Utility of detailed preoperative cardiac testing and incidence of post-thoracotomy myocardial infarction

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Objective: Recent literature has questioned the efficacy of routine detailed preoperative cardiac ischemia testing and preoperative cardiac intervention before noncardiac surgical procedures.

Methods: We performed a retrospective review of patients undergoing thoracotomy (n = 294) between January of 1999 and January of 2005.

Results: The median age was 62 years. Detailed preoperative cardiac testing was performed on 184 patients (63%) and went beyond a thorough history, physical examination, and electrocardiogram to include at least one of the following: dobutamine stress echo (n = 116), nuclear stress test (n = 66), treadmill test (n = 8), and coronary angiogram (n = 40). Evidence for coronary disease was detected in 43% of tests (99/230) performed. Revascularization was performed in 10% of all patients (4/40) who underwent coronary angiography. Postoperative myocardial infarction occurred in 7 patients (2.4%) with 4 myocardial infarction-related mortalities. No significant difference was found in the incidence of myocardial infarction in patients with (n = 184) or without (n = 110) detailed preoperative cardiac testing (3.3% vs 0.9%, $P = .29$). Of the 4 patients (1.4%) who underwent revascularization to treat coronary lesions identified during prethoracotomy workup, 2 had a myocardial infarction, 1 of which was caused by thrombosis of a coronary stent. In the subset of patients who underwent lobectomy (n = 149), detailed cardiac testing was performed on 107 patients (72%). The incidence of myocardial infarction was similar in tested and untested patients (2.8% vs 2.4% respectively, $P = 1.0$).

Conclusion: Selective use of detailed preoperative cardiac testing refines risk stratification and identifies patients for corrective cardiac interventions; however, it did not prove fully protective against myocardial infarction after thoracotomy in our study.

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Patients scheduled for general thoracic operations often undergo a preoperative cardiac evaluation in an effort to both risk stratify and minimize the perioperative incidence of cardiac events. The presumption is that rigorous analysis would identify patients at risk and expose potentially correctable cardiac lesions. Therapeutic interventions addressing the lesions can then be performed preoperatively, thus reducing cardiovascular complications at the time of surgery.

There is a growing body of evidence that in this era of optimal medical treatment, noninvasive cardiac testing should be reserved for patients at a qualifying level of risk.^{1,2} Moreover, preoperative revascularization in patients being evaluated before noncardiac surgery is controversial. The theme of the recent literature is that preoperative cardiac intervention is rarely necessary simply to decrease the risk of surgery unless such intervention is indicated irrespective of the preoperative context.^{2,3} In fact, preoperative coronary revascularization does not seem to reduce perioperative risk in patients with significant but stable coronary artery disease (CAD).^{4,5}

There are conflicting issues that drive preoperative cardiac evaluation today. The current medico-legal environment is intolerant of adverse outcomes, whereas commonsense medical practice and economic pressures in health care would minimize

Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CAD	= coronary artery disease
DSE	= dobutamine stress echocardiogram
ECG	= electrocardiogram
EST	= exercise treadmill stress test
LAD	= left anterior descending
MI	= myocardial infarction
PTCA	= percutaneous transluminal coronary angioplasty
Pthal	= Persantine thallium stress test

unnecessary testing. The American College of Cardiology/American Heart Association guidelines^{1,2} consider thoracic procedures as medium risk. There is little information in the literature regarding the actual risks in the population undergoing thoracic surgery, the impact of preoperative noninvasive cardiac testing, and the benefits of corrective preoperative coronary revascularization.

Our institution serves as a tertiary referral center, and our patients tend to have multiple comorbidities. Until recently, the bias has been to perform detailed preoperative myocardial ischemia testing on the majority of patients undergoing elective thoracotomy. Our objective was to assess the incidence of myocardial infarction (MI) in patients undergoing thoracotomy, including the subset of patients undergoing lobectomy, and to evaluate the impact of detailed preoperative cardiac testing. We also sought to determine whether revascularization performed because of CAD identified during prethoracotomy workup was protective against postoperative MI.

Materials and Methods

With institutional review board approval, a retrospective review was performed of all patients undergoing open thoracotomy at the Michael E. DeBakey Veterans Affairs Medical Center between January of 1999 and January of 2005. Waiver of individual consent was granted because the study did not involve any form of patient contact. Thoracotomy surgeries subject to the study included lung biopsies or resections, decortications, benign and malignant mediastinal lesions, and thoracic spine exposures. The access incision involved a posterolateral thoracotomy with division of the latissimus dorsi muscle and rib spreading with or without rib division or resection. All esophagectomies, video-assisted thoracoscopic procedures, and surgeries involving minimal access incisions that did not involve rib spreading were excluded. Data were extracted from the patient charts and the Veterans Affairs computerized patient record system, including patient demographics, risk factors, preoperative cardiac symptoms, cardiac workup, interventions, and subsequent cardiac complications.

All patients underwent a rigorous clinical evaluation that included a full history and physical examination. Preoperative electrocardiograms (ECGs) were obtained routinely for all patients. Transthoracic echocardiography was occasionally performed to evaluate the cardiac valves if a murmur was detected or to measure the ejection fraction. Patients were classified as having a positive

history of CAD when there were clear documentations of such in the medical records, symptoms consistent with CAD, or an abnormal ECG.

For the purposes of this study, detailed cardiac testing was defined as 1 or a combination of the following procedures: dobutamine stress echocardiogram (DSE), Persantine thallium stress test (Pthal) or exercise treadmill stress test (EST), or coronary angiogram. At our institution the bias was to perform noninvasive testing (DSE, Pthal, and EST) on the majority of patients undergoing a thoracotomy. The decision for testing was not always guided by the magnitude of the cardiac risk level determined by the clinical evaluation (history, physical, and ECG). More than 1 test was performed in patients because of inconclusive test results or the presence of an indication for a definitive diagnostic cardiac catheterization. The most common indication for coronary angiography was a large area of the heart at risk with more than moderate ischemia on noninvasive testing.

Cardiac interventions were defined as any invasive therapeutic procedure, including percutaneous transluminal coronary angioplasty (PTCA), percutaneous stenting, and coronary artery bypass grafting (CABG). The criteria for postoperative MI were elevation in cardiac enzymes associated with ischemic manifestations, including chest pain, congestive heart failure, or hemodynamic changes, or elevation in enzymes associated with electrocardiographic changes occurring within 30 days of surgery. Isolated transient postoperative atrial fibrillation or other self-limiting arrhythmia were not tracked for the purposes of this study unless they were associated with or led to MI.

Perioperative beta-blockers were routinely administered to all patients with known cardiovascular disease. Postoperative tachycardia and hypertension were treated aggressively with beta-blockers as the first-line medications. In the absence of bleeding concerns, aspirin was often added postoperatively, and a deep venous thrombosis prophylaxis regimen of either subcutaneous heparin or sequential compressive devices was instituted. Epidural analgesia is sparingly used in the practice of our anesthesia department and was not used in this study cohort.

Unless otherwise specified, we presented the quantitative data as mean $\pm$ standard deviation and categorical data as percentages. For parametric variables, we used the Student *t* test to compare the differences between the patients who underwent detailed preoperative cardiac testing and the patients who did not. For categorical variables, Fisher's 2-tailed exact test was used to compare between the tested and nontested groups. Statistical analyses were conducted using the Statistical Package for the Social Sciences version 13.0 (SPSS Inc, Chicago, Ill).

Results**Patient Characteristics**

A total of 294 patients underwent a full thoracotomy. The median age was 62 years (range 29–86 years). Only 7 patients were female, which is not unexpected in a Veterans Affairs population. For the subset of patients who underwent lobectomy (*n* = 149), the median age was 65 years (range 40–86 years) and only 3 were female. Preoperative medical comorbidities and risk factors are summarized in Table 1. Thirty percent of patients had a history of CAD. All revascularization procedures, including CABG, PTCA, and coronary

TABLE 1. Patients' risk profile

Comorbidities	Thoracotomy n = 294 (%)	Lobectomy subset n = 149 (%)
Smoker	256 (87)	135 (90)
Emphysema	121 (41)	62 (41)
Diabetes	65 (22)	28 (19)
Hypertension	161 (55)	87 (58)
Renal insufficiency	12 (4)	5 (3.3)
Stroke	8 (3)	6 (4)
Peripheral vascular disease	6 (2)	3 (2)
Coronary artery disease	88 (30)	45 (30)
Congestive heart failure	16 (5)	7 (5)
Myocardial infarction	34 (12)	20 (13)
Previous CABG	20 (7)	11 (7)
Previous PTCA/stent	6 (2)	1 (1)

CABG, Coronary artery bypass grafting; PTCA, percutaneous transluminal coronary angioplasty.

stenting, took place more than 1 year before thoracotomy and therefore did not include the interventions ordered during the preoperative workup.

Diagnosis and Procedures

The underlying pathologic condition was primary cancer (n = 190), metastatic cancer (n = 10), and benign diseases or infection (n = 94). The surgeries performed were diverse in type, extent, and indications. Lung resections (n = 236, 80%) accounted for the majority of the operations and included pneumonectomy (n = 24), lobectomy (n = 149), bilobectomy (n = 8), wedge resection (n = 54), and sleeve resection (n = 1). Exposure for thoracic spine access and pleural procedures, including pleural evacuation/decortications for hemothorax and empyema, were the second most common surgical category (n = 53). Mediastinal and diaphragmatic surgery (n = 5) accounted for the remaining procedures.

Cardiac Workup

A comprehensive history and physical examination with an ECG were performed in all patients undergoing a thoracotomy (n = 294). Detailed testing was performed on 184 patients (63%) (Figure 1). Detailed cardiac testing (n = 230 tests) included 1 or a combination of DSE (n = 116), Pthal (n = 66), EST (n = 8), and coronary angiogram (n = 40). Abnormal findings were reported in 99 (43%) of those tests.

Figure 2 summarizes the choice and frequency of use of the various cardiac testing modalities for 3 distinct categories of patients undergoing thoracotomy: 1) patients with no history of CAD, 2) patients with a history of CAD, and 3) patients with symptomatic CAD (subset of patients with history of CAD). The rates of positive findings of the different testing modalities for each of the 3 patient categories are also demonstrated. In the subset of patients undergoing lobectomy, the corresponding data are displayed in Figure 3.

Cardiac Ischemia and Intervention

Evidence of ischemia was detected in 75 patients (26%) undergoing a thoracotomy by detailed noninvasive testing (DSE, Pthal, or EST). Coronary angiography was performed in 29 of those patients: 11 with a significant coronary lesion, 9 with a nonhemodynamically significant lesion, and 9 with a totally normal coronary anatomy. Eleven additional angiograms were performed because of a concerning history and ECG findings, and 4 of those angiograms were significantly abnormal. Revascularization was performed in 10% of all patients (4/40) who underwent coronary angiography. The median delay between the intervention and the surgery was 39.5 days.

Evidence of ischemia was detected in 45 patients (30%) who underwent a lobectomy by DSE, Pthal, or EST. Coronary angiography was performed in 21 of those patients: 9 with a significant coronary lesion, 9 with a nonhemodynamically significant lesion, and 3 with a totally normal coronary

Figure 1. Schematic illustration of the number of patients (n = 184) undergoing various cardiac testing procedures. EST, Exercise treadmill stress test; DSE, dobutamine stress echocardiogram; Pthal, Persantine thallium stress test; Cath, cardiac catheterization.

Figure 2. Percentage of thoracotomy patients with no history of coronary artery disease, with a history of CAD, and with symptomatic CAD undergoing various cardiac testing modalities. Positive findings for ischemia of the different testing modalities are depicted by the black component of the bar representing the modality. *CAD*, Coronary artery disease; *EST*, exercise stress test; *DSE*, dobutamine stress echocardiogram; *Pthal*, persantine thallium stress test; *Cath*, cardiac catheterization.

anatomy. Five additional angiograms were performed because of a concerning history and ECG findings, and 2 of those angiograms were significantly abnormal. Coronary stenting was performed in 2 patients.

Myocardial Infarction

Postoperative MI occurred in 7 patients (2.4%) undergoing a thoracotomy, 6 of whom had a history of CAD. Two of

the patients who had a postoperative MI underwent revascularization preoperatively with angioplasty and coronary stenting. Table 2 summarizes the circumstances and details of the adverse cardiac events. No significant difference was found in the incidence of MI in patients with ($n = 184$) or without ($n = 110$) detailed preoperative cardiac workup (3.3% vs 0.9%, $P = .29$). Patients who underwent detailed preoperative testing were older (mean age 64.0 ± 10.3 years

Figure 3. Percentage of lobectomy patients with no history of coronary artery disease, with a history of CAD, and with symptomatic CAD undergoing various cardiac testing modalities. Positive findings for ischemia of the different testing modalities are depicted by the black component of the bar representing the modality. *CAD*, Coronary artery disease; *EST*, exercise stress test; *DSE*, dobutamine stress echocardiogram; *Pthal*, persantine thallium stress test; *Cath*, cardiac catheterization.

TABLE 2. Postoperative myocardial infarction

Age (y)	Cardiac history	Symptom profile	Procedure	Preoperative work up
65	CABG 5 y prior; angio 1 y prior	DOE	Left upper lobectomy	ECG TTE Cath
51	None	Asymptomatic	Right upper lobectomy, chest wall resection	ECG TTE
61	LAD stent 3 y prior	DOE	Right lower and middle lobectomy	ECG TTE DSE Cath
72	Previous MI CABG 10 y prior	Stable angina	Left upper lobectomy	ECG TTE DSE Cath
59	History of CAD	Asymptomatic	Left pneumonectomy Right lower lobectomy	ECG PThal
54	Prior MI	Excellent exercise tolerance	Right upper lobe wedge	ECG DSE
81	CABG 9 y prior	DOE		ECG DSE

ASA, Aspirin; BB, beta-blocker; CABG, coronary artery bypass grafting; CAD, coronary artery disease; Cath, coronary angiogram; CHF, congestive heart failure; DOE, dyspnea on exertion; DSE, dobutamine stress echocardiogram; ECG, electrocardiogram; EF, ejection fraction; LAD, left anterior descending; MI, myocardial infarction; POD, postoperative day; PTCA, percutaneous transluminal coronary angioplasty; PThal, Persantine thallium stress test; RCA, right coronary artery; TTE, transthoracic echocardiogram. *Aspirin and beta-blockers were started after MI.

vs 58.4 ± 11.7 years, $P = .0001$) and had a higher prevalence of a history of CAD (54% vs 7%, $P = .001$).

There were 4 (2.7%) post-lobectomy MIs. The details of the patients affected are summarized in Table 2. The incidence of MI was 2.8% in the patients who underwent detailed cardiac testing ($n = 107$) and 2.4% in those who did not ($n = 42$) ($P = 1.0$). Again, patients who underwent detailed cardiac testing tended to be older (mean age 66.4 ± 9.4 years vs 62.5 ± 11.7 years, $P = .04$) and to have a higher prevalence of a history of CAD (40% vs 12%, $P = .003$).

Mortality

There were 4 cardiac fatalities, 2 of whom had preoperative coronary interventions (Table 2). One death was secondary to acute occlusion of the left anterior descending (LAD) coronary artery stent. This patient had a preoperative angiogram that showed restenosis of the LAD stent and 100% right coronary artery occlusion. Angioplasty of the LAD stent was

performed, and perioperative beta-blockers and aspirin were administered. On postoperative day 2, the patient was reintubated for respiratory failure. On postoperative day 4, sudden cardiac death occurred. An autopsy indicated rethrombosis of the LAD stent.

The hospital stay was a median of 13 days (range 2–220 days). Two patients had extended hospital stays (158 and 220 days) because of multiple complications, including sepsis and multisystem organ failure. The 30-day mortality was 5.8% (17/294) with 7 deaths related to MI. Other causes of death included hemorrhage (1), sepsis (5), pulmonary embolism (2), multiorgan failure (1), acute respiratory distress syndrome (3), and tension pneumothorax (1).

Discussion

As the population of the United States continues to age, it is estimated that by 2050 more than 19 million Americans will be above 80 years old.⁶ Eighty percent of patients older

TABLE 2. Continued

Abnormal result	Preoperative interventions	ASA/BB	MI details
Anterolateral changes EF 30% Patent grafts	None	+/+	MI POD 2
— —	None	—/—*	Intraoperative MI
Lateral ischemia EF 40% Moderate-to-severe anterior ischemia 80% mid-LAD lesion, occluded RCA	PTCA of LAD in stent lesion performed 34 d prior	+/+	MI POD 2, thrombosis of LAD stent, death
Anterior changes EF 50% inferolateral ischemia 3-vessel CAD	RCA stent PTCA distal LAD 31 d prior	+/+	MI POD 3 respiratory failure, death
Lateral changes Minimal inferoapical ischemia Inferior infarct Mild inferior ischemia	None	+/+	MI POD 3
— —	None	++	MI POD 5, death
— —	None	+/+	MI POD 16, CHF, ventricular fibrillation, death

than 80 years have identifiable CAD.⁷ Thoracic surgeons will be faced with a growing number of elderly patients presenting for surgery. With these statistics in mind, it is probable that a majority of patients undergoing thoracotomy procedures will have some degree of CAD. The risk of perioperative MI is estimated to be approximately 0.15% in patients without evidence of cardiac disease; however, in patients with a history of MI, the incidence of reinfarction during major noncardiac operations is estimated from 2.8% to 17.7%.^{8,9}

Several indices have been successfully used to assess a patient's cardiac risk.^{10–13} Simple and economic assessments, such as taking a good history and reviewing the symptoms, symptom-limited stair climbing, and resting ECG, can often identify most patients with symptoms of unstable CAD, left main CAD, critical aortic stenosis, or severe left ventricular dysfunction.^{13–15} Until recently, those simple, yet time-tested, clinical evaluations were marginalized in favor of elaborate stress testing, such as DSE, Pthal, and EST. Such

noninvasive evaluations were regarded as the gold standard for cardiac risk stratification. Furthermore, if we move beyond the decision to submit a patient for a detailed ischemia-sensitive cardiac workup, the need for coronary intervention to remedy the cardiac stigmata before noncardiac surgery remains controversial.

In our patient cohort there was no difference detected in the incidence of postoperative MI in patients who underwent a detailed preoperative cardiac testing that went beyond a thorough clinical evaluation (history and physical examination with ECG) and those who did not. In the subset of patients with no cardiac disease elicited by careful clinical evaluation, the results of the majority of the detailed cardiac testing (DSE, Pthal, EST, or coronary angiogram) were unremarkable or negative (Figures 2 and 3), and none required a coronary intervention. Therefore, the yield of such testing in this patient subset is low and not generally indicated. On the other hand, in patients with cardiac disease determined by careful clinical evaluation, further risk stratification by

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detailed cardiac testing resulted in a higher yield of positive findings for CAD and in some cases led to corrective revascularization.

It is significant that 2 of the patients who had a post-thoracotomy MI underwent revascularization preoperatively with angioplasty or coronary stenting. McFalls and colleagues⁵ recently evaluated the utility of preoperative cardiac evaluation and intervention before elective major vascular surgery in a Veterans Affairs cooperative study. Patients with clinically significant but stable CAD were randomly assigned to undergo preoperative coronary revascularization (PTCA or CABG) versus optimized medical therapy followed by the planned vascular operation. There were no postoperative differences of in-hospital death or MI between the 2 groups. These results indicate that coronary revascularization does not provide an additional benefit in reducing the incidence of perioperative cardiac death or MI provided optimal medical management is instituted in patients undergoing vascular surgery.

In our series, the risk of MI in all patients undergoing a procedure involving a thoracotomy was 2.4% and 2.7% if a lobectomy was performed. This should be balanced against the risk of coronary revascularization. Accepted operative mortality associated with CABG is 1% to 2%, and percutaneous coronary interventions have an age-dependent risk of MI, stroke, and death ranging from 0.5% to 4%.¹⁶ Given that revascularization is not completely protective, the mortality risk of coronary revascularization may compound the risk of thoracotomy. A higher risk of coronary events and mortality in the setting of noncardiac surgery shortly after coronary intervention has been reported.^{17,18} The obligatory antiplatelet therapy requirements following today's drug-eluting stents will significantly delay the treatment of the underlying thoracic disease.

Currently, there is a trend that is leading away from routine detailed preoperative cardiac testing and invasive interventions and instead focusing on medical therapy, including beta-blockers, to reduce the risk of perioperative cardiac events, especially in those with known stable CAD.³ The DECREASE trial showed a nearly 85% reduction in the combined incidence of nonfatal MI and death from cardiac causes after elective vascular surgery, owing to effective preoperative, intraoperative, and postoperative beta-blockage.¹⁹ The American College of Cardiology/American Heart Association guidelines were recently updated to reflect the growing body of evidence regarding the importance of perioperative beta-blockers in patients undergoing noncardiac surgery.²⁰ The modern era of intraoperative beta-blockade, aspirin, and statin use has significantly affected the coronary risks of surgical patients. In addition, there is some evidence that postoperative epidural analgesia, especially thoracic epidural analgesia, significantly reduces the rate of postoperative MI.²¹

We believe that detailed cardiac testing is rarely indicated in patients who according to a careful clinical assessment are

deemed to be at low cardiac risk for a thoracotomy. In the presence of a history of CAD or significant risk factors, non-invasive cardiac testing can help quantify the degree of severity of ischemia and determine the need for invasive coronary angiography and intervention. Prophylactic revascularization before thoracotomy has limited indications and is not fully protective against postoperative adverse cardiac events. Indeed, careful clinical risk assessment and optimal perioperative medical management can avoid unnecessary treatment delays by avoiding unnecessary cardiac testing in many patients needing a thoracotomy.

There are several limitations relating to this study. Given its retrospective nature, it is difficult to factor out the individual biases in the decision to test for or treat preexisting cardiac disease. Surgical judgment undoubtedly influenced decision-making at different stages in the patient care plan, and surgeons with different levels of experience were involved in patient care during the study period. In addition, although the subject of the study was surgery involving a thoracotomy incision, there was a significant degree of heterogeneity in the nature and extent of the surgeries performed. However, similar results regarding the role and impact of detailed cardiac testing were encountered with a more focused analysis addressing the lobectomy subset.

Conclusions

The decision to submit a patient undergoing a thoracotomy to detailed preoperative cardiac testing for further risk stratification should be selective and guided by a careful clinical evaluation. However, such testing and subsequent prethoracotomy corrective coronary intervention did not show definite benefit in avoiding MI in the context of modern era medical cardiac risk management.

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