surgery Is a Strong Independent Predictor for Long-Term Mortality

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Objective: To establish the all-cause mortality of right ventricular dysfunction after cardiac surgery in a heterogeneous group of cardiac surgery patients.
Design: Retrospective analysis of a heterogeneous group of 1,109 cardiac surgery patients in a 4-year period.
Setting: Single-center study in a tertiary teaching hospital.
Participants: One thousand one hundred nine cardiac surgery patients. By protocol, patients were monitored with a pulmonary artery catheter, enabling continuous right ventricular ejection fraction (RVEF) measurements.
Interventions: None.
Measurements and Main Results: Measurements were performed once per minute for the first 24 postoperative hours and expressed as average over the complete period. Primary outcome was 2-year all-cause mortality. RVEF was categorized into 3 subgroups: $< 20\%$, 20-30%, and $> 30\%$. Median follow-up time was 739 days. Two-year mortality was significantly different across groups: 4.1% for patients with RVEF $> 30\%$, 8.2% in the group with RVEF 20-30%, and 16.7% for patients with RVEF $< 20\%$, $p < 0.001$. Additional risk factors for a poor RVEF were age, body weight, New York Heart Association class, chronic obstructive pulmonary disease, poor left ventricular function, and higher risk scores (Acute Physiology and Chronic Health Evaluation and European System for Cardiac Operative Risk Evaluation). In a multivariate analysis, RVEF as a continuous variable was associated independently with the primary outcome (odds ratio 0.95 confidence interval 0.91-0.99, $p = 0.011$.) Odds ratios for RVEF $< 20\%$ were 1.88 (confidence interval 1.18-3.00, $p = 0.008$).
Conclusions: Right ventricular function is associated independently with 2-year all-cause mortality in a heterogenic cardiac surgery population.

Key Words: cardiac surgery; right ventricular function; thermodilution; mortality

IN CARDIAC SURGERY, impaired left ventricular (LV) function has been recognized as an independent risk factor for morbidity and mortality.[1] However, data on impact of right ventricular (RV) function on mortality in cardiac surgery are scarce. Most data on RV function in cardiac surgery were limited to small-sample-sized studies, performed in patient populations selected for well-known hemodynamic features already associated with RV failure.[2–4] Pulmonary hypertension has been recognized as a risk factor for RV dysfunction with

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subsequent prognostic value.[5] Others observed a significant correlation between pre-coronary artery bypass grafting (CABG) RV dysfunction and outcome among patients with pre-existing poor LV function.[3] Furthermore, RV function was found to be a strong predictor of long-term postoperative survival in a small preselected population undergoing mitral valve repair.[4] As of now, the overall prognostic impact of RV dysfunction on mortality in a large cardiac surgery population, not selected for RV-related risk factors, remains unclear. Therefore, the authors performed a large-sample-size observational study on long-term mortality in a cohort of heterogeneous cardiac surgery patients.

Methods

Study Population

This study was a single-center retrospective observational study involving a heterogeneous group of cardiac surgery patients admitted to the intensive care unit (ICU) between January 2011 and January 2015. According to the authors' institutional protocol, all cardiac surgery patients were admitted to the ICU in the direct postoperative phase. Patients who fulfilled predefined criteria (Table 1) (in short: valve surgery or poor LV) were by protocol equipped with a pulmonary artery catheter after induction of anesthesia and included in the study. Exclusion criteria were age < 18 years and a non-functioning pulmonary artery catheter after ICU admission. The study was approved by the local ethical and scientific committee and the need for informed consent was waived in accordance with applicable laws.

Data Collection

Data were extracted from several hospital information systems. Immediately after induction, LV function was semi-quantitatively assessed as good, moderate, or poor by board-certified echocardiographers using the Philips IE33 transesophageal echocardiography (TEE) system (Philips Medical Systems, Eindhoven, the Netherlands).

Hemodynamic parameters were derived from a pulmonary artery catheter (7.5F CEDV-Pulmonary Artery Catheter, model 744H, Baxter Healthcare Corporation, Irvine, CA), which interfaced with a computerized monitoring system (Vigilance® CCO/SvO2/CEDV Monitor, Baxter Healthcare Corporation, Irvine, CA).

Table 1
Inclusion Criteria

Mitral valve repair/replacement including MitraClip
Aortic valve replacement, including TAVI
Aortic arch surgery, including Bentall procedure
Any combination of heart valve surgery
CABG + heart valve surgery
Isolated CABG procedure with poor LV function

Abbreviations: CABG, coronary artery bypass grafting; LV, left ventricular; TAVI, transaortic valve intervention.

A thermal filament on the catheter, placed into the RV, enabled continuous measurement of the right ventricular ejection fraction (RVEF). During the postoperative ICU admission, RVEF was measured continuously at a rate of 1 sample per minute from the start of ICU admission. Measurements were started at the start of the ICU admission and were averaged over the first 24 hours of ICU admission, or until ICU discharge in case patients were transferred from the ICU to the ward within 24 hours postoperatively. Data on long-term outcome after hospital discharge were derived from a linkage between the social security number of the patient and a national registration of demographic characteristics of all Dutch individuals.

Normal values of RVEF in current literature gave a lower limit of 30% up to 45%.[3,4,6] However, this limit was based on measurements with echocardiography (two-dimensional [2D] or three-dimensional [3D]), angiocardiography, or magnetic resonance imaging. Different studies in the past[7,8] already established that the pulmonary artery catheter underestimates the RVEF in comparison with other measurement techniques. Because there are no international criteria for a cut-off value of RVEF to define RV failure, the authors first composed a distribution curve of the RVEF. According to statistical law, patients subsequently were separated into 3 groups based upon the mean plus or minus 1 standard deviation (Fig 1). Furthermore, to corroborate this cut-off value, the authors also predefined RV failure as an RVEF below the 95% confidence interval of previous publications in cardiosurgical patients. Using this predefinition, the authors found a cut-off value for the RVEF measured with a pulmonary artery catheter $< 20\%$.[8]

Surgery Details

Patients were anesthetized according to local protocol based on a combination of sufentanil, 3-7 μg/kg, rocuronium, 0.6 mg/kg, and midazolam, 0.1 mg/kg, for anesthesia induction and tracheal intubation, and sevoflurane for maintenance. All patients received tranexaminic acid and, if less than 75 years of age, dexamethasone, 1 mg/kg. Cardiopulmonary bypass was performed at a continuous blood flow (2.2-3.0 L/min/m^2) during normo- or mild hypothermia ($> 34^\circ$C). The CPB hardware consisted of a HL-30 heart–lung machine and

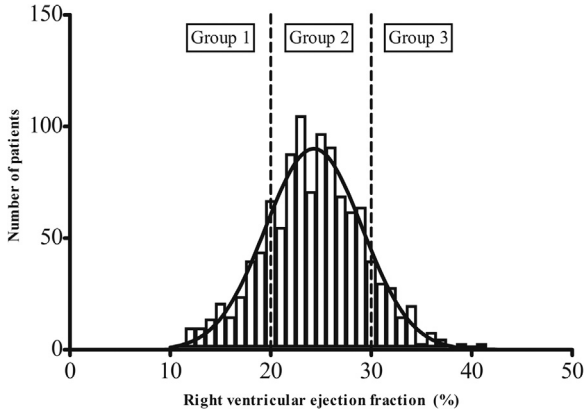

Fig 1. Gaussian curve of right ventricular ejection fraction in percentage and cut-off values for groups.

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