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From the Southern Association for Vascular Surgery

Heart rate variables in the Vascular Quality Initiative are not reliable predictors of adverse cardiac outcomes or mortality after major elective vascular surgery

Salvatore Scali, MD,[a] Daniel Bertges, MD,[b] Daniel Neal, MS,[a] Virendra Patel, MD, MPH,[c] Jens Eldrup-Jorgensen, MD,[d] Jack Cronenwett, MD,[e] and Adam Beck, MD,[a] *Gainesville, Fla; Burlington, Vt; Boston, Mass; Portland, Me; and Lebanon, NH*

Objective: **Heart rate (HR) parameters are known indicators of cardiovascular complications after cardiac surgery, but there is little evidence of their role in predicting outcome after major vascular surgery. The purpose of this study was to determine whether arrival HR (AHR) and highest intraoperative HR are associated with mortality or major adverse cardiac events (MACEs) after elective vascular surgery in the Vascular Quality Initiative (VQI).**

Methods: **Patients undergoing elective lower extremity bypass (LEB), aortofemoral bypass (AFB), and open abdominal aortic aneurysm (AAA) repair in the VQI were analyzed. MACE was defined as any postoperative myocardial infarction, dysrhythmia, or congestive heart failure. Controlled HR was defined as AHR <75 beats/min on operating room arrival. Delta HR (DHR) was defined as highest intraoperative HR − AHR. Procedure-specific MACE models were derived for risk stratification, and generalized estimating equations were used to account for clustering of center effects. HR, beta-blocker exposure, cardiac risk, and their interactions were explored to determine association with MACE or 30-day mortality. A Bonferroni correction with $P < .004$ was used to declare significance.**

Results: **There were 13,291 patients reviewed (LEB, n = 8155 [62%]; AFB, n = 2629 [18%]; open AAA, n = 2629 [20%]). Rates of any preoperative beta-blocker exposure were as follows: LEB, 66.5% (n = 5412); AFB, 57% (n = 1342); and open AAA, 74.2% (n = 1949). AHR and DHR outcome association was variable across patients and procedures. AHR <75 beats/min was associated with increased postoperative myocardial infarction risk for LEB patients across all risk strata (odds ratio [OR], 1.4; 95% confidence interval [CI], 1.03-1.9; $P = .03$), whereas AHR <75 beats/min was associated with decreased dysrhythmia risk (OR, 0.42; 95% CI, 0.28-0.63; $P = .0001$) and 30-day death (OR, 0.50; 95% CI, 0.33-0.77; $P = .001$) in patients at moderate and high cardiac risk. These HR associations disappeared in controlling for beta-blocker status. For AFB and open AAA repair patients, there was no significant association between AHR and MACE or 30-day mortality, irrespective or cardiac risk or beta-blocker status. DHR and extremes of highest intraoperative HR (>90 or 100 beats/min) were analyzed among all three operations, and no consistent associations with MACE or 30-day mortality were detected.**

Conclusions: **The VQI AHR and highest intraoperative HR variables are highly confounded by patient presentation, operative variables, and beta-blocker therapy. The discordance between cardiac risk and HR as well as the lack of consistent correlation to outcome makes them unreliable predictors. The VQI has elected to discontinue collecting AHR and highest intraoperative HR data, given insufficient evidence to suggest their importance as an outcome measure. (J Vasc Surg 2015;62:710-20.)**

Cardiovascular complications after major noncardiac surgery can lead to significant morbidity and mortality. Perioperative myocardial infarction (MI) rates are routinely reported to be 1% to 5%; however, rates as high as 14% to 30% can occur in selected high-risk vascular surgery operations.[1-3] The pathophysiology of postoperative major

From the Division of Vascular Surgery and Endovascular Therapy, University of Florida, Gainesville[a]; the Division of Vascular Surgery, University of Vermont, Burlington[b]; the Division of Vascular Surgery, Massachusetts General Hospital, Harvard Medical School, Boston[c]; the Division of Vascular Surgery, Maine Medical Center, Portland[d]; and the Section of Vascular Surgery, Dartmouth-Hitchcock Medical Center, Lebanon.[e]

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Correspondence: Salvatore T. Scali, MD, FACS, Assistant Professor of Surgery, Division of Vascular Surgery and Endovascular Therapy, University of Florida School of Medicine, PO Box 100128, 1600 SW Archer Rd, Ste NG-45, Gainesville, FL 32610 (e-mail: salvatore.scali@surgery.ufl.edu).

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adverse cardiac events (MACEs) such as MI, arrhythmia, and congestive heart failure (CHF) is frequently linked to subendocardial ischemia or plaque rupture.[4] These events are precipitated by disequilibrium between myocardial oxygen supply and demand, which is dictated by the balance between heart rate (HR), ventricular wall stress, blood pressure, circulating oxygen tension, and coronary vasoconstriction.[5] A number of publications highlight different patient- and procedure-related factors that have an impact on these parameters and lead to reliable prediction of MACE and mortality.[2,6-8]

HR and various metrics of HR variability are useful clinical predictors of acute MI,[9,10] coronary artery bypass,[11] neonatal,[12] and post-gastric bypass[13] outcomes. Interestingly, limited data exist about the association of HR parameters with outcomes after vascular surgery. Unfortunately, commonly used data sources, such as the National Inpatient Sample, Medicare Part B File, and American College of Surgeons National Surgical Quality Improvement Program, do not have HR information. The Society for Vascular Surgery Vascular Quality Initiative (SVS VQI) prospectively captures arrival HR (AHR) and highest intraoperative HR for major arterial reconstructions. Because of concerns about the value of capturing these variables, the SVS VQI Arterial Quality Committee recently convened an HR study group in an effort to identify the utility of capturing this variable as a quality measure.

The purpose of this study was to determine whether AHR and highest intraoperative HR are associated with MACEs or mortality after major elective vascular surgery.

METHODS

This study was approved by the SVS VQI Research Advisory Committee and the Arterial Quality Committee and includes national data from all VQI regional quality groups. Details regarding this multicenter collaboration have been published and are available at www.vascularqualityinitiative.org/components/svs-pso.[14,15] This study was approved by the Institutional Review Board at the University of Florida, and the need for patient consent was waived.

Study cohort. All VQI patients undergoing *elective* open infrainguinal lower extremity bypass (LEB; any indication or conduit; n = 9594), aortofemoral bypass (AFB; aortic inflow only for any indication or conduit; n = 1599), and open abdominal aortic aneurysm (AAA; n = 3089) repair from January 2003 to June 2013 were reviewed. These procedures were selected because of the known elevated postoperative MACE risk for patients undergoing major open arterial reconstruction for peripheral arterial disease and AAA.[2,16-18] Urgent or emergent procedures were intentionally excluded because of the greater potential for hemodynamic confounding and practice variability. If beta-blocker status and HR data were missing, patients were excluded. Only the first observation on any patient who received more than one operation was analyzed.

Exposure variables and end points. Individual patient demographic and clinical variables (>100) are prospectively collected in the VQI registry.[19] Coronary artery disease was defined as a history of MI, any coronary revascularization (coronary artery bypass graft, percutaneous coronary intervention), or a history of angina. Specific details about other comorbidity definitions within the VQI have been published[19] and are available online (www.svsvqi.org). Data about preoperative cardiac stress testing are included in the VQI database and include the most recent (≤2 years) stress electrocardiogram, stress echocardiogram, or nuclear stress test.

HR control was defined by an operating room AHR <75 beats/min. Because VQI data offer no true measure of HR variability, we took the difference between AHR and highest intraoperative HR (delta HR [DHR]) as a crude surrogate for variability. Beta-blocker exposure history was divided into three categories: none, acute (0-30 days preoperatively), or chronic (>30 days preoperatively).

Primary end points included (1) any in-hospital, postoperative MACE (clinically significant arrhythmia, CHF, or MI) and (2) 30-day death. Death events were not considered in the MACE definition because the VQI does not record cause of death, so we were unable to determine if deaths were cardiac related. MI was defined as new ST- or T-wave electrocardiography changes, troponin elevation, or documentation by echocardiography or other imaging modality. Clinically significant arrhythmias included any new atrial or ventricular rhythm disturbance requiring treatment with medication or cardioversion. CHF included new pulmonary edema documented by chest radiograph and requiring treatment or monitoring in the intensive care unit. Mortality events were verified by the Social Security Death Masterfile.

Classification of patients by MACE risk. To evaluate whether the possible effects of AHR and DHR differed across patient types, we used statistical methods to classify each patient's cardiac risk as low, intermediate, or high. For each procedure, the R statistical software package (version 3.0.2; Vienna, Austria) was used to create a logistic regression model for the composite MACE outcome. Candidate predictors were derived from known factors associated with MACE[2] as well as additional variables available in the data set that were identified by literature review.[6,16] To minimize the impact of missing data, we first used a stepwise elimination algorithm based on the Akaike information criterion (the stepAIC function in the R package MASS) to suggest a best subset of predictors. We then eliminated all variables from the model that were not selected by the variable reduction algorithm, as long as their exclusion resulted in no appreciable loss of predictive power. Variable elimination continued only to the point at which the area under the receiver operating characteristic curve (AUC) was no more than 1% lower than the AUC for the full model. To account for possible regional and center effects, selected variables were entered into generalized estimating equations logistic regression models. The model-estimated risk scores (log-odds of MACE) were assigned to each patient, and risk score tertiles were used to categorize patients into low, intermediate, and high cardiac risk.

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