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Not All Perioperative Myocardial Infarctions Can Be Prevented with Preoperative Revascularization

CURRENT universal definitions classify myocardial infarction (MI) into five types.[1] In general, perioperative MI (PMIs) are of type I (plaque rupture) or type II (prolonged supply-demand imbalance) variety.[2] Increased catecholamines, hemodynamic instability, inflammation, and coronary vasoconstriction during and after surgery can lead to rupture or erosion of a potentially unstable coronary plaque, often referred to as a "vulnerable" plaque, resulting in acute coronary thrombosis and PMI.[3] However, the relative proportion of plaque rupture, demand ischemia, or their combination as the etiology of PMI is unknown. In this issue of ANESTHESIOLOGY, Galal *et al.*[4] demonstrated that although preoperative dobutamine stress echocardiography can predict patients who are at risk for PMI, it could not predict the location of those PMI in 54 consecutive patients undergoing major vascular surgery.

How can we reconcile this surprising finding? Only 10% of patients undergoing vascular surgery were shown to have pristine coronary anatomy.[5] The majority of them have multivessel disease, and they can be identified as at risk for PMI by preoperative dobutamine stress echocardiography. It was previously shown that 66% of MI occur in plaques with less than a 50% luminal stenosis[6] and that the MI-related coronary vascular territory is frequently not related to the territory with the most severe coronary stenosis as seen by coronary angiography.[7] Moreover, statin therapy markedly reduces the risk of MI[8] with minimal effect on the severity of coronary luminal stenosis.[9] This disconnection between the severity of anatomic obstruction and the MI risk is one of the main pieces of evidence that plaque rupture depends on its composition rather than on its size.[10] Although preoperative dobutamine stress echocardiography and other functional tests are good for the diagnosis of significant coronary artery obstruction and the identification of patients at risk for MI,[11] they may fail to identify the myocardial territory at risk from rupture of a nonobstructive coronary artery plaque. If this etiology contributes significantly to PMI, preoperative revascularization approaches based on dobutamine stress echocardiography and coronary angiography will not protect against all PMI. This may in part explain why it has been difficult to show short-term benefit (up to 3 yr) of preoperative revascularization in reduction of PMI or survival[12,13] but may show better long-term survival.[14] These findings are consistent with the current American Heart Association/American College of Cardiology consensus recommendations that preoperative revascularization is warranted if it would benefit patients in the long-term irrespective of the planned surgery.[15]

Galal *et al.* also found that the new wall motion abnormalities (WMA) detected by intraoperative transesophageal echocardiography (TEE) had 100% positive predictive value and better agreement with the location of PMI compared with preoperative dobutamine stress echocardiography. Deterioration of regional WMA correlates better with in-hospital[16] and long-term adverse cardiac outcomes[17] after cardiac surgery. This led to some positive findings when monoplane TEE was used as an ischemia monitor in smaller trials in noncardiac surgery. However, a larger well-designed trial[18] concluded that TEE findings were sensitive, nonspecific, and did not correlate with postoperative MI. Subsequently, the presence of sustained WMA (3 h) after aortic cross clamp was shown to predict PMI.[19] Eisenberg *et al.*[20] concluded that in 332 patients undergoing vascular and abdominal surgery, TEE offered little incremental value compared with two-lead electrocardiogram monitoring, even though the new WMA by intraoperative TEE had a 2.2 relative risk of predicting postoperative outcomes. It is to be noted that the relevant ischemic outcome in all these studies was seen in very few patients, and there was no attempt to correlate PMI location with intraoperative WMA. Thus, unlike in cardiac surgical patients, routine use of TEE as an intraoperative ischemia monitor in high-risk noncardiac surgery did not gain widespread acceptance due to the paucity of literature, the lack of studies with multiplane TEE, nonselective target population studied, and concerns about personnel availability, cost, and safety. This is reflected in the current American Society of Anesthesiologists/Society of Cardiovascular Anesthesiologists recommendation that TEE can be used in acute persistent hemodynamically unstable and life threatening situations during noncardiac surgery (Class IIa, Level C).

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As TEE interpretation has improved with omniplane imaging, three-dimensional TEE, and strain rate imaging, it is now primed to be a cutting-edge technology for early intraoperative ischemia detection. The findings of Galal *et al.* provide a compelling argument for further exploration of intraoperative TEE in high-risk patients such as the ones with preoperative positive dobutamine stress echocardiography (a high pretest probability increases the posttest probability). Galal *et al.* performed protocol-based TEE ischemia and WMA monitoring and analyzed the recordings in the echo-laboratory afterward. They did not study the effect of intraoperative clinical interventions in response to TEE-detected ischemia on PMI. It will be important to study the effect of comprehensive patient management using preoperative risk stratification, early intraoperative detection of ischemia by TEE, and targeted intra- and postoperative interventions and management of PMI with multimodal therapy in an intensive/high-dependency setting.

On the basis of the findings by Galal *et al.*, the authors suggest that preoperative revascularization will often be ineffective because preoperative myocardium "at risk" identified differs from the actual location of PMI. This is an interesting and a provocative finding; however, there are several caveats to be considered. The composite outcome was seen in just 15 patients, and the agreement of location of PMI, a major focus of this study, is based only on six patients. A detailed description of the characteristics of these six patients could give more insights. It would be interesting to see whether the disagreement in location of PMI was in major *versus* minor coronary arterial distribution. For example, the disagreement between inferior and anterior wall is different from the disagreement between anterior and anteroseptal walls. Whether all PMIs were seen in patients with aortic surgery with cross-clamping is unknown. It may very well be that the aortic cross-clamp is a more severe or a "better" stress test than the dobutamine stress echocardiography. It is to be noted that perioperative aspirin and statin therapy that can stabilize the plaques was achieved only in two thirds of this study population. Other limitations include lack of description of the duration and severity of new WMA, relationship to loading conditions, and correlation to intraoperative electrocardiogram evidence of ischemia. Patients with severe valvular disease, decreased ejection fraction, and female gender were not investigated in this study; therefore, the findings may not be generalized to these populations.

PMI remains a significant cause of morbidity, mortality, and increased healthcare costs. The mechanisms of PMI need to be further explored and well understood before an effective intervention strategy can be established. The current strategies of revascularization and optimal medical therapy to reduce the incidence of PMI have met with some success, but PMI is still a common occurrence. Alternative surgical approaches, such as minimally invasive techniques, is an attractive option but it is not suitable for all procedures or patients. The current challenge is to establish a comprehensive strategy with long-term β-adrenergic blockade, statin therapy, and targeted preoperative revascularization, keeping in mind the added risk of coronary stent thrombosis or dual antiplatelet therapy. The study by Galal *et al.* suggests that intraoperative TEE may be a sensitive method for identification of patients at risk for PMI, should these measures fail and allow for early aggressive treatment of these patients.

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Relation between Preoperative and Intraoperative New Wall Motion Abnormalities in Vascular Surgery Patients

A Transesophageal Echocardiographic Study

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ABSTRACT

Background: Coronary revascularization of the suspected culprit coronary lesion assessed by preoperative stress testing is not associated with improved outcome in vascular surgery patients.

Methods: Fifty-four major vascular surgery patients underwent preoperative dobutamine echocardiography and intraoperative transesophageal echocardiography. The locations of left ventricular rest wall motion abnormalities and new wall motion abnormalities (NWMAs) were scored using a seven-wall model. During 30-day follow-up, postoperative cardiac troponin release, myocardial infarction, and cardiac death were noted.

Results: Rest wall motion abnormalities were noted by dobutamine echocardiography in 17 patients (31%), and transesophageal echocardiography was noted in 16 (30%). NWMAs were induced during dobutamine echocardiography in 17 patients (31%), whereas NWMAs were observed by transesophageal echocardiography in 23 (43%), κ value = 0.65. Although preoperative and intraoperative rest wall motion abnormalities showed an excellent agreement for the location (κ value = 0.92), the agreement for preoperative and intraoperative NWMAs in different locations was poor (κ value = 0.26–0.44). The composite cardiac endpoint occurred in 14 patients (26%).

Conclusions: There was a poor correlation between the locations of preoperatively assessed stress-induced NWMAs by dobutamine echocardiography and those observed intraoperatively using transesophageal echocardiography. However, the composite endpoint of outcome was met more frequently in relation with intraoperative NWMAs.

What We Already Know about This Topic

- Coronary revascularization after stress testing before vascular surgery does not improve outcome, perhaps because the location of myocardial ischemia during surgery may occur in an unpredictable fashion

What This Article Tells Us That Is New

- In 54 patients undergoing major vascular surgery dobutamine echo stress testing predicted new wall motion abnormalities and infarction from surgery but did not predict the location of ischemia and infarction
- These results further question the value of surgical compared with medical therapy for patients with coronary arterial disease undergoing vascular surgery

VASCULAR surgery patients represent a population at increased risk for developing postoperative adverse cardiac outcomes.[1,2] Cardiac stress testing before surgery is widely used to identify patients at increased risk for postoperative cardiac events. Recently, prophylactic coronary revascularization was studied in vascular surgery patients.[3] However, revascularization of the suspected intraoperative culprit coronary lesion, assessed by preoperative testing, was not associated with an improved outcome.

Although the pathophysiology of perioperative myocardial infarction (MI) is not entirely clear, it is now well accepted that coronary plaque rupture, leading to thrombus formation and subsequent vessel occlusion, is an important cause. This is similar to the nonoperative setting. The surgical stress response includes a catecholamine surge with asso-

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ciated hemodynamic stress, vasospasm, reduced fibrinolytic activity, platelet activation, and consequent hypercoagulability.[4] In patients with significant coronary artery disease (CAD), MI may also be caused by a sustained myocardial supply or demand mismatch caused by tachycardia and increased myocardial contractility. The association of postoperative MI with myocardial ischemia and nontransmural or circumferential subendocardial infarction supports this mechanism. Although transmural ischemia is considered to be relatively uncommon, half of all fatalities have direct evidence of plaque disruption defined as fissure or rupture of plaque and hemorrhage into the plaque cavity.[5–7]

The use of intraoperative transesophageal echocardiography (TEE) has recognized a high prevalence of transient myocardial ischemic episodes causing regional wall motion abnormalities (WMA) in patients undergoing major noncardiac surgery and requiring vigilant monitoring for serious cardiac outcomes.[8–10] Those transient events reflect the balancing effects of coronary reserve and myocardial viability *versus* a multifactorial perioperative ischemic load (burden). Different detection modalities, such as persantine-thallium scintigraphy and electrocardiography, were compared with intraoperative TEE in detecting ischemia with inconclusive results.[11,12] However, the location of ischemic events has never been a primary goal in all previous investigations.

Our hypothesis is that although dobutamine echocardiography (DE) can identify patients at risk, the location of the cardiac event is difficult to foresee because of the unpredictable plaque rupture of nonsignificant, vulnerable, coronary artery lesions. In this study, we matched preoperatively assessed ischemic left ventricular (LV) territories using DE and intraoperatively observed new wall motion abnormalities (NWMAs) using TEE to examine the chance of reproducibility of a NWMA at the same location preoperatively and intraoperatively. This matching correlation would be more emphasizing if perioperative NWMAs were predictive of postoperative cardiac outcomes.

Materials and Methods

Study Participants

In this prospective cohort study, patients older than 40 yr scheduled for noncardiac vascular surgery at the Erasmus University Medical Center, Rotterdam, the Netherlands, between June 2005 and September 2008 were candidates for inclusion in the study. Patients had to be scheduled for abdominal aortic aneurysm repair, abdominal aortic stenosis surgery, or lower limb arterial reconstruction. We used the Lee's revised cardiac risk index, which included history of ischemic heart disease, heart failure, cerebrovascular accidents, insulin therapy for diabetes mellitus, and renal disease with serum creatinine more than 2.0 mg/dl, to abbreviate the cardiac risk factors and to identify patients at risk.[13] All patients underwent DE before surgery. Exclusion criteria for the study were the inability to retrieve adequate echocardiographic views pre- or intraoperatively. After approval from the medical ethics committee board and after obtaining informed consent from the patients, we included 54 consecutive adult patients.

Dobutamine Echocardiography

All patients underwent DE to evaluate LV wall motion using dobutamine (±atropine) as a stressor. Two-dimensional echocardiography was performed at rest using Hewlett-Packard Sonos 1000 echo apparatus (Hewlett-Packard, Andover, MA) with 2.5- and 3.5-MHz transducers. The technique yielded standard parasternal and apical echocardiographic views under basal conditions and throughout graded dobutamine infusion. A stepwise incremental dose of dobutamine was administered, beginning at 10 $\mu g \cdot kg^{-1} \cdot min^{-1}$ and increased by 10 $\mu g \cdot kg^{-1} \cdot min^{-1}$ every 3 min until a definite endpoint was attained.[14–16] During the dobutamine infusion, heart rate, blood pressure, and electrocardiography were monitored. When the target heart rate (85% of maximum age- and gender-predicted heart rate) was not obtained at the maximum dobutamine dose (40 $\mu g \cdot kg^{-1} \cdot min^{-1}$), atropine (0.25–1.0 mg) was administered.[15,17] Test endpoints were achievement of target heart rate, maximal dose of dobutamine and atropine, extensive NWMAs, more than 2-mV downsloping ST-segment depression measured 80 ms after the J-point compared with the baseline, hypertension (blood pressure $>$ 240/120 mmHg), a decrease in systolic blood pressure of more than 40 mmHg compared with at rest, significant arrhythmias, or any intolerable adverse effects considered to be the result of dobutamine or atropine. An intravenous β-blocker (metoprolol, 1–5 mg) was available to reverse the adverse effects of dobutamine or atropine. The test was completed only after all ischemic regions had returned to baseline.

Transesophageal Echocardiography

After induction of anesthesia and tracheal intubation, the TEE probe was inserted. We based our TEE examination on the recommendations of the American Society of Echocardiography Council for Intraoperative Echocardiography and the Society of Cardiovascular Anesthesiologists guidelines for performing a comprehensive intraoperative multiplane TEE examination.[18] The LV wall motion was monitored in six views, namely, three midesophageal views (the four-chamber midesophageal view, the midesophageal two-chamber view, and the midesophageal long-axis view) and three transgastric views (basal, midpapillary, and apical transgastric views). Baseline images of the LV in short- and long-axis were acquired and tape-recorded for offline analysis. The TEE probe depth and imaging planes of the basal views were noted to reproduce equivalent views intraoperatively. To improve the detection of intraoperative NWMAs, we adopted a semicontinuous method, keeping the TEE probe in the transgastric position with the midpapillary LV short-axis view continuously displayed and repeating the whole set of the examination views every 10 min and whenever there was echocardiographic suspicion of NWMAs, hemodynamic

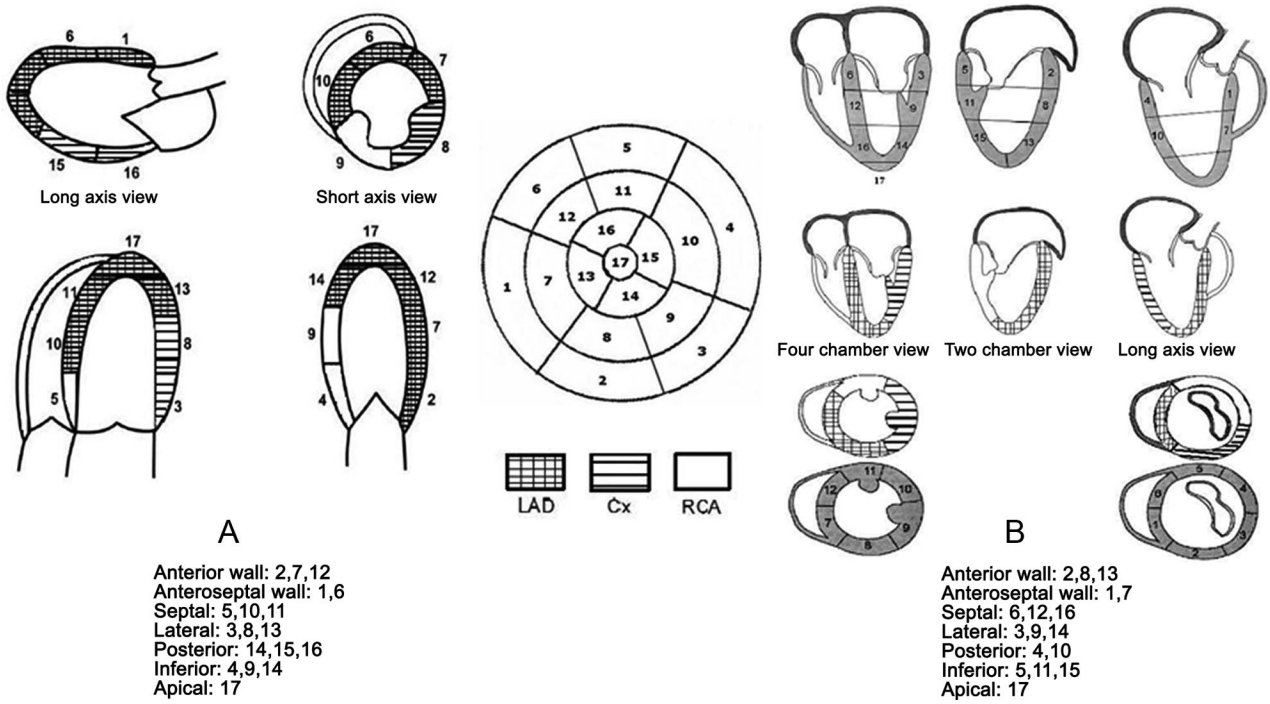

Fig. 1. Left ventricular (LV) myocardial segmentation for echocardiographic wall motion analysis with corresponding distribution of coronary arterial blood supply, showing segmental distribution of the seven LV walls in dobutamine echocardiography (*A*) and in transesophageal echocardiography (*B*). Cx = circumflex artery; LAD = left anterior descending coronary artery; RCA = right coronary artery.

change, or surgical maneuver requiring special attention. For safety reasons, echocardiographic monitoring was freezed whenever the probe temperature exceeded 37.5°C, which allowed the probe to cool down shortly.

TEE images were obtained using a standard adult 5-MHz multiplane transesophageal probe (GE LOGIQ 500 Probe, model H4552TB; General Electric, Stockton, CA) and the VingMed® System 5 Echocardiographic Imaging System (General Electric-VingMed Ultrasound, Horton, Norway). The main investigator was responsible for intraoperative image acquisition and passed a comprehensive training in TEE in the study institute and performed 150 comprehensive TEE examinations as recommended by the American society of Echocardiography Council for Intraoperative Echocardiography and the Society of Cardiovascular Anesthesiologists.[18] The occurrences of LV NWMAs, as well as the segmental location of each abnormality, were recorded for each patient. The training physicians (anesthesiologists and surgeons) were blinded to intraoperative echocardiographic findings except if significant NWMAs (involving more than four segments) necessitating immediate management were apparent on the screen.

Interpretation of Echocardiographic Views

DE test results and intraoperative TEE recordings were scored for rest WMA and NWMAs using a 17-segment model as proposed by the American Society of Echocardiography and interpreted accordingly into a seven-wall LV model.[19–21] Transcription of LV segments to their LV wall involvement was performed as shown in figure 1 redrawn based on the illustrations of LV wall in the transthoracic echocardiography reports recommended by our institute and in the recommendation of the American Society of Echocardiography Council for Intraoperative Echocardiography and the Society of Cardiovascular Anesthesiologists for the comprehensive TEE examination.[18]

A five-point scale was used for wall motion analysis: 1 = normal, 2 = mild–moderate hypokinesis, 3 = severely hypokinetic, 4 = akinesis, and 5 = dyskinetic, as used earlier.[14–17] Recorded echocardiographic loops were displayed simultaneously with resting images in a cine-loop format for interpretation. All images were analyzed at one time by two experienced readers blinded to clinical, electrocardiography, or other perioperative patient data. A NWMA was interpreted whenever a new or worsening regional LV motion was observed. Normal wall motion or an unchanged rest WMA was not considered for myocardial ischemia. Disagreements in interpretation were resolved by consensus.

Definition of Endpoints

All patients were monitored postoperatively for the development of adverse cardiac events. Standard electrocardiography and cardiac troponin-T (cTnT) were serially measured after surgery on days 1, 3, 7, and 30 or at discharge. Tests were repeated when patients had symptoms and/or signs of clinical myocardial ischemia. Troponin-T level was measured by an electrochemiluminescence immunoassay on the Elecsys 2010 (Roche Diagnostics, Mannheim, Germany). The recommended lower limit of 0.03 ng/ml was used to define positive troponin-T levels because lower levels do not meet the imprecision criteria of less than 10%.

The study endpoint was the combination of increased cTnT, MI, and cardiac death. Criteria for MI diagnosis included at least two of the following: cTnT more than or equal to 0.1 ng/ml, typical electrocardiographic changes (new Q waves $>$ 1 mm or $>$ 30 ms in electrocardiogram), and typical chest pain complaints. Cardiac death was defined as fatal MI (postmortem evidence of acute MI or definite criteria for MI within the 24 h before death) and sudden cardiac death. Sudden cardiac death was defined as unexpected natural death due to cardiac causes within 1 h of the onset of acute symptoms.

Statistical Analysis

Categoric variables are expressed as percentages and were compared using the Pearson chi-square test. Continuous variables are presented as mean (±SD) and were compared using the unpaired Student *t* test. Correlation between DE and intraoperative TEE results in different LV locations was tested by means of kappa statistic (κ) to verify whether a paired rest WMA or NWMA locality, estimated by both techniques, might differ from agreement that could occur by chance alone. The κ measure of agreement between two observations ranges between 0 and 1 (0 is chance agreement; less than, 0.4 poor agreement; 0.4–0.75, fair to good agreement; and more than 0.75, excellent agreement). The measured κ value is presented in table or text.

For all tests, a *P* value less than 0.05 (two sided) was considered significant. All analyses were performed using the syntax commands of SPSS® v15.0 statistical package for Windows® (SPSS Inc., Chicago, IL).

Results

Fifty-four consecutive patients were enrolled in the study. Preoperative baseline clinical characteristics, including baseline echocardiographic variables, are shown in table 1. None of the examined patients had pacing devices. Operative characteristics are shown in table 2. We excluded six eligible patients from our study: two because of inability to insert the TEE probe that encountered resistance and four cases because of improper visualization of standard echo views mentioned in the methods section.

DE and TEE showed rest WMA in 17 (31%) and 16 (30%) patients, respectively, κ value on patient base = 0.92. The agreement for location of rest WMA was excellent, κ range = 0.77–1.0. Stress-induced NWMAs during DE occurred in 17 patients (31%), whereas intraoperative NWMAs were observed by TEE in 23 patients (43%), κ value on patient base = 0.65. However, the agreement for location of NWMAs using a seven-wall model was poor, κ range = 0.26–0.44. Echocardiographic locations of NWMAs are presented in figure 2 and table 3. κ value for interobserver variability for the different LV walls ranged between 0.91 and 0.98. A random sample of 10 patients was selected and rescored for LV wall motion by each scoring investigator. Intraobserver κ value for the different LV walls ranged between 0.97 and 1.00.

During 30-day follow-up, the composite endpoint occurred in 15 patients (28%); cTnT release in 14 (26%), MI in 6 (11%), and cardiac death in 3 (6%) (table 4). Of these 15 patients, 10 (67%) experienced both pre- and intraoperative NWMAs, whereas in 4 (27%), only intraoperative NWMAs were observed. Troponin release was observed in only one patient (7%) without pre- and intraoperative NWMAs. This patient did not experience ischemic symptoms or electrocardiographic abnormalities. The relationship of preoperative and intraoperative NWMAs and postoperative outcome is presented in table 4. In all six patients who experienced a postoperative MI, the location of electrocardiographic changes matched with the intraoperatively observed NWMAs by TEE, whereas in 2 (33%), there was an agreement with the preoperatively induced ischemia during DE.

Figure 3 represents the subdivision of the total population according to preoperative and intraoperative development of NWMAs and postoperative cardiac outcome. The presence of multivessel CAD as detected by DE and intraoperatively by TEE was in favor of a composite outcome ($P < 0.05$ for DE and $P = 0.001$ for intraoperative TEE) but not of a single-vessel disease (P = NS). In table 5, we present the calculated diagnostic indices of both preoperative DE and intraoperative TEE for the study outcomes.

Discussion

In this study, we used echocardiography to observe the location of NWMAs induced preoperatively during DE and those developed intraoperatively by TEE monitoring in 54 high-risk vascular surgery patients. By using the κ coefficient, we observed an excellent correlation between preoperative and intraoperative rest WMA (κ range, 0.8–1.0), indicating concordance between preoperative and intraoperative echocardiographic recordings. However, poor agreement correlations were found between pre- and intraoperative locations of NWMAs ($\kappa \leq 0.4$).

Although patients with severe and unstable coronary disease are warranted to undergo preoperative stress testing to direct toward the optimal prophylactic strategy, those who have stable coronary disease do not show much benefit from stress testing over clinical stratification. DE, among other stress tests, accurately determines reversible ischemic regions. However, those tests have stronger negative than positive predictive power, particularly in the stable coronary disease population. Perioperative β-blockade has proven to be a sufficient prophylactic regimen in such patients. In the current investigation, approximately 45% of our population presented with established CAD, 14% presented with two risk factors, and 43% showed three or more risk factors among the Lee's revised cardiac risk index, with fair LV function in average estimated by mean ejection fraction. This stratification puts this population in the gray zone of where optimized medical therapy is weighed against coronary revasculariza-

Table 1. Baseline and Perioperative Patient Characteristics in All and Subpopulations Based on the Acquisition of Perioperative NWMA

		Preoperative DE			Intraoperative TEE		
	All Patients N = 54	NWMA N = 17 (31)	No NWMA N = 37 (69)	*P* Value	NWMA N = 23 (43)	No NWMA N = 31 (57)	*P* Value
Patient demographics							
Mean age (±SD)	65.5 ± 12.1	69.7 ± 12.1	63.6 ± 11.7	NS	71.0 ± 11.9	61.4 ± 10.7	< 0.05
Male sex	48 (89)	15 (88)	33 (89)	NS	20 (87)	28 (90)	NS
Angina pectoris	13 (24)	6 (46)	7 (54)	NS	10 (44)	3 (10)	NS
Previous myocardial infarction	24 (44)	10 (59)	14 (38)	NS	14 (61)	10 (32)	< 0.05
Previous coronary revascularization*	14 (26)	6 (43)	7 (57)	NS	7 (30)	7 (23)	NS
Previous stroke	11 (20)	5 (29)	6 (16)	NS	7 (30)	4 (13)	NS
Diabetes mellitus†	12 (22)	8 (47)	4 (11)	< 0.05	6 (26)	6 (19)	NS
Renal dysfunction‡	8 (15)	5 (29)	3 (8)	< 0.05	6 (26)	2 (7)	< 0.05
Hypertension§	34 (63)	11 (65)	23 (62)	NS	15 (65)	19 (61)	NS
Hypercholesterolemia	29 (54)	13 (77)	16 (43)	< 0.05	15 (65)	14 (45)	NS
Chronic obstructive pulmonary disease	22 (41)	8 (47)	14 (38)	NS	13 (57)	9 (29)	< 0.05
Congestive heart failure	3 (6)	0 (0)	3 (8)	NS	3 (13)	0 (0)	< 0.05
Echocardiographic features							
Left ventricular hypertrophy	23 (43)	9 (53)	14 (38)	NS	14 (61)	9 (29)	NS
Ejection fraction (mean ± SD)	47.1 ± 8.6	44.8 ± 9.6	47.7 ± 6.5	NS	44.9 ± 5.8	44.7 ± 5.2	NS
Fractional area change (mean ± SD)	43.9 ± 8.2	44.3 ± 7.9	43.3 ± 8.3	NS	45.0 ± 8.8	43.1 ± 8.1	NS
Fraction shortening (mean ± SD)	26.9 ± 5.2	25.2 ± 5.1	28.4 ± 5.0	NS	25.9 ± 3.6	27.4 ± 5.8	NS
ASA physical status classification							
ASA class I	3 (6)	0 (0)	3 (8)	NS	0 (0)	3 (10)	NS
ASA class II	13 (24)	4 (24)	9 (24)	NS	5 (22)	8 (26)	NS
ASA class III	29 (54)	8 (47)	21 (57)	NS	12 (52)	17 (55)	NS
ASA class IV	9 (17)	5 (29)	4 (11)	NS	6 (26)	3 (10)	NS
LEE RCRI							
I	17 (32)	0 (0)	17 (46)	0.001	2 (9)	15 (48)	< 0.05
II	14 (26)	3 (18)	11 (30)	NS	6 (26)	8 (26)	NS
≥ III	23 (43)	14 (61)	9 (39)	< 0.001	15 (65)	8 (26)	< 0.01
Medication							
β-Blockers	54 (100)	17 (100)	37 (100)	NS	23 (100)	31 (100)	NS
Statins	29 (54)	14 (82)	15 (41)	< 0.05	16 (70)	13 (42)	< 0.05
ACE inhibitors	13 (24)	7 (41)	6 (16)	< 0.05	9 (39)	4 (13)	< 0.05
Calcium channel blockers	9 (17)	6 (35)	3 (8)	< 0.05	6 (26)	3 (10)	NS
Aspirin	35 (65)	11 (65)	24 (65)	NS	14 (61)	21 (68)	NS
Nitrates	2 (4)	1 (6)	1 (3)	NS	2 (9)	0 (0)	NS
Diuretics	12 (22)	5 (29)	7 (19)	NS	8 (35)	4 (13)	NS

Continuous variables are shown as mean (SD), while dichotomous variables are shown as number (% of column totals).

* Coronary artery bypass graft surgery and/or percutaneous coronary intervention procedures. † Fasting blood sugar ≥ 7 mM or use of hypoglycemic agents. ‡ Serum creatinine level ≥ 2.0 mg/dl (177 mM) or requirement of dialysis. § Arterial blood pressure ≥ 140/90 mmHg or use of antihypertensive drugs.

ACE = angiotensin-converting enzyme; ASA = American Society of Anesthesiologists; DE = dobutamine echocardiography; LEE RCRI = Lee's Revised Cardiac Risk Index; NWMA = new wall motion abnormalities; TEE = transesophageal echocardiography.

tion. The purpose of this study was to determine which of the two prophylactic measures is optimal to provide better postoperative cardiac outcome.[22,23]

Autopsy studies have shown the pathologic similarity of perioperative MI to that occurring in the nonoperative setting; however, they were unsuccessful in predicting the site of vulnerable plaque rupture in most instances of perioperative MI based on the severity of coronary stenosis.[6,7] This means that selective targeting of isolated culprit plaques by means of a focused revascularization technique as a prophylactic measure cannot be used with adequate results.

Because of the high propensity of CAD in the peripheral arterial disease population requiring elective surgical intervention, preoperative cardiac evaluation might suggest an

Table 2. Population Operative Characteristics with Respect to the Distribution of Hemodynamic Covariates on the Acquisition of Perioperative NWMA

	All Patients N = 54	Intraoperative TEE		
		NWMA N = 23 (43)	No NWMA N = 31 (57)	*P* Value
Anesthetic technique				
General anesthetic	31 (57%)	10 (44%)	21 (68%)	NS
Combined general and epidural anesthesia	23 (43%)	13 (57%)	10 (32%)	NS
Surgical procedure				
Open aortic prosthetic repair	34 (63%)	17 (74%)	17 (55%)	NS
Clamping duration, min	49.4 ± 54.6	52.4 ± 45.1	47.9 ± 55.7	NS
LLR	20 (38%)	6 (26%)	14 (45%)	NS
Procedure duration, min*	267.6 ± 72.1	275.1 ± 45.4	264.6 ± 64.1	NS
Operative blood loss, l*	0.5 (0.6–1.9)	0.6 (0.2–1.9)	0.5 (0.4–1.8)	NS
Intraoperative fluid administration				
Crystalloids, l*	4.0 ± 0.2	4.6 ± 2.9	3.8 ± 1.9	NS
Colloids, l*	1.5 ± 0.8	1.6 ± 0.8	1.4 ± 0.7	NS
Packed cells, units*	4.3 ± 1.5	3.8 ± 1.8	4.5 ± 1.2	NS
Plasma, units*	3.0 ± 1.0	2.5 ± 1.1	3.1 ± 0.8	NS
Cell-saver blood†	0.4 (0.3–1.2)	0.4 (0.2–1.0)	0.6 (0.3–1.4)	NS
Hemodynamic variables				
Heart rate*	67.1 ± 11.9	69.6 ± 11.5	66.5 ± 7.7	NS
Mean arterial pressure*	77.7 ± 13.4	80.5 ± 11.5	73.2 ± 15.4	NS
Intraoperative urine output, l†	0.5 (0.4–0.7)	0.7 (0.5–0.8)	0.6 (0.4–0.7)	NS

Continuous variables are shown as mean ± SD (*) or mean ± interquartile range (†), whereas dichotomous variables are shown as number (% of column totals).

LLR = lower extremity arterial revascularizations; NWMA = new wall motion abnormalities; TEE = transesophageal echocardiography.

indication for coronary revascularization in those presenting with severe coronary stenosis.[5,24,25] Pooled data from previous studies were not in favor of preoperative coronary revascularization before major noncardiac surgery. In the Coronary Artery Revascularization Prophylaxis trial, coronary arterial revascularization in 258 symptomatically stable patients, but with severe CAD, did not confer beneficial perioperative or long-term outcomes than in the control group

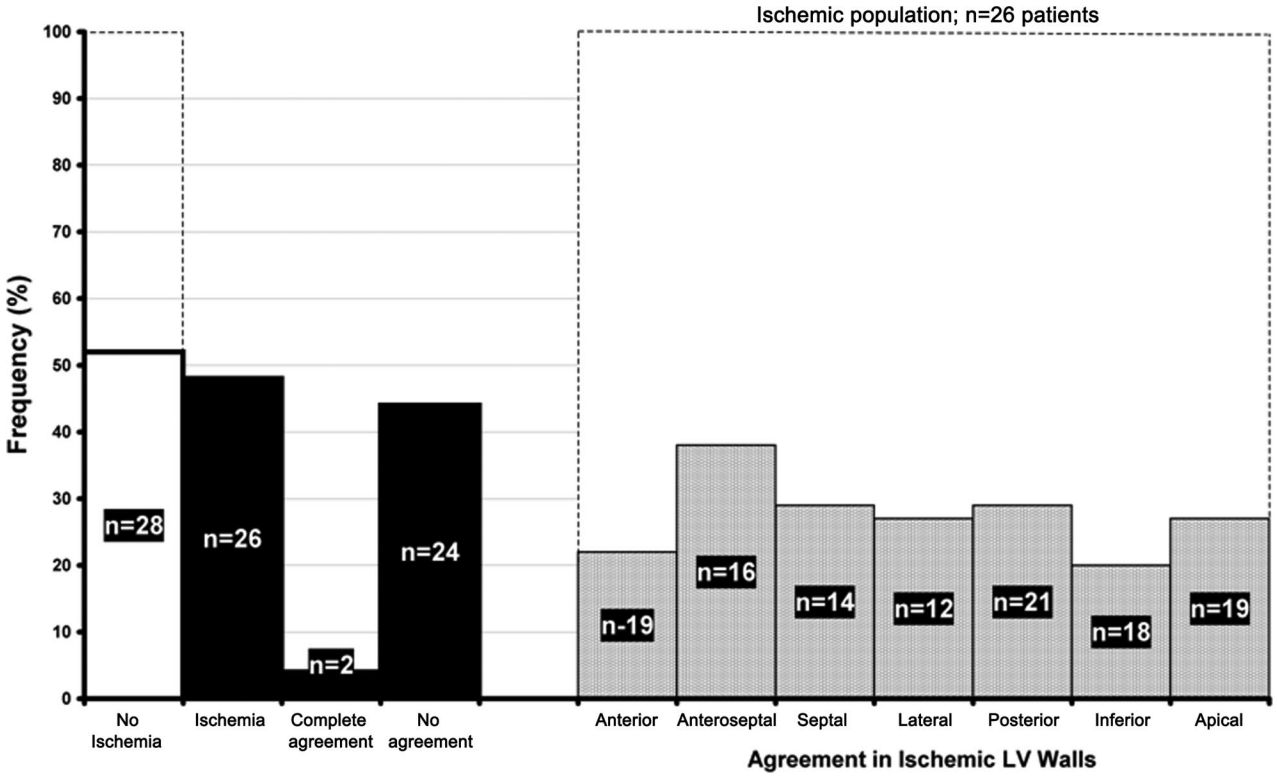

Fig. 2. Agreement for location in ischemic left ventricular (LV) walls between preoperative and intraoperative echocardiographies.

Table 3. Agreement for the Association and Locality Distribution of Resting (a) and Ischemic (b) LV Walls Presenting with WMA in Preoperative DE and Intraoperative TEE

	DE, N (%)	TEE, N (%)	κ Value
(a) Prerecording variables (at rest)			
Patients with rest WMA	17 (31)	16 (30)	0.917
Locality of the rest WMA			
Anterior wall	7 (41)	9 (56)	0.821
Anteroseptal wall	10 (59)	12 (75)	0.843
Septal wall	11 (65)	11 (69)	1.0
Lateral wall	7 (41)	9 (56)	0.821
Posterior wall	7 (41)	7 (44)	1.0
Inferior wall	9 (53)	9 (56)	1.0
Apical	13 (76)	10 (63)	0.769
(b) Preoperative ischemia during DE and intraoperative ischemia by TEE			
Patients with NWMA	17 (31)	23 (89)	0.653
Locality of the NWMA			
Anterior wall	5 (29)	6 (26)	0.292
Anteroseptal wall	8 (47)	14 (61)	0.440
Septal wall	9 (53)	13 (57)	0.321
Lateral wall	5 (29)	9 (39)	0.351
Posterior wall	4 (24)	5 (22)	0.260
Inferior wall	4 (24)	8 (35)	0.395
Apical	9 (53)	4 (17)	0.351
Single-vessel reversible ischemia	7 (41)	8 (35)	0.233
Multivessel reversible ischemia	10 (69)	15 (65)	0.336

DE = dobutamine echocardiography; LV = left ventricular; NWMA = new wall motion abnormalities; TEE = transesophageal echocardiography; WMA = wall motion abnormalities.

(252 patients) before major vascular operations.[3] Similar findings were shown in the DECREASE-V (Dutch Echocardiographic Cardiac Risk Evaluation Applying Stress Echocardiography) randomized pilot study in 101 high-risk vascular surgery patients randomized either to no intervention (n = 52) or coronary revascularization before vascular surgery (n = 49).[26] The Coronary Artery Surgery Study trial investigators suggested similar conclusions when equivocal long-term outcomes were observed between coronary artery bypass graft surgery and intensive medical treatment patient groups.[27] These findings remained unchanged after 10 yr of follow-up. Comparable results were shown by medical treatment, surgical treatment, or percutaneous coronary intervention.[28] Finally, reports of unwanted outcomes had been addressed for percutaneous coronary intervention before noncardiac surgery in the population at risk for CAD.[29,30] Indeed, the reason that coronary artery bypass graft was found superior to percutaneous coronary intervention before vascular surgery in one study was the more extensive revascularization in the coronary artery bypass graft group.[31]

We reported postoperative cardiac outcomes as 26%, 11%, and 6% for postoperative cTnT release, MI, and cardiac death, respectively. These events were predictable by the induction of NWMAs by a DE stress test and even better predicted by the occurrence of intraoperative NWMAs. In our population, NWMAs induced during DE or detected intraoperatively by TEE presented more with multivessel CAD form, which was also correlated with the combined cardiac outcome ($P = 0.003$ for multivessel reversible ischemia by preoperative DE and $P = 0.001$ for multivessel reversible ischemia by intraoperative TEE) but not a single coronary vessel–related NWMAs (P = NS). This indicated the more extensive nature of coronary vascular disease they had.

We found perfect matching of intraoperative NWMAs location with postoperative electrocardiographic locality of MI, indicating the accumulation of most perioperative stressors on the vulnerable myocardium of the vascular surgery patient in the intraoperative phase exhausting the moribund coronary reserve around the end of surgery, which would hence yield most fatal MIs in the immediate postoperative phase up to 12 h. This coincides with the well-established knowledge that more than 50% of perioperative MIs do occur in the immediate postoperative period and lead to recommending twice daily electrocardiography in the first postoperative day. In addition, we reported postoperative cTnT release in 14 patients (26%). In 8 (57%) of them, troponin release was not associated with MI. Le Manach *et al.* found earlier postoperative abnormal troponin in a larger

Table 4. Postoperative Patient Outcomes According to Ischemia Wall Agreement between Preoperative and Intraoperative NWMA

		Preoperative DE			Intraoperative TEE		
	All Patients N = 54	NWMA N = 17 (31)	No NWMA N = 37 (69)	*P* Value	NWMA N = 23 (43)	No NWMA N = 31 (57)	*P* Value
Postoperative outcomes							
PO cTnT release	14 (26)	9 (53)	5 (14)	< 0.05	13 (57)	1 (3)	< 0.001
PO MI	6 (11)	6 (35)	0 (0)	< 0.001	6 (26)	0 (0)	< 0.05
Cardiac death	3 (6)	2 (12)	1 (3)	NS	3 (13)	0 (0)	< 0.05
Composite outcome	15 (28)	10 (59)	5 (14)	0.001	14 (61)	1 (3)	< 0.001

DE = dobutamine echocardiography; NWMA = new wall motion abnormalities; PO cTnT = postoperative cardiac troponin-T; PO MI = postoperative myocardial infarction; TEE = transesophageal echocardiography.

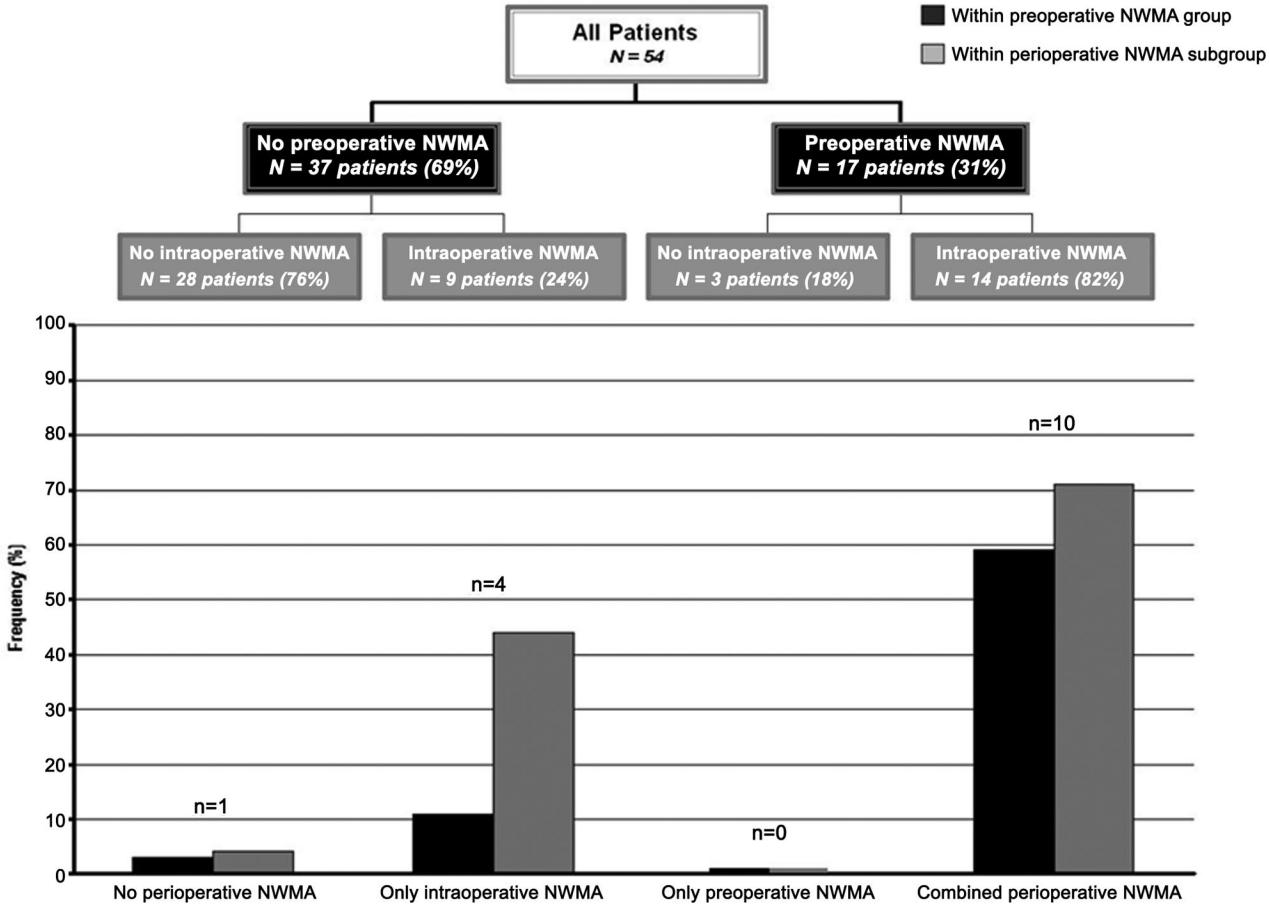

Fig. 3. Composite cardiac outcome according to perioperative new wall motion abnormalities (NWMA).

cohort of vascular surgery patients (14% of 1,136 patient population). Increased cardiac troponins were related to postoperative MI (in 35% of the patients with increased troponin levels) in two distinct fashions (early and late), indicating two different sets of myocardial stressors nearer and later from the end of surgery.[32] The prevalence of increased postoperative troponin in our study is similar to or even reduced to that reported in other research in similar populations.[25,33,34] Silent myocardial ischemic events would result from the effects of perioperative stressors in a myocardial demand or supply mismatch insufficient to progress to evident myocardial damage. This is supported by the finding

Table 5. Sensitivity, Specificity, PPV, and NPV of Preoperative DE and Intraoperative TEE for the Study Outcomes

Echocardiographic Technique	Intraoperative NWMA, %	↑ PO cTnT, %	PO MI, %	Cardiac Death, %	Composite Endpoint, %
PPV					
DE	61	64	100	67	67
TEE	—	93	100	100	93
NPV					
DE	90	80	77	71	82
TEE	—	75	65	61	77
Sensitivity					
DE	82	53	35	12	59
TEE	—	57	26	13	61
Specificity					
DE	76	87	100	97	87
TEE	—	97	100	100	97

DE = dobutamine echocardiography; NPV = negative predictive value; NWMA = new wall motion abnormalities; PO cTnT = postoperative cardiac troponin-T; PO MI = postoperative myocardial infarction; PPV = positive predictive value; TEE = transesophageal echocardiography.

that perioperative cTnT is related to poor long-term cardiac outcomes. This would explain the higher rates of subclinical ischemic events (increased cTnT or transient NWMAs) over harder cardiac events in our and other populations.[23,25,35]

Intraoperative TEE showed an additional incremental value on the prediction of postoperative cardiac events. Both preoperative NWMAs during DE and intraoperative NWMAs detected by TEE had a significant association with the composite cardiac outcome ($P < 0.001$). No events of cardiac death or postoperative MI occurred in patients without intraoperative NWMAs.

Study Limitation

We had several limitations in this study. Some patients were excluded for either technical difficulty in image acquisition at any stage or inappropriate views to judge LV wall motion. We could not continue to enroll more patients because of time factors, limiting the level of power of our significant results, especially those related to the regression analysis. Some NWMAs were probably missed, particularly before probe insertion after the start of anesthesia induction. Coronary angiography was not clinically indicated preoperatively in the studied patients, and hence, we could not relate our findings to the more pathognomonic angiographic data. Some reversible segmental LV WMA could have been missed in some views while obtaining others for offline analysis. Nevertheless, concomitant mechanical effects such as tethering by a coexisting myocardial scarring or ballooning effect during aortic cross-clamping would have influenced our judgment for a NWMA. Finally, κ measurement is a useful statistic to look for the chance of agreement between two sets of readings. However, it has few flaws, particularly its vulnerability toward difference in prevalence regardless of a fixed specificity and sensitivity between the two readings, particularly when sophisticated variables and heterogenous examination groups are used.[36,37]

Conclusion

In patients undergoing major vascular surgery, preoperative DE and intraoperative transesophageal echocardiographic monitoring of wall motion changes had good correlation with postoperative cTnT release and MI. However, TEE had a stronger association with all postoperative cardiac events. Reproducibility of WMA in the same myocardial wall locations at different perioperative times was not achievable. This suggests the superiority of optimized medical therapies over the invasive interventions focused on particular culprit lesions for the prophylaxis against perioperative myocardial ischemia. In our population receiving β-blocking medications, the higher predictive power of intraoperative TEE over preoperative DE for postoperative outcomes further emphasizes the importance of optimized medical treatments over preoperative cardiac testing in fairly stable populations with coronary disease.

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