Perioperative cardiac events in endovascular repair of complex aortic aneurysms and association with preoperative studies

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Background: **Endovascular repair of complex aortic aneurysms (CAAs) can be performed in high-risk individuals, yet is still associated with significant morbidity, including spinal cord ischemia, cardiac complications, and death. This analysis was undertaken to better define the cardiac risk for CAA.**

Methods: **A prospective database of patients undergoing thoracoabdominal or juxtarenal aortic aneurysm repair with branched and fenestrated endografts was used to retrospectively determine the number of cardiac events, defined as myocardial infarction (MI), atrial fibrillation (AF), and ventricular arrhythmia (VA), that occurred ≤30 days of surgery. Postoperative serial troponin measurements were performed in 266 patients. Any additional available cardiac information, including preoperative echocardiography, physiologic stress tests, and history of cardiac disease, was obtained from medical records. The efficacy of preoperative stress testing and the association of various echo parameters were evaluated in the context of cardiac outcomes using univariable and multivariable logistic regression models.**

Results: **Between August 2001 and December 2007, 395 patients underwent endovascular repair of a thoracoabdominal or juxtarenal aortic aneurysm. The incidence of AF, VA, and 30-day cardiac-related death was 9%, 3%, and 2%, respectively. Overall 30-day mortality was 6%. Univariable analysis showed the presence of mitral annulus calcification was associated with MI (odds ratio [OR], 3.5; 95% confidence interval [CI], 0.9-13.8; $P = .07$). Left atrium cavity area, ejection fraction, left ventricle mass, and left ventricular mass index were univariably associated with the presence of VA. Multivariable analysis showed only the left atrium cavity area was independently associated with VA (OR, 1.2; 95% CI, 1.0-1.5; $P = .07$). Stress test was done in 179 patients. Negative stress test results occurred in 152 (85%), of whom 9 (6%) sustained an MI during the 30-day perioperative course. MI occurred in 2 of the 27 patients (7%) who had a positive stress test result.**

Conclusions: **Endovascular repair of CAA can be performed in high-risk individuals but is associated with significant cardiac risk. It remains difficult to risk stratify patients using preoperative stress testing. Echo evaluation may help to identify patients who may be more likely to develop ventricular arrhythmias in the postoperative period and thus warrant closer monitoring. Postoperative troponin monitoring of all patients undergoing repair of CAA is warranted given the overall risk of MI. (J Vasc Surg 2011;53:21-7.)**

Surgical treatment of thoracoabdominal aneurysm (TAA) was first reported in 1955[1] and remains a challenge for clinicians. Conventional surgery for TAA is associated with a 30-day mortality rate of 5% to 23%.[2-10] Endovascular repair is a minimally invasive technique that may decrease the risk of periprocedural complications, thus expanding the patient population considered eligible for treatment and decreasing complications in conventional-risk patients.[12,13] Development of fenestrated and branched devices made possible the pure endovascular repair of thoracoabdominal and juxtarenal aneurysms. We have previously reported acceptable mortality and spinal cord ischemia rates compared with a healthier cohort undergoing conventional, open repair.[14] Patient age, renal insufficiency, aneurysm extent, cardiac function, and emergency presentation have been identified previously as risk factors for death after conventional aortic surgery.[15-19] The prevalence of underlying coronary artery disease (CAD) in patients with aortic aneurysms has been reported as 30% to 70%, and it is also associated with increased mortality and cardiac complications during the postoperative period.[11,20-23]

Despite consensus-based guidelines,[27] optimal management of CAD during the preoperative workup for major vascular surgery remains controversial.[16,18,24-26] The aim of this study was to describe the incidence of cardiac events in patients undergoing endovascular repair of complex abdominal and TAAs and to evaluate the association between preoperative patient information derived from 2-dimensional transthoracic echocardiograms, cardiac stress tests, and intervention, and perioperative cardiac morbidity and mortality.

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METHODS

A retrospective review was performed of a prospectively collected database of patients undergoing TAA or juxtarenal aortic aneurysm repair using branched and fenestrated endografts under a physician-sponsored investigational device exemption protocol, between August 2001 and December 2007. All patients enrolled were considered high-risk for conventional open surgery and signed a consent approved by the Institutional Review Board.

We evaluated baseline clinical characteristics, the number of cardiac events ≤30 days of surgery, and 30-day cardiac-related mortality. Medical records were retrospectively reviewed to determine the number of patients with troponin T levels >0.1 ng/mL during the 30-day period after surgery and the results of bidimensional transthoracic echocardiogram, stress tests, cardiac catheterizations, and any other coronary intervention. The decision for the patient to undergo cardiac testing or risk stratification was at the discretion of the treating surgeon.

A cardiac event was defined as myocardial infarction (MI), ventricular arrhythmia, and atrial fibrillation (new onset or that required changes in a previous prescription). MI was defined in accordance with the latest consensus document, indicated by troponin T >0.1 ng/mL associated with symptoms of angina, electrocardiogram changes of ischemia, or wall motility changes verified through echocardiogram.[28] Ventricular arrhythmia was documented when sustained or nonsustained ventricular tachycardia or ventricular fibrillation was verified by telemetry or electrocardiogram, if treatment was provided. The echocardiogram parameters were used to analyze wall motion abnormality (WMA), presence of mitral annular calcification (MAC), left atrium size (LAS) and cavity area (LACA), and left ventricular mass (LVM) and mass index (LVMI). LVM was calculated as described by Deveraux et al[29,30] and LVMI as the result of LVM divided by body surface area.

Continuous variables were described as mean with the standard deviation (SD) and categoric variables as number and percentage. Univariable and multivariable logistic regression models were used to evaluate the associations between preoperative echocardiographic parameters and myocardial events. Echocardiographic parameters were determined a priori and included wall motion abnormality, MAC, LACA, LA size, EF, LVM, LVMI, and stage of diastolic dysfunction. Associations from the logistic models are given as odds ratios (ORs) with 95% confidence intervals (95% CIs) and *P* values. Variables with a $P \leq .2$ in the univariable analysis were chosen for the multivariable analysis. In the multivariable analysis, variables with a $P < .05$ were regarded as significant. All analyses were done using S-Plus 7.0 software (Insightful Corp, Seattle, Wash).

RESULTS

A total of 395 patients underwent endovascular repair of complex aortic aneurysms using custom-made fenestrated and branched devices. Retrospective review identified postoperative serial troponin T measurements were performed in 266 patients (Fig 1), and all remaining patients were excluded from analysis. Patient baseline characteristics are reported in Table I. The mean age was 74 years, with a high prevalence of reported CAD (78%) and chronic obstructive pulmonary disease (35%), of which 46% (42 of 92) were dependent on home oxygen supplementation. All patients underwent some form of preoperative cardiac evaluation (Fig 2). A stress test was performed and reached adequate myocardial stressing in 179 patients, and 160 patients underwent preoperative echocardiography. Cardiac catheterization was done in 49, and 18 were cleared by the cardiologist without any further cardiac tests. In 20 patients, we were not able to retrieve data from the preoperative cardiac evaluation.

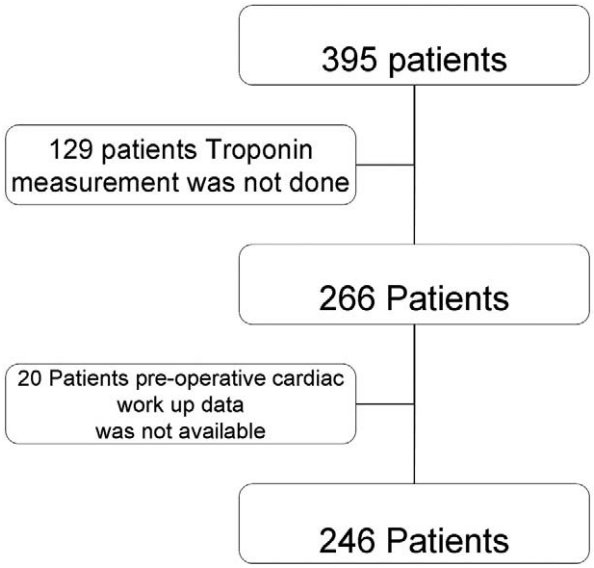

Fig 1. Flow diagram shows inclusion and exclusion of patients in the study.

Percutaneous coronary intervention (PCI) was performed in 19 patients during the preoperative workup (8 patients after a positive stress test, the remaining as a result of symptoms). Continued medical treatment was recommended in those patients without critical coronary stenosis or with unsuitable anatomy for PCI. Coronary artery bypass grafting (CABG) was performed in 12 patients before the endovascular procedure as a result of the cardiac workup.

Troponin elevation occurred in 33 patients, and 19 met the consensus criteria for MI.[28] Troponin was elevated in the remaining 14 patients without clinical findings (symptoms, electrocardiographic, or echocardiographic). The incidence of AF, VA, and 30-day cardiac-related death rate was 9% (24 of 266), 3% (9 of 266), and 2% (5 of 266), respectively, and the overall 30-day mortality rate from any cause was 6% (17 of 266).

Univariable analysis showed no echocardiographic parameter was associated with AF (Table II, online only) or 30-day cardiac-related death. The presence of MAC

Table I. Baseline patient characteristics

Variable	*Value (N = 266)*
Age, mean (SD)	74.1 (8.3)
Male, No. (%)	220 (82)
BMI, mean (SD), kg/m^2	27.6 (5.8)
History of No. (%)	
Coronary artery disease[a]	208 (78)
Diabetes mellitus	50 (19)
Chronic heart failure	53 (20)
Hypertension	222 (83)
Stable angina	10 (4)
AVR/MVR	21 (8)
Myocardial infarction	98 (37)
Arrhythmia	62 (23)
CABG	61 (23)
PCI/stent	38 (14)
COPD	92 (35)
Use of home oxygen	42 (16)
Chronic renal insufficiency, No. (%)[b]	55 (21)
Dialysis, No. (%)	6 (2)
Smoking, No. (%)	
Never	30 (11)
Past	194 (73)
Present	42 (16)
ASA risk score, No. (%)	
II	3 (1)
III	156 (59)
IV	10 (40)
Type of aneurysm, No. (%)	
Juxtarenal	160 (60)
Suprarenal	23 (9)
Thoracoabdominal, No. (%)	82 (31)
I	4 (2)
II	14 (5)
III	19 (7)
IV	44 (17)
Unknown	1 (0.4)
Pseudoaneurysm	1 (0.4)

ASA, American Society of Anesthesiology; *AVR,* aortic valve replacement; *CABG,* coronary artery bypass grafting; *COPD,* chronic obstructive pulmonary disease; *MVR,* mitral valve replacement; *PCI,* percutaneous coronary intervention.

[a]History of previous myocardial infarction, PCI, CABG, and/or presence of ischemic changes in electrocardiogram.

[b]Serum creatinine level >1.5 mg/dL.

showed a trend of association with MI (MI: 5 of 9 [56%] vs no MI: 40 of 153 [26%]; OR, 3.5; 95% CI, 0.9-13.8; $P = .07$; Table III, online only). Univariable analysis showed LACA, EF, LVM, and LVMI were associated with the presence of VA (Table IV, online only). In multivariable analysis, however, only LACA was independently associated with VA (OR, 1.2; 95% CI, 1.0-1.5; $P = .07$). Negative stress test results were noted in 152 of the 179 patients (85%), of whom 9 (6%) sustained an MI during the 30-day perioperative course. Of the 27 patients who had a positive stress test result, MI developed in 2 (7%), despite prophylactic revascularization through PCI in selected patients (Fig 3).

Of the 19 patients with MI, the preoperative stress tests were interpreted as a negative result in 9, 2 patients primarily underwent cardiac catheterization and received only continued medical treatment because they were unfit for revascularization, 2 patients had positive stress test results and underwent PCI but myocardial ischemia still developed, 3 patients had been cleared by a cardiologist and were considered to be at high risk for acute coronary syndrome but had no other options. We were not able to retrieve the preoperative cardiac evaluation for three patients.

DISCUSSION

In this study, we retrospectively analyzed 395 high-risk patients with a significantly high prevalence of reported preoperative CAD (78%) who underwent endovascular repair of a complex aortic aneurysm. Atherosclerotic aneurysm degeneration of the aorta is strongly associated with other manifestations of atherosclerosis,[23] leading to high suspicion of coronary risk after many types of interventions. Yet, clinical diagnosis of perioperative MI may be difficult in patients undergoing major vascular surgery, mainly because of the transient and silent nature of perioperative MI, often resulting in non–Q-wave infarction.[31]

Routine measurement of serum troponin T levels, telemetric monitoring, and easy access to bedside echocardiogram have improved the ability to accurately diagnose MI, particularly during the early postoperative period, leading to a refinement of the criteria for the diagnosis of MI in 2007.[28,32] Previous reports of large series of TAAs treated with conventional open surgery included patients with variable criteria that are less sensitive than troponin for detecting MI. Nevertheless, our results showed a comparable 30-day mortality rate and incidence of cardiac events when confronted with a healthier cohort undergoing conventional open repair (Table V).

In an effort to decrease the risk of MI, the American College of Cardiology/American Heart Association 2007 guidelines on Perioperative Cardiovascular Evaluation and Care for Noncardiac Surgery[27] recommended that patients with three or more clinical risk factors (ischemic heart disease, compensated or prior heart failure, diabetes mellitus, renal insufficiency, and cerebrovascular disease) and poor functional capacity who require vascular surgery should undergo a cardiac stress test only if it might change perioperative management. Functional cardiac evaluation has been the mainstay of preoperative clinical testing using dobutamine echocardiography or nuclear myocardial perfusion imaging. Proper interpretation requires adequate visualization of the cardiac musculature, either through an echo window or nuclear imaging, and the ability to expose the heart to a stressed state (tachycardia). Conventional management follows further delineation of anatomic defects and the potential to address them in the setting of a marked functional defect to minimize prior cardiac risk.

The accuracy of this thought process was challenged by the results of the Coronary Artery Revascularization Prophylaxis (CARP) trial.[18,24,33-35] This study provides useful information but was also heavily criticized given the inclusion of a wide variety of vascular procedures included in the stratification. Such data resulted in the conclusion that a conservative strategy is warranted in most patients with stable symptoms.[27] Whether and how a patient requiring

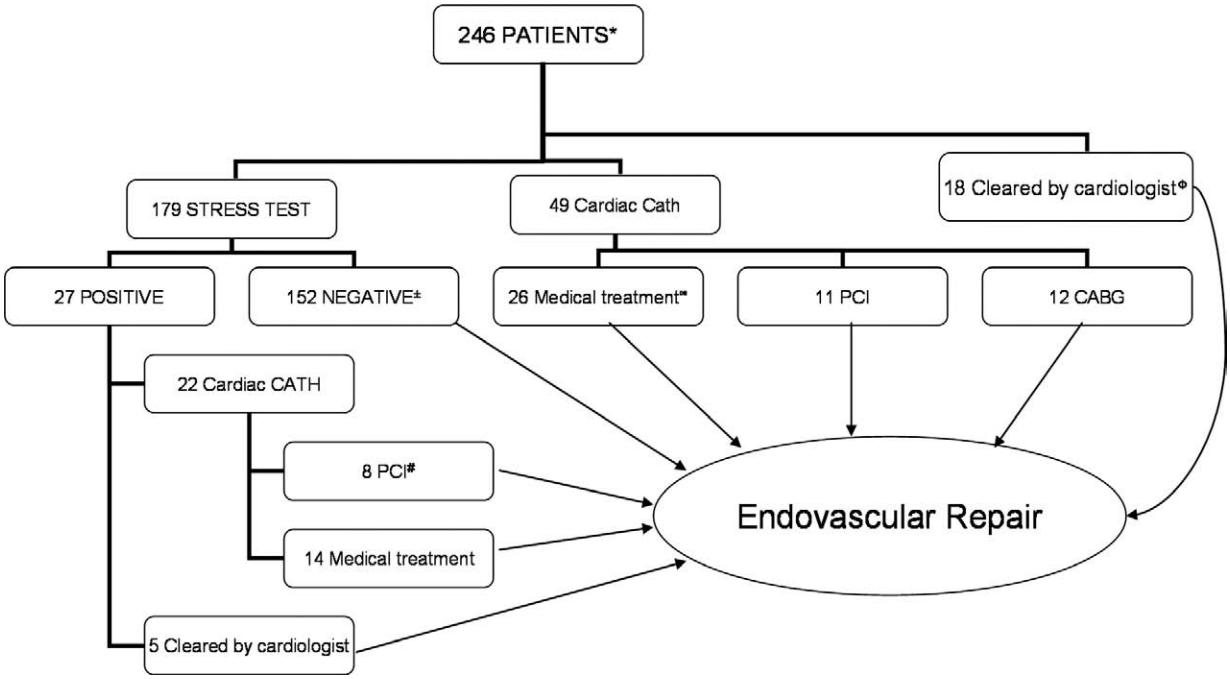

Fig 2. Path of patients' cardiac assessment before endovascular repair of thoracoabdominal aneurysm. *CABG,* Coronary artery bypass grafting; *PCI,* percutaneous coronary intervention. *Preoperative evaluation data from 20 patients were not available; 3 developed myocardial infarction (MI) after surgery; ±9 patients in this group developed MI after surgery; #2 patients in this group developed MI after surgery; ∞2 patients in this group developed MI after surgery; Φ3 patients in this group developed MI after surgery.

an aneurysm repair should be worked-up from the cardiac risk standpoint remains a focus of debate.

The 2-dimensional transthoracic echocardiogram is well accepted for evaluation of cardiac function and for providing powerful prognostic information for cardiovascular outcomes, such as presence of left ventricular hypertrophy,[36] aortic sclerosis,[37] and left ventricle ejection fraction,[15,37] all of which have been associated with a varying degree of cardiac risk. The association of echocardiographic parameters with underlying CAD is less well established, however. Chang et al[38] noted that LV enlargement, LV hypertrophy, LVEF, wall motion abnormality, mitral annular calcification, and aortic sclerosis were predictors of perfusion defects by single photon-emission computed tomography and that EF <50%, WMA, MAC, and aortic sclerosis were predictors of coronary artery stenosis by angiography. None of these factors have been shown to be useful in assessing risk before aneurysm surgery.

Our results confirm the lack of predictive utility for stress test in the identification of patients at risk for MI. MI was a complication in 6% of patients with a negative stress test result and in 7% with a positive stress test result. Only 30% of patients with positive stress test result underwent PCI. The routine use of statins and β-blockers (unless contraindicated) may explain the relatively overall low risk. Of all the preoperative parameters assessed, only MAC was weakly associated with MI.

Presence of aortic valvular calcification, aortic stenosis, and MAC have been shown to be manifestations of subclinical cardiovascular disease and associated with an increased risk of CAD and cardiac death.[39-41] Adler et al,[42] comparing the results of coronary catheterization in age-matched patients with and without MAC, found that the presence of annular calcification was an independent predictor for coronary artery stenosis. In agreement with that, we found that the presence of MAC showed a trend to significance in predicting development of MI during the perioperative period. This association may be due to shared risk factors, including age, hypertension, hyperlipidemia, diabetes, and obesity. Carpentier et al[43] proposed a mechanism of MAC where mechanical factors (blood pressure and excess tension on leaflets) together with chemical factors (collagen and proteoglycans alteration) would cause annulus dehiscence and subsequent calcification. These data reinforce the theory that MAC may more accurately predict the effect of longitudinal blood pressure elevation than the blood pressure reading at one examination,[41] thus a marker of arterial stiffness.

Although readily treatable, atrial and ventricular dysrhythmias can both be fatal. Patients at risk for the development of such events should, at minimum, be closely monitored. The use of prophylactic medications, such as amiodarone, before the development of AF is a consideration, but again remains the subject of discussion. Our

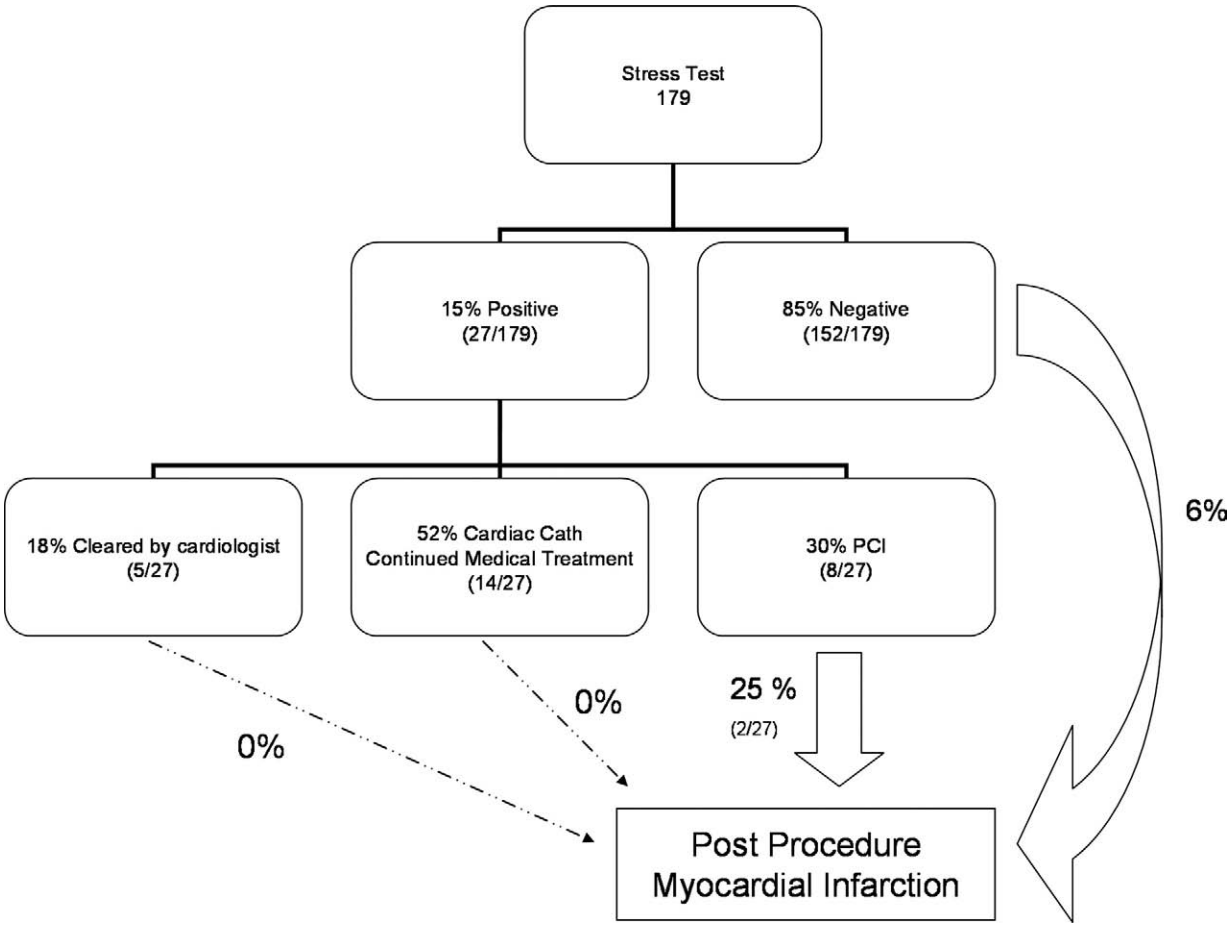

Fig 3. Clinical course of patients undergoing stress test before endovascular thoracoabdominal aneurysm repair. *PCI,* Percutaneous coronary intervention.

Table V. Mortality and cardiac-related mortality at 30 days and incidence of cardiac events in patients undergoing thoracoabdominal surgical and combined endovascular and surgical approach (*CESA*) repair

Repair/first author	*No.*	*30-day mortality* *No. (%)*	*Cardiac-related death* *No. (%)*	*Cardiac events* *No. (%)*
Open TAA repair				
Coselli,[2] 2007	2286	150 (6.56)	N/A	181 (7.9)
Schepens,[44] 2009	571	51 (8.9)	14 (2.5%)	N/A
Conrad,[11] 2007	455	39 (8.6)	5 (1%)	67 (14.7)
CESA				
Quinones-Baldrich,[45] 2009	20	0	0	1
Black,[46] 2006	17	3 (18)	1	N/A
Resch,[47] 2006	13	3	0	N/A
Our study	266	17 (6.3)	5 (2)	45/266 (17)

N/A, Not applicable; *TAA,* thoracoabdominal aneurysm.

results would suggest that the large LACA, low EF, and high LVM and LVMI are associated with VA, but no echo parameters were found to be associated with AF.

This analysis has several weaknesses. Given the highly selected value of the population, the results may have limited generalizability. The retrospective nature of the study affected the quality of the data and forced us to exclude many patients. Limited patient numbers, particularly those with a positive stress test result or treated with coronary interventions, thwart strong established conclusions.

Finally, the somewhat subjective values of both stress and echo interpretation coupled with a composite end

point indicative of MI can hamper the development of simple or binary patient management strategies.

CONCLUSIONS

Given these data, it remains difficult to find a benefit in the routine performance of stress tests before complex endovascular aneurysm repair in a patient without cardiac symptoms. Echo evaluation may help to stratify patients into those in whom postoperative dysrhythmias are more likely to develop and thus warrant closer monitoring. Yet, we cannot ignore the significant incidence of MI and thus recommend that all postoperative patients should undergo troponin monitoring with other appropriate diagnostic tests to allow for optimal management of any ischemia.

AUTHOR CONTRIBUTIONS

Conception and design: RG, TM
Analysis and interpretation: GB, RG, TM, ME, GP, AH, MC
Data collection: GB, TM
Writing the article: GB, RG, TM, ME, GP, AH, MC
Critical revision of the article: GB, RG, TM, ME, GP, AH, MC
Final approval of the article: GB, RG, TM, ME, GP, AE, MC
Statistical analysis: AH
Obtained funding: Not applicable
Overall responsibility: RG

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Table II (online only). Univariable analysis of the association between echo parameters and atrial fibrillation

Variable	*Atrial fibrillation*		*OR (95% CI) (Univariate)*	P
	Yes	*No*		
Wall motion abnormality, No. (%)	2/20 (10)	35/144 (88)	0.3 (0.1-1.6)	.3
Mitral anular calcification, No. (%)	7/20 (35)	38/142 (27)	1.5 (0.6-3.9)	.5
Left atrial cavity, mean (SD) cm^2	21.8 (5.1)	22.3 (7.2)	1.0 (0.9-1.1)	.8
No.	12	102		
Left atrial size, mean (SD) cm	4.2 (0.7)	4.6 (3.1)	0.8 (0.5-1.5)	.5
No.	18	124		
Ejection fraction, mean (SD)	0.52 (0.09)	0.50 (0.13)	3.8 (0.1-162.3)	.5
No.	21	192		
LV mass, mean (SD), g	219.7 (67.3)	240.1 (90.8)	1.0 (1.0-1.0)	.4
No.	20	136		
LV mass index, mean (SD), g/m^2	112.7 (25.1)	119.5 (43.6)	1.0 (1.0-1.0)	.5
No.	19	125		
Stage diastolic dysfunction, No. (%)				
1	11/13 (85)	87/101 (86)	1	.8
2	2/13 (15)	10/101 (10)	1.5 (0.3-8.2)	
3	0	4/101 (4)	Extreme	

CI, Confidence interval; *LV*, left ventricle; *OR*, odds ratio; *SD*, standard deviation.

Table III (online only). Univariate analysis of the association between echo parameters and myocardial infarction

Variable	*Miocardial infarction*		*OR (95% CI) (Univariate)*	P
	Yes	*No*		
Wall motion abnormality, No. (%)	1/9 (11)	36/155 (23)	0.4 (0.1-3.4)	.4
Mitral anular calcification, No. (%)	5/9 (56)	40/153 (26)	3.5 (0.9-13.8)	.07
Left atrial cavity, mean (SD), cm^2	22.2 (2.7)	22.3 (7.2)	1.0 (0.9-1.1)	.9
No.	5	109		
Left atrial size, mean (SD), cm	4.7 (1.0)	4.6 (3.0)	1.0 (0.8-1.2)	.9
No.	9	133		
Ejection fraction, mean (SD)	0.47 (0.17)	0.51 (0.13)	0.1 (0.01-7.2)	.3
No.	12	201		
LV mass, mean (SD), g	228.3 (71.6)	238.1 (89.4)	1.0 (1.0-1.0)	.7
No.	10	146		
LV mass index, mean (SD), g/m^2	108.8 (25.7)	119.1 (42.3)	1.0 (1.0-1.0)	.5
No.	7	137		
Stage diastolic dysfunction, No. (%)				
1	3/5 (60)	95/109 (87)	1	.3
2	1/5 (20)	11/109 (10)	2.9 (0.3-30.1)	
3	1/5 (20)	3/109 (3)	10.6 (0.7-133.7)	

CI, Confidence interval; *LV*, left ventricle; *OR*, odds ratio; *SD*, standard deviation.

Table IV (online only). Univariable analysis of the association between echo parameters and ventricular arrhythmia

Variable	*Ventricular arrhythmia*		*OR (95% CI) (Univariate)*	P
	Yes	*No*		
Wall motion abnormality, No. (%)	1/4 (25)	36/160 (22)	1.1 (0.1-11.4)	.9
Mitral anular calcification, No. (%)	1/4 (25)	44/158 (28)	0.9 (0.1-8.5)	.9
Left atrial cavity, mean (SD), cm^2	39.0 (7.1)	22.0 (6.7)	1.2 (1.0-1.4)	.01
No.	2	112		
Left atrial size, mean (SD), cm	4.8 (0.8)	4.6 (2.9)	1.0 (0.8-1.4)	.9
No.	3	139		
Ejection fraction, mean (SD)	0.33 (0.15)	0.51 (0.13)	Extreme	.002
No.	7	206		
LV mass, mean (SD), g	347.6 (63.4)	234.6 (87.1)	1.0 (1.0-1.0)	.02
No.	4	152		
LV mass index, mean (SD), g/m^2	189.3 (64.0)	117.1 (40.1)	1.0 (1.0-1.0)	.01
No.	3	141		
Stage diastolic dysfunction, No. (%)				
1	0	85/97 (88)	1	.9
2	0	9/97 (9)	Extreme	
3	1/1 (100)	3/97 (3)	Extreme	

CI, Confidence interval; *LV*, left ventricle; *OR*, odds ratio; *SD*, standard deviation.