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Preexisting Right Ventricular Dysfunction Is Associated With Higher Postoperative Cardiac Complications and Longer Hospital Stay in HighRisk Patients Undergoing Nonemergent Major Vascular Surgery

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Objectives: To evaluate whether the presence of preexisting right ventricular (RV) dysfunction in high-risk patients undergoing non-emergent major vascular surgery is associated independently with higher incidents of postoperative cardiac complications and a longer length of hospital stay.
Design: Retrospective chart review.
Setting: Singlecenter university hospital setting.
Participants: The patient population consisted of those identified as American Society of Anesthesiologists classification III and above who had a preoperative echocardiogram within 1 year of undergoing nonemergent major vascular surgery between January 2010 and May 2017.
Measurements and Main Results: After multivariate analyses, RV dysfunction (RVD) is associated independently with a higher incidence of postoperative major cardiac complications with an odds ratio = 6.3 (95% confidence interval [CI], 1.038.5; p = 0.046). In addition, patients with RVD had a 50% longer length of stay than those without RVD (incident rate ratio [95% CI], 1.5 [1.21.8]; p < 0.001).
Conclusion: In this retrospective study of high-risk patients undergoing major vascular surgery, RV dysfunction was associated independently with a higher incidence of postoperative major cardiovascular events and longer length of hospital stays. Based on current findings, the prognostic value of RVD extends beyond the cardiac surgical cohort. Knowledge in management of patients with RVD in the perioperative setting should be understood by all anesthesiologists. Of note, a future study with a larger sample size is needed to validate the current findings given the small sample size of this study.

Patients undergoing major vascular surgery are at high risk for postoperative cardiac complications and perioperative morbidity and mortality.[14] In addition to the elevated surgical risk associated with major vascular procedures, the increased perioperative morbidity and mortality has been attributed to a higher prevalence of cardiac disease in the vascular patient population.[5] For example, congestive heart failure (CHF) is an important predictor for postoperative cardiac events in patients undergoing vascular surgery.[6] Although prior studies have investigated the association between left ventricular function and postoperative adverse cardiac outcomes in this surgical cohort, evaluation of the prognostic value of right ventricular function has been lacking.[7,8]

Right ventricular (RV) function may be an overlooked contributor to perioperative morbidity and mortality. Although left ventricular function is critical, global cardiac function results from the intimate relationship between both the left and the right ventricles. Indeed, this intimate relationship is demonstrated by observing RVD as a result of left-sided heart failure even when ejection fraction (EF) is preserved. In fact, 33% to 50% of patients with left-sided heart failure have been reported to have evidence of RVD.[9] Similarly, through interventricular dependence, RVD by itself can compromise left ventricular function and has been shown to have important prognostic value.[10,11] Indeed, in patients undergoing cardiac surgery, the presence of RVD has been found to predict independently worse short and long-term outcomes.[1214]

This study aimed to detect the prevalence of preexisting RVD in patients undergoing major vascular surgery and evaluate whether preexisting RVD, diagnosed by preoperative echocardiogram (echo), was associated independently with a higher incidence of postoperative major adverse cardiovascular events (MACE). In addition, the study investigated whether preexisting RVD was associated with longer hospital stays and higher inhospital mortality relating to cardiac events or as a composite all-cause event. The authors' hypothesis was that preexisting RVD would be associated with an increased risk of MACE and longer length of stay (LOS). In addition, the authors predicted that the presence of RVD would be associated with a higher incidence of inhospital mortality relating to both cardiac events or as a composite all-cause event in patients undergoing non-emergent major vascular surgery.

Materials and Methods

Study Population

This study was approved by the institutional review board at the University of California Irvine Medical Center (UCI IRB HS# 20174099). A retrospective single-center chart review of all patients undergoing major vascular surgery between 2010 and 2017 was conducted. Major vascular procedures included all surgeries involving the aorta (both open and endovascular), open inferior vena cava thrombectomy with nephrectomy, and any vascular bypass surgery for peripheral vascular or arterial occlusive disease. Carotid endarterectomies and procedures relating to arteriovenous fistula were not included as these surgeries are considered intermediate risk and low risk, respectively. In addition, any procedure that required cardiopulmonary bypass and any emergency surgery were excluded. Only adult patients between ages 18 and 89 who were identified as American Society of Anesthesiologists physical status classification of III and above were considered for inclusion. Finally, only those patients with a preoperative echocardiogram performed within 1 year of the indexed surgery and for which the study had image quality sufficient to determine retrospectively RV function were enrolled into the study. In patients who had multiple echo studies within 1 year of the indexed surgery, the study that was closest to the indexed surgery was selected for review.

Data Collection

Patients' demographic and perioperative data were collected via manual chart review of the hospital's electronic record. Intraoperative variables were collected from Surgical Information Systems (Surgical Information Systems Corp., Alpharetta, GA), and demographic and perioperative variables were obtained from the main hospital chart, Quest (Allscripts Corp., Alpharetta, GA). For each patient meeting inclusion criteria, the following data were collected: age, sex, presence or absence of history of CHF, coronary artery disease, hypertension (HTN), cerebrovascular accident, diabetes, chronic obstructive pulmonary disease, obstructive sleep apnea, and pulmonary HTN. In addition, intraoperative and postoperative variables including type of anesthesia (general anesthesia versus monitored anesthesia care), length of surgery, need for intraoperative transfusion of allogeneic blood products, need for intraoperative infusion of inotropic or vasopressor agents, postoperative development of respiratory complications and acute kidney injury (AKI), and postoperative need for subsequent surgeries during the same admission and postoperative infections were collected so they could be evaluated as confounding factors. Postoperative respiratory complication was defined as prolonged intubation for more than 24 hours or need for reintubation or tracheostomy. Post operative AKI was defined as patients with a postoperative rise of creatinine greater than 60% from the baseline.15 The postoperative need for subsequent surgeries included all procedures that required anesthesia care. Postoperative infection was defined as a composite event including wound or surgical site infection, urinary tract infection, pulmonary infection, and systemic infection.

Evaluation of Cardiac Function

The preoperative echocardiogram obtained within 1 year of the index surgery was used to identify patients with RV dysfunction. All of the echo studies originally were performed by the cardiology service at the study institution. Almost all of the echo studies were transthoracic echocardiogram with only 2 studies being transesophageal echocardiogram. Both images and results of the original study reports were reviewed and retrieved from the institution's cardiovascular imaging database (Syngo Dynamics Siemens Healthcare, Tarrytown, NY). Study reports were reviewed and the following collected: left ventricular EF (LVEF), right ventricular systolic pressure (RVSP), any valvular pathology categorized as severe, presence of left ventricular diastolic dysfunction, and RV function.

RV function was reported as a binary variable (normal v abnormal). RV function collected from the official report was determined based on visual estimation by the cardiologists. A second experienced cardiologist was asked to review all echo studies and visually estimate RV function independently from the results of the official report. The second experienced cardiologist was blinded to all clinical information. Visual estimation of the RV function was determined based on multiple acoustic windows including apical 4chamber (lateral wall of the RV and RV apex), parasternal short-axis (anterior, lateral, and inferior wall of the RV), parasternal RV inflow (anterior and inferior wall of the RV), and subcostal 4chamber (inferior wall of the RV). For echo studies in which the second cardiologist's interpretation of the RV function was different from that of the original report, tricuspid annular plane systolic excursion (TAPSE) was obtained. A TAPSE <1.6 cm was used as the cutoff to differentiate abnormal from normal RV function when the disagreements occurred.16 TAPSE was obtained by the principal investigator who is echo certified by the National Board of Echocardiography. The principal investigator also was blinded to all clinical information at the time in which TAPSE was obtained.

Outcomes and Definitions

The primary outcome was incidence of postoperative MACE. Postoperative MACE was defined broadly as composite events including nonfatal cardiac arrest, myocardial infarction, development of CHF, cerebrovascular event such as stroke, and cardiovascular mortality defined as death attributable to any or a combination of the adverse cardiovascular events just described.1719 Secondary outcomes included LOS, inhospital cardiac, and all-cause mortality.

Statistical Analysis

All statistical analysis was performed using SPSS for windows version 24 (SPSS Inc., Chicago, IL). Dichotomous variables are reported as counts and percentages, and continuous variables are described as mean and standard deviation (if normally distributed) or median with interquartile range. For continuous variables, normal distribution was tested using Shapiro-Wilk test. Differences between the groups were per formed using the Fisher exact test for dichotomous variables and Student t test or Mann-Whitney U test for continuous variables with normal and non-normal distribution, respectively. Logistic regression analysis was performed to estimate the odds ratio (OR) and 95% confidence interval (CI) for the effect of RVD on binary outcomes. LOS was treated as count data; as such, LOS was analyzed via Poisson regression to estimate the incident rate ratio (IRR) and 95% CI. Of note, all patients who had died during the hospital stay were not included in the analyses for LOS. Multivariate regression was performed for both logistic and Poisson regression to account for covariates. Only covariates found to be associated individually with outcome of interest with $p < 0.10$ were included in the multivariate regression. Where 2 covariates are expected to have high association resulting in multicollinearity, only the continuous variable is included in the final multivariable model. For goodness of fit, the Hosmer-Lemeshow test was used to test the logistic regression model, whereas the omnibus test was used for the Poisson regression model. For all tests, a p value <0.05 was considered statistically significant.

Results

Group Characteristics

One hundred eight patients were found who met the criteria and were included for data analysis. Most of the patients were male (75%) with a median age of 72[60, 78]; 9.3% of patients had RVD. A comparison of demographic data in patients with and without RVD showed that there was no difference in sex and age between the groups ($p = 0.264$ and $p = 0.542$, respectively). Comparing other preoperative covariates between the 2 groups, 70% of the patients with RVD had a history of CHF compared with 27% of patients without RVD ($p = 0.009$). There was a higher percentage of patients with a history of pulmonary HTN in those with RVD (40% v 11%; $p = 0.049$). Examining LVEF, the median LVEF was significantly lower in patients with RVD ($p < 0.001$; Fig 1). Comparing RVSP between the 2 groups, those with RVD had a higher mean ($p = 0.009$). Out of 108 patients, only 6 had severe valvular pathology. Among these 6 patients, only 1 patient belonged to the group with RV dysfunction. As such, valvular pathology was not compared between the groups and not included in the subsequent analysis. In addition, a large percentage of patients had indeterminate diastolic dysfunction based on the final echo report. Therefore, diastolic dysfunction was not com pared between the groups and was excluded in the remaining analysis. For the remaining preoperative variables, there was no significant difference found between the 2 groups (Table 1). For intraoperative variables, there was no difference between the groups regarding length of surgery, types of anesthesia, use of infusion of inotropic or vasopressor agents, and need for transfusion of allogenic blood products (Table 2). Finally, for postoperative variables, no difference was found between the groups regarding incidence of postoperative respiratory complications and AKI (Table 2).

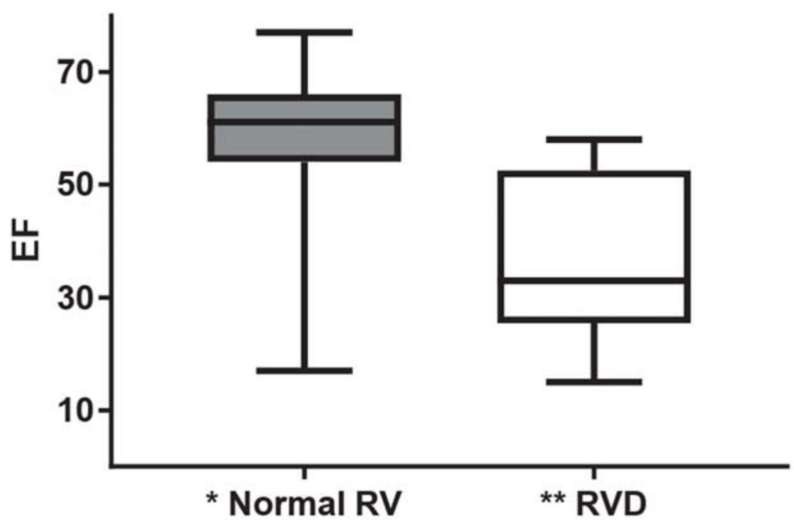

Fig 1. Boxplot: median LVEF. EF, ejection fraction; RV, right ventricle; RVD, right ventricular dysfunction. *The median EF for patients with normal RV function is 61% (25th = 54%, 75th = 66%). **The median EF for patients with RVD is 37% (25th = 27%, 75th = 52%).

Table 1
Baseline Demographic and Comorbidity Data Between Groups

Baseline Characteristics	Normal Right Ventricular Function N = 98	Right Ventricular Dysfunction N = 10	p Value
Male, n (%)	75 (77)	6 (60)	0.264
Age	72 (62-79)	70 (47-80)	0.542
CAD, n (%)	49 (50)	8 (80)	0.098
CHF, n (%)	26 (27)	7 (70)	0.009
CVA, n (%)	15 (15)	4 (40)	0.072
DM, n (%)	33 (34)	2 (20)	0.494
COPD, n (%)	22 (22)	2 (20)	1.000
OSA, n (%)	5 (5)	0 (0)	1.000
Pulmonary HTN, n (%)	11 (11)	4 (40)	0.049
HTN, n (%)	84 (86)	9 (90)	1.000
RVSP	35.0 (13.3)	47.4 (11.8)	0.009

NOTE. Data are presented as mean § standard deviation for RVSP, median (25th, 75th) for age, and n (%) for categorical variables. Groups are compared using Student t test for RVSP, Mann-Whitney U test for age, and Fisher exact test for categorical variables. Abbreviations: CAD, coronary artery disease; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; DM, diabetes; HTN, hypertension; OSA, obstructive sleep apnea; RVSP, right ventricular systolic pressure.

Table 2
Other Intraoperative and Postoperative Variables and Remaining Secondary Outcomes

Remaining Covariates & Secondary Outcomes	Normal Right Ventricular Function N = 98	Right Ventricular Dysfunction N = 10	p Value
Other intraoperative and postoperative variables			
Intraoperative infusion of inotropic medication	24 (25)	3 (30)	0.708
Intraoperative need for transfusion	46 (47)	4 (40)	0.749
Postoperative respiratory complications	18 (18)	3 (30)	0.379
Postoperative AKI	16 (16)	2 (20)	0.672
Length of surgery	392 (300-522)	362 (201-433)	0.146
General anesthesia	91 (93)	9 (90)	0.553
Remaining secondary outcome			
In-hospital cardiac death	4 (4)	1 (10)	0.391
In-hospital all-cause death	6 (6)	2 (20)	0.160

NOTE. All values are reported as count (%). Length of surgery is reported in minutes as median (25%, 75%). Abbreviation: AKI, acute kidney injury.

Primary Outcome

Univariate Analyses

A total of 10 patients suffered postoperative MACE, making an overall incidence of 9.3%. Seven of the patients had at least 1 cardiac arrest event, 1 patient had acute decompensated heart failure, 1 patient had myocardial infarction, and 1 patient had a stroke. The incidence of MACE for those with RVD was 40% compared with 6.1% in those without RVD (p = 0.006). In the univariate analyses, the OR for those with MACE was 10.1 in patients with RVD compared with those without RVD (95% CI, 2.245.8; p = 0.003). Using LVEF as a single predictor, an increase in EF predicted a lower risk of MACE with an OR = 0.9 (95% CI, 0.91.0; p = 0.012). In the subgroup analysis, for patients with moderately reduced EF defined as EF <45%, the OR for MACE was 7.8 compared with those with normal EF (95% CI, 1.932.9; p = 0.005). For patients with low EF defined as an EF <35%, the OR for MACE was 11.7 (95% CI, 2.555.5; p = 0.002) compared with patients with an EF >35%. In the remaining univariate analyses, history of CHF, cerebro-vascular accident, and pulmonary HTN, as well as RVSP, were not associated with postoperative MACE (Table 3).

Multivariate Analyses

Because raw LVEF, EF <45%, and EF <35% were expected to exhibit collinearity, only LVEF was selected as a covariate in the multivariate analyses. After controlling for LVEF, RVD was associated independently with MACE with an OR = 6.3 (95% CI, 1.038.5; p = 0.046), whereas LVEF was not associated independently with MACE (OR [95% CI]: 1.0 [0.921.02]; Table 3).

Table 3
Models for Postoperative Major Cardiac Events

Covariates	OR	95% CI	p Value
Univariable models			
RVD	10.1	2.2, 45.8	0.003
LVEF	0.9	0.9, 1.0	0.012
LVEF <45%	7.8	1.9, 32.9	0.005
LVEF <35%	11.7	2.5, 55.5	0.002
CHF	1.0	0.2, 4.0	0.952
CVA	1.2	0.2, 6.0	0.846
Pulmonary HTN	1.9	0.3, 10.3	0.471
RVSP	1.0	1.0, 1.1	0.318
Multivariable model			
RVD	6.3	1.0, 38.5	0.046
LVEF	1.0	0.9, 1.0	0.212

NOTE. Logistic regression was performed to estimate OR, 95% CI, and p value. Only covariate that is individually associated with outcome with a p value < 0.1 was included in the multivariable model. Only LVEF was included in the multivariable model because of multicollinearity.
Abbreviations: CHF, congestive heart failure; CI, confidence interval; CVA, cerebrovascular accident; HTN, hypertension; LVEF, left ventricular ejection fraction; OR, odds ratio; RVD, right ventricular dysfunction; RVSP, right ventricular systolic pressure.

Secondary Outcomes

Patients with RVD had a 50% longer LOS than those with out RV dysfunction (IRR [95% CI]: 1.5 [1.21.8]; p < 0.001). Other covariates that were associated significantly with longer LOS in univariate analysis included the need for multiple surgeries during the hospital stay (IRR [95% CI]: 2.0 [1.72.2]; p < 0.001), presence of postoperative infection (IRR [95% CI]: 1.3 [1.11.5]; p = 0.001), and RVSP (IRR [95% CI]: 1.0 [1.01.0]; p < 0.001). In contrast, LVEF did not predict LOS (IRR [95% CI]: 1.0

[1.01.0]). In multivariable analysis for LOS, RVD, RVSP, and postoperative need for multiple surgeries all were associated independently with longer LOS in the final model ($p = 0.001$, $p < 0.001$, and $p < 0.001$, respectively; Table 4, Model 5). Accounting for RVSP and postoperative need for multiple surgeries, RVD continued to be an independent risk factor for LOS (IRR [95% CI]: 3.8 [1.88.32]; $p = 0.001$; Figure 2).

For inhospital mortality, there were a total of 8 deaths (7.4%). One patient died from massive intraoperative bleeding, 1 died from septic shock, 2 died from postoperative cardiac arrest, and the remaining died from a protracted postoperative course relating to surgical complications. There was no difference in the incidence of all-cause mortality between patients with and without RVD ($p = 0.391$). Similarly, for cardiac-related inhospital mortality, there was no difference in incidence between patients with and without RVD ($p = 0.160$; Table 2).

Table 4
Models for Length of Stay

Covariates	IRR	95% CI	p Value
Univariable model			
RVD	1.50	1.2-1.8	<0.001
Multiple surgeries	1.96	1.7-2.2	< 0.001
Postinfection	1.28	1.1-1.5	0.001
LVEF	1.00	1.0-1.0	0.427
EF <45%	1.02	0.9-1.2	0.846
EF <35%	1.19	1.0-1.5	0.095
CHF	0.91	0.8-1.0	0.137
CAD	1.09	1.0-1.2	0.146
CVA	1.01	0.9-1.2	0.892
Pulmonary HTN	1.16	1.0-1.4	0.074
RVSP	1.01	1.0-1.0	< 0.001
Multivariable model 1			
RVD	1.57	1.2-2.0	<0.001
LVEF <35%	0.90	0.7-1.2	0.379
Multivariable model 2			
RVD	1.46	1.2-1.8	<0.001
Pulmonary HTN	1.09	0.9-1.3	0.316
Multivariable model 3			
RVD	1.51	1.2-1.8	<0.001
Postop infection	1.37	1.2-1.6	<0.001
Multivariable model 4			
RVD	1.57	1.3-1.9	<0.001
Postop infection	1.16	1.0-1.4	0.103
Postop need for multiple surgeries	1.62	1.4-1.9	<0.001
Pulmonary HTN	0.89	0.7-1.1	0.205
Multivariable model 5			
RVD	3.82	1.8-8.3	0.001
RVSP	1.01	1.0-1.0	< 0.001
RVSPxRVD	0.98	1.0-1.0	0.012
Postop need for multiple surgeries	1.89	1.9-2.5	< 0.001

NOTE. Poisson's regression was performed to estimate IRR, 95% CI, and p value. Only covariate that is individually associated with outcome with a p value < 0.1 was included in the multivariable model. LVEF <35% was removed in model 4 owing to non-significant Omnibus test. Pulmonary HTN was removed in model 5 owing to multicollinearity. All CI noted to be 1.01.0 are results of rounding.
Abbreviations: CAD, coronary artery disease; CHF congestive heart failure; CI, confidence interval; CVA, cerebrovascular accident; EF, ejection fraction; HTN, hypertension; IRR, incident rate ratio; LVEF, left ventricular ejection fraction; RVD, right ventricular dysfunction; RVSP, right ventricular systolic pressure.

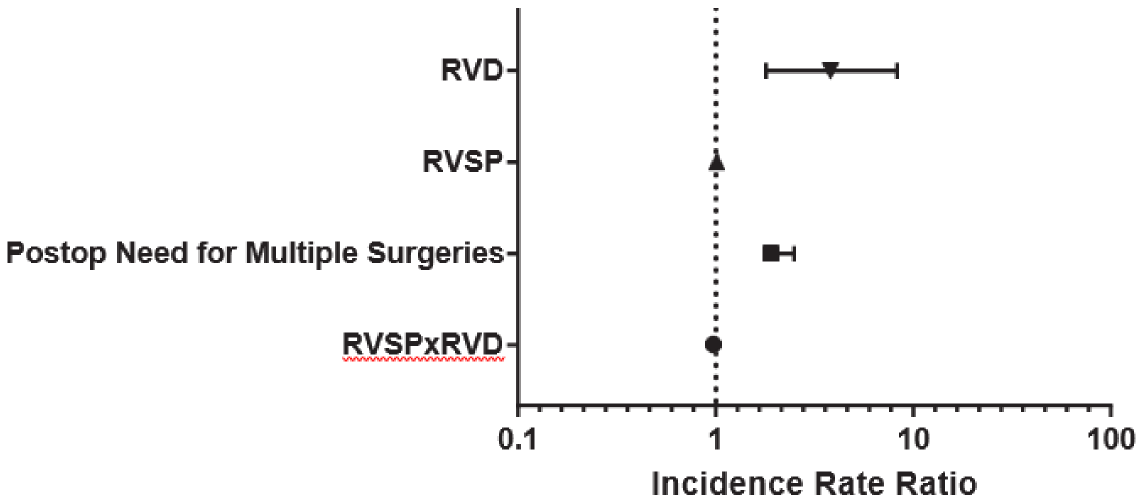

Fig 2. Multiple Poisson model on length of stay (Table 4; Model 5). RVD, right ventricular dysfunction; RVSP, right ventricular systolic pressure; RVSPxRVD, interactive term between RVSP and RVD. All covariates included in this final model are statistically significant with $p < 0.05$.

Discussion

Key Findings

In this study, the prognostic significance of preexisting RVD in high-risk patients undergoing non-emergent major vascular surgery was evaluated. RVD was found to be associated independently with a higher incidence of postoperative MACE and longer length of hospital stay. Indeed, the results showed that after accounting for left ventricular function, patients with RV dysfunction remained to have a more than 6fold risk for postoperative MACE compared with patients with normal RV function. In addition, patients with RV dysfunction had a 50% longer hospital stay compare with those with normal RV function even after adjusting for factors known to contribute to a longer LOS.

Implications

These results have significant clinical implications. First, RV function has important prognostic value in high-risk patients undergoing major vascular surgery.

Preoperative assessment of RV function in patients with comorbidities known to be associated with RVD should be considered especially when surgeries are performed electively. In addition, the presence of RVD should be considered as having added perioperative risk during stages of surgical planning and risk discussion with patients. Second, perioperative management should involve strategies that aim to mitigate factors that can worsen RV function in patients with preexisting dysfunction. These strategies may include avoiding factors that can worsen pulmonary arterial pressure, instituting mechanical ventilatory strategies that promote low plateau and low positive end expiratory pressure,20 optimal blood pressure control to maintain coronary perfusion to the already compromised right ventricle, and consideration for invasive monitoring such as intraoperative transesophageal echocardiogram to guide both fluid and inotropic management.

Other Findings

The finding that LVEF did not reach a statistical significance for association with postoperative MACE was interesting. Although this may be due to the small sample size being underpowered, the results from this present study agreed with findings from prior studies. In Sprung et al. and Karkos et al., a lower or abnormal EF was found not to be associated with postoperative myocardial infarction in vascular surgical cohorts.6,7 Similarly, Martyal et al. did not find LVEF to be associated independently with postoperative cardiac complications in patients undergoing vascular surgery.21 Finally, in a meta-analysis by Karkos et al., resting LVEF was not a reliable predictor of perioperative cardiac events in the vascular surgical cohort.22 As suggested by Karkos et al., resting LVEF does not always predict cardiovascular response to perioperative stress. Together with the advancement in endovascular technology with decreased morbidity,23 the reliability of LVEF as a predictor for perioperative cardiac events in patients under going vascular surgery is still questionable.

In the multivariable analysis for LOS, an interaction term between RVSP and RV dysfunction (RVSPxRVD) was included based on the clinical knowledge that RVSP reflects pressure generated by the right ventricle during systole. As such, RVSP is affected by RV function itself and may be lower in a patient with poor RV systolic function compared with one with normal function in the presence of pulmonary HTN. This reasoning is supported by the authors' observation that although the mean RVSP is higher in those with RV dysfunction, patients with highest RVSP (2 standard deviations above the mean) all had normal RV function.

Of interest, the authors found that the interaction term of RVSPxRVD had a coefficient of 0.98 ($p = 0.012$) for LOS. However, this does not represent a protective effect. Rather, this reflects the interaction between RVSP and RV function. To shed light on this observation, the authors performed a post hoc analysis on the association between RVSP and LOS in relation to the interaction between RVSP and RV function. Dividing patients into 2 groups, those with RVSP 1 standard deviation (STD) from the mean and those with RVSP >1 STD, the authors found a positive correlation between RVSP and LOS in the first group but a negative correlation in the latter group (Fig. 3 and 4). That is, the direction of the association between RVSP and LOS appears to be opposite between groups with lower versus higher RVSP, and high RVSP appears to be associated with a shorter LOS. However, evaluating the distribution of patients with and without RV dysfunction among those with RVSP greater than 1 STD from the mean, the authors found that patients with an RVSP greater than 2 STD (RVSP >63.8 mmHg) all had normal RV function (Fig 4). As such, it is not that high RVSP is associated with shorter LOS; rather, those with high RVSP with normal RV function did not have a prolonged LOS. From this, the authors can conclude that there is an interaction between RVSP and RV function and that RV function is the mediator underlying the discrepant association between RVSP and LOS in patients with low versus high RVSP.

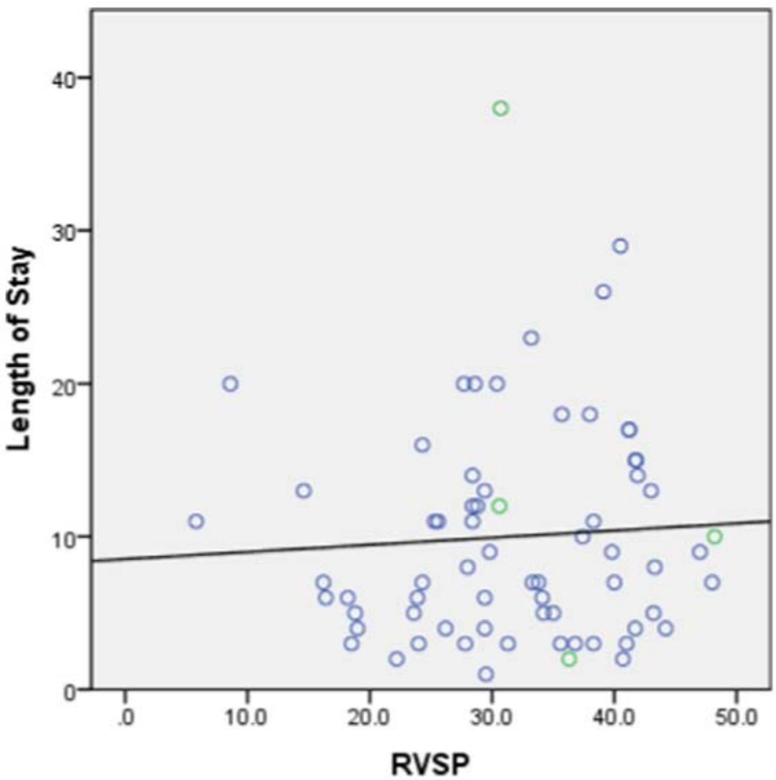

Fig 3. Scatterplot: relationship between length of stay and RVSP in subjects with RVSP > 1 STD. RVSP, right ventricular systolic pressure; STD, standard deviation. *Blue open circle* = subjects with normal right ventricular function. *Green open circle* = subjects with right ventricular dysfunction.

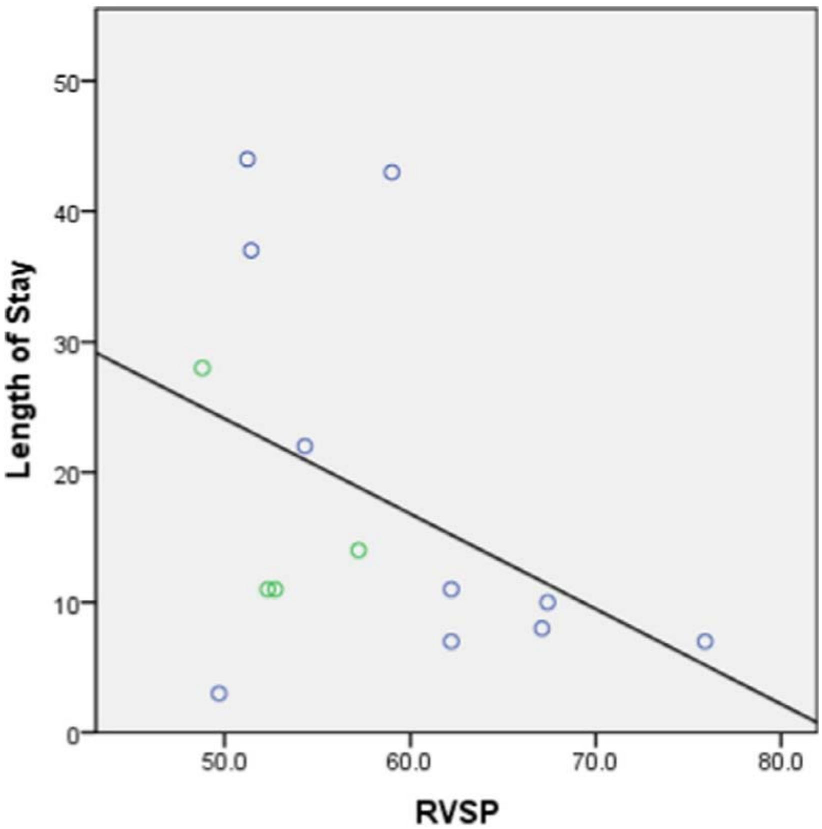

Fig 4. Scatterplot: relationship between length of stay and RVSP in subjects with RVSP >1 STD. RVSP, right ventricular systolic pressure; STD, standard deviation. *Blue open circle* = subjects with normal right ventricular function. *Green open circle* = subjects with right ventricular dysfunction.

Limitations

Although the study found a 9% prevalence for RVD in this surgical cohort, more study is needed to validate this finding owing to selection bias. By including only patients with preoperative echo, it is possible that patients with cardiac disease were selected preferentially. As such, the prevalence of RVD reported in this study may be overestimated. For assessment of RV function, using a 1year cutoff for preoperative echo is another limitation because cardiac function may change or even become progressively worse. However, most of the patients in this cohort (86%) had preoperative echo within 1 month of their designated surgery. There was only 1 patient with preoperative echo being closer to the 1year cutoff. For the remaining patients, echoes were performed within 2 to 6 months.

The relative overall small sample size resulted in the wide CIs observed in this study. In addition, the small sample size and low event rates likely resulted in the study being under powered to detect an association between RV dysfunction and In-hospital cardiac mortality; there were only 2 deaths that were attributed to cardiac complications in the cohort.

Other study limitations include data being collected from a single tertiary care center and the study being retrospective in nature. Because this study was performed only at 1 single center, generalization of the findings may be limited. Another major limitation was the retrospective nature of the study. Because only covariates that were documented well and consistently could be evaluated, it is possible that other unexplored variables also are associated with outcomes and may lead to confounding. In addition, events such as myocardial infarction were identified based purely on progress notes or discharge summary rather than on laboratory testing such as troponin, so the findings of the study are dependent on accuracy of the medical charting. Of note, there is also limitation in using RVSP as a surrogate marker for pulmonary arterial pressure because RVSP is dependent on quality of the tricuspid regurgitation spectral Doppler signal and how estimation of right atrial pressure was derived. However, the authors believe the choice of RVSP is a reasonable one because preoperative right heart catheterization was not performed in this cohort.

Lastly, determining RV function based on visual estimation is inferior compared with an objective approach. However, the authors were able to obtain a Cohen's kappa coefficient of 0.496, suggesting a moderate agreement between cardiologists who had read and interpreted the echo images. For the 10 cases (9%) in which there was disagreement regarding RV function, the authors were able to obtain TAPSE as an objective parameter to determine RV function. Of note, the authors were not able to use TAPSE for all patients in this cohort because about one-third of the echo studies had images that did not allow TAPSE measurement.

Although the results of this study have important clinical implications, additional studies are needed to validate current findings. Future study approach including the use of a multi centered dataset and a larger sample size will be of particular importance. A multicenter study will not only increase the study power but also allow generalization of the findings. In addition, including other a priori covariates may shed light on their effects on postoperative cardiac complications and inter actions with the presence of RVD. Notably, a covariate such as diastolic dysfunction would be an important potential con founding factor because it is known that prevalence of diastolic dysfunction is high among the vascular surgical cohort.17 Finally, the use of newer echo parameters, such as speckle tracking strain, strain rate, and 3dimensional echo, to assess RV function may have the advantage of higher sensitivity and may add invaluable insight to current findings.

Conclusion

In this retrospective study of high-risk patients undergoing nonemergent major vascular surgery, preexisting right ventricular dysfunction was associated independently with a higher incidence of postoperative major cardiovascular events and a longer length of hospital stay. In contrast, LVEF was not associated independently with these outcomes. Based on these findings, the prognostic value of RVD extends beyond the cardiac surgical cohort. Therefore, knowledge in the role of RVD, its pathophysiology, and its management in the perioperative setting should be understood by all anesthesiologists and physicians providing care in the perioperative setting.

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