ORIGINAL ARTICLE

Stress-only or stress/rest myocardial perfusion imaging in patients undergoing evaluation for bariatric surgery

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Background. **Bariatric surgery for management of obesity is being used with increasing frequency. Stress testing with myocardial perfusion imaging is often employed as part of the workup prior to anticipated bariatric surgery. The incidence of clinically significant abnormalities on stress MPI performed for this indication, however, has not been established.**

Methods and Results. **We retrospectively reviewed a series of 383 consecutive stress MPI studies performed on patients undergoing workup prior to planned bariatric surgery. The study population had a mean age 42 ± 10 years, and was 83% female, with a body mass index of 49 ± 8. The majority of patients (81%) were able to exercise using either the Bruce or Modified Bruce protocol, and 67% underwent stress-only imaging. Overall SPECT MPI findings were normal in 89% and equivocal in 6% of patients. The incidence of abnormal findings on MPI was 5% (3% mild and 2% moderate-to-severe abnormalities). At 1 year, overall survival was 99.5%, with no difference between those with and without MPI abnormalities. Similarly, the incidence of post-operative cardiac events was very low (2%), and mostly due to atrial arrhythmias or borderline elevations of troponin.**

Conclusion. **In a typical pre-bariatric surgery population, the incidence of abnormal stress MPI is low. The majority of patients were able to use a stress-only strategy for assessment of perfusion. At 1 year the incidence of adverse cardiovascular outcomes is very low. Additional studies should be focused on determining whether any subgroup of such patients may benefit more from pre-operative stress testing. (J Nucl Cardiol 2011;18:886–92.)**

Key Words: Outcomes research • myocardial perfusion imaging: SPECT • diagnostic and prognostic application

See related editorial, pp. 836–839

INTRODUCTION

Obesity is an epidemic in the United States with increasing public health implications. According to recent National Health and Nutrition Examination Survey (NHANES) data, more than two-thirds of the adult population are overweight, about half of whom are obese (defined by a body mass index [BMI] $\geq$ 30 kg/m^2).[1] Severe obesity is considered a chronic disease and can lead to potentially serious health consequences including hypertension, dyslipidemia, diabetes mellitus, coronary and peripheral atherosclerotic disease, heart failure, stroke, thromboembolism, and certain cancers.[2-5] In addition, an association exists between obesity and an increased incidence of arrhythmia, including sudden cardiac death.[6] Furthermore, obesity has been associated with increased mortality rates in multiple epidemiologic studies and may be responsible for as many as 112,000 excess deaths per year in the United States.[7,8]

The best approach to the treatment of obesity remains to be determined, but bariatric surgery (gastric bypass or banding procedures) is being used with increasing frequency.[9] There are several reasons for the

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Received for publication Feb 14, 2011; final revision accepted May 23, 2011.

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1071-3581/$34.00

doi:10.1007/s12350-011-9405-9

increased utilization of bariatric surgery. First, in comparison to other treatments, bariatric surgery results in significant and persistent weight loss over time.[10] Second, bariatric surgery reduces subsequent morbidity in many patients, with most patients showing resolution or improvement in diabetes, hyperlipidemia, and obstructive sleep apnea post-operatively.[11,12] Third, recent studies indicate that morbidly obese patients who undergo bariatric surgery have a lower risk of overall mortality compared to patients who do not undergo the procedure.[10,13] Finally, although minor complications are common, the overall rate of perioperative mortality or serious adverse medical events is low (≤1%) for these procedures.[14,15]

Despite the low perioperative risk associated with bariatric surgery, many patients are screened for cardiovascular disease prior to an anticipated operation. This practice is driven by a number of factors including the high prevalence of CAD risk factors in this population and the presence of underlying functional limitations which may make the assessment of symptoms suggestive of CAD difficult to do. The aim of this study is to estimate the incidence of abnormal findings by MPI in patients with morbid obesity that are being considered for bariatric surgery. Since the incidence of adverse cardiovascular outcomes following surgery in patients risk stratified by MPI has not previously been reported, we also gathered 1-year data reporting mortality and cardiovascular outcomes in these patients. Finally, we sought to quantify the value of using a stress-only imaging strategy in this population.

METHODS

Study Population

A consecutive series of 383 obese patients referred for stress myocardial perfusion imaging (MPI) from March 2004 to February 2007 was studied. The reason for all studies was pre-operative cardiac risk stratification in anticipation of possible bariatric surgery. The referral for pre-operative risk stratification was made at the discretion of the bariatric surgery team. Patients were referred for MPI for the following indications: exertional dyspnea, severely reduced functional capacity, chest pain, and, rarely, known CAD.

Stress Imaging Protocol

Stress testing was preferentially performed with exercise using either a symptom-limited Bruce or modified Bruce protocol. In the absence of other symptoms such as dyspnea and chest pain, the term fatigue was used to denote a symptom-limited exercise stress test. Pharmacologic stress using adenosine was performed when exercise testing was not possible or inadequate. Adenosine stress was performed using a 4- to 6-minute infusion (140 mcg/kg/minute). ECG and hemodynamic monitoring was performed routinely. Discontinuation of anti-ischemic medications was not performed routinely, and was left to the discretion of the referring physician.

Myocardial perfusion studies were performed using Tc-99m-based perfusion tracer (sestamibi or tetrofosmin) with initial plan for a 2-day stress/rest protocol. Rest imaging was not required in patients interpreted as having normal volumes and perfusion. Stress studies were obtained in all patients after injection of 25-40 mCi of Tc-99m sestamibi or tetrofosmin. If studies were abnormal or equivocal, rest studies were obtained on a separate day. Images were acquired 30-60 minutes after stress injection, and 60 minutes after rest injection. Gated SPECT myocardial perfusion images were obtained with dual-head SPECT cameras (Philips/ADAC Vertex or V60). All images were obtained using attenuation correction with simultaneous acquisition of transmission images using external line sources. Acquisition parameters included: 25-40 seconds per step, 64 total steps, low energy high-resolution collimation, and 8 frames per cardiac cycle gating.

Image Analysis

Myocardial perfusion images were processed and analyzed using commercially available quantitative software (AutoQuant). The method of quantification is summarized as follows: tomographic images were reconstructed using standard filtered back projection (non-attenuation corrected images) or iterative reconstruction (attenuation corrected images), and Butterworth low-pass filtering. Short- and long-axis SPECT images were generated. Polar maps, representing the entire left ventricle, were then generated based on an automatic algorithm for defining the boundaries of the myocardium. When automatic processing failed (<5% of studies), manual adjustment of the regions of interest was performed.

For quantitative assessment of defect severity, the polar maps of myocardial perfusion were divided into 17 anatomical segments. Regional perfusion defect size was generated by comparison of radiotracer uptake to that of a normal database, and was expressed quantitatively for each myocardial segment. Summed stress score (SSS) and summed rest score (SRS) were calculated for each study, representing the extent and severity of perfusion defects on stress and rest images, respectively.[16-18] Left ventricular volumes and ejection fraction were determined by automated analysis of gated SPECT images.

Images were interpreted by experienced nuclear cardiologists and radiologists incorporating all qualitative and quantitative parameters. Abnormal studies were defined as any of the following: perfusion defects on stress images (SSS > 3), transient left ventricular cavity dilatation, left ventricular dysfunction (LVEF $< 45\%$). Stress defects were considered ''moderate-to-severely abnormal'' if SSS was greater or equal to 9, LVEF $< 45\%$, or if transient left ventricular cavity dilatation was present. Studies were considered equivocal if the reader's impression (including SSS, qualitative reading) suggested that the presence of artifact limited the interpretation.

Follow-Up

For those patients who underwent bariatric surgery, follow-up for perioperative cardiovascular complications were performed by chart review in all patients. Chart reviews and review of SSDI database were performed on all patients regardless of surgical status at 1 year from the time of the stress test, to determine whether alive or dead, and for any hospital admissions due to myocardial infarction or revascularization. Follow-up data were obtained in all but one patient.

Statistics

Continuous variables are presented as mean ± 1 SD. Patient characteristics were compared using an unpaired two-tailed t test for evaluation of continuous variables and a chi-squared test to evaluate differences in categorical variables. A *P* value <0.05 was considered to be statistically significant. All analysis was performed using Microsoft Excel software.

RESULTS

Patient Characteristics

Patients were relatively young, predominantly female, and had very high body mass index (Table 1). Risk factors for CAD were common, and 78% of patients had at least one CAD risk factor other than male gender. The presence of preexisting CAD, however, was rare and the use of cardiac medications was low (Table 1). Data describing the pre-operative probability of CAD was available for 339 patients (89%).[19]

Stress Data

The majority of patients underwent exercise stress, achieving modest workloads (Table 2). 19% of patients required pharmacologic stress. Among patients who exercised, overall workload achieved was fair (∼7 METs), and most tests were stopped due to fatigue. A target heart rate of ≥85% of maximum predicted was achieved in 77% of patients; 93% of patients achieved ≥80% of maximum predicted heart rate. Use of beta-blockers was significantly higher in patients with sub-optimal heart rate response (<85% MPHR) compared with those who achieved the target heart rate (23% vs 5%, $P < .001$). Chest pain and dyspnea occurred in 6% and 15%, respectively. Three patients developed diagnostic ST depressions during the study and no patient had a high risk Duke treadmill score.

SPECT Myocardial Perfusion Results

Stress-only imaging was utilized in 257 (67%) patients, 118 (31%) underwent 2-day stress-rest, and 8 (2%) underwent 1-day rest-stress protocols. The large majority of studies were normal (Figure 1). Six percent of patients had equivocal studies, mostly due to attenuation artifact. Twenty (5.2%) of the 383 patients had abnormal MPI: 17 with reversible perfusion defects; the remaining 3 patients had isolated fixed perfusion

Table 1. Patient characteristics

	All (n = 383)	Normal or equivocal (n = 363)	Abnormal (n = 20)	*P* value
Age (years)	42 ± 10	42 ± 10	46 ± 9	.12
Male (%)	67 (17)	60 (17)	7 (35)	.06
BMI	49 ± 8	49 ± 7	54 ± 10	.01
CAD risk factors				
Diabetes (%)	88 (23)	81 (22)	7 (35)	.19
Hypertension (%)	168 (44)	159 (44)	9 (45)	.46
Hyperlipidemia (%)	95 (25)	86 (24)	9 (45)	.03
Family history (%)	134 (35)	123 (34)	11 (55)	.05
Smoker (%)	102 (27)	93 (26)	9 (45)	.06
History of CAD (%)	4 (1)	1 (0.3)	3 (15)	<.001
History of CHF (%)	0	0	0	
Medications				
Beta blockers (%)	49 (3)	44 (12)	5 (25)	.09
Calcium channel blockers (%)	43 (11)	41 (11)	2 (10)	.71
ACE inhibitors (%)	86 (22)	79 (22)	7 (35)	.17
Lipid therapy (%)	72 (19)	63 (17)	9 (45)	.002
Nitrates (%)	8 (2)	1 (0)	7 (35)	<.001

Table 2. Stress data

	All (n = 383)	Normal or equivocal (n = 363)	Abnormal (n = 20)	*P* value
Stress type				
Exercise (%)	312 (81)	297 (82)	15 (75)	NS
Vasodilator (%)	71 (19)	66 (18)	5 (25)	NS
METs achieved	6.9 ± 4.2	6.9 ± 4.3	7.1 ± 2.2	NS
RPP (mm Hg × bpm)	27034 ± 4152	27171 ± 4119	24310 ± 3981	.01
Duke treadmill score		6.2 ± 1.7	5.5 ± 2.3	NS
Low risk > 5 (%)		255 (86)	9 (60)	.02
Intermediate risk (−10 to +4) (%)		42 (14)	6 (40)	.02
High risk (<−10)		0	0	
Symptoms during exercise				
Dyspnea (%)	48 (15)	42 (14)	6 (40)	.02
Fatigue (%)	233 (75)	226 (76)	7 (47)	.02
Leg/muscle pain (%)	29 (9)	27 (9)	2 (13)	NS
Chest pain (%)	19 (6)	17 (6)	2 (13)	NS
Suboptimal exercise achieved*				
<80% MPHR	25 (8%)	22 (7%)	3 (20%)	NS
<85% MPHR	73 (23%)	68 (23%)	5 (33%)	NS

*Within subgroup able to exercise (n = 312).

defects, depressed LV function, or transient LV dilatation. MPI abnormalities were moderate to severe in 8 patients: 4 with SSS ≥ 9, 2 with transient LV dilatation, and 2 with LVEF < 45% Of the 339 patients for whom a pretest risk estimate was available, MPI abnormality was present in 3/3 (100%) patients with known CAD, 8/144 (6%) of patients with intermediate probability and 7/192 (4%) patients with low probability of CAD.

Abnormal SPECT MPI was more common in patients with higher BMI, and those with hyperlipidemia. The prevalence of cholesterol-lowering drug and/or nitrate use was also significantly higher (Table 1). In addition, while not achieving statistical significance there was a trend toward increased prevalence of other traditional risk factors (tobacco use, and family history of early coronary artery disease) among the patients with abnormal SPECT MPI studies.

Regarding exercise test data, patients with abnormal MPI were more likely to have dyspnea with stress, achieve a lower rate-pressure product, and have an intermediate Duke treadmill score (Table 2). Otherwise, no significant differences were noted on exercise performance.

Post-operative and 1-Year Follow-Up

Post-operative and 1-year follow-up was available in 392 of 393 patients and is shown in Table 3. The incidence of cardiac complications (death, myocardial infarction, or revascularization) was very small precluding determination of statistical significance between the groups. At 1 year, overall survival was 99.5% in patients with normal MPI and 99% in those with abnormal MPI. Individual patients with abnormal MPI are listed in Table 4 with a summary of the MPI result and follow-up data. Of the 20 patients identified to have abnormal myocardial perfusion, 14 underwent the operation and surgery was withheld in 6. Four patients underwent coronary angiography, which showed significant coronary artery disease in only one.

DISCUSSION

In this study, we report the incidence of abnormal stress myocardial perfusion imaging studies (MPI) and 1-year follow-up in patients who were evaluated preoperatively for bariatric surgical procedures. Our major findings can be summarized as follows. First, this patient population has a very low incidence of death or cardiac events at 1-year follow-up with 0.7% incidence of death from all causes, 0.5% incidence of coronary revascularization, and no myocardial infarctions. Second, perioperative cardiovascular events were extremely low, and composed mainly of borderline elevations of troponin. Third, despite the high prevalence of risk factors for CAD and relatively modest functional capacity, we

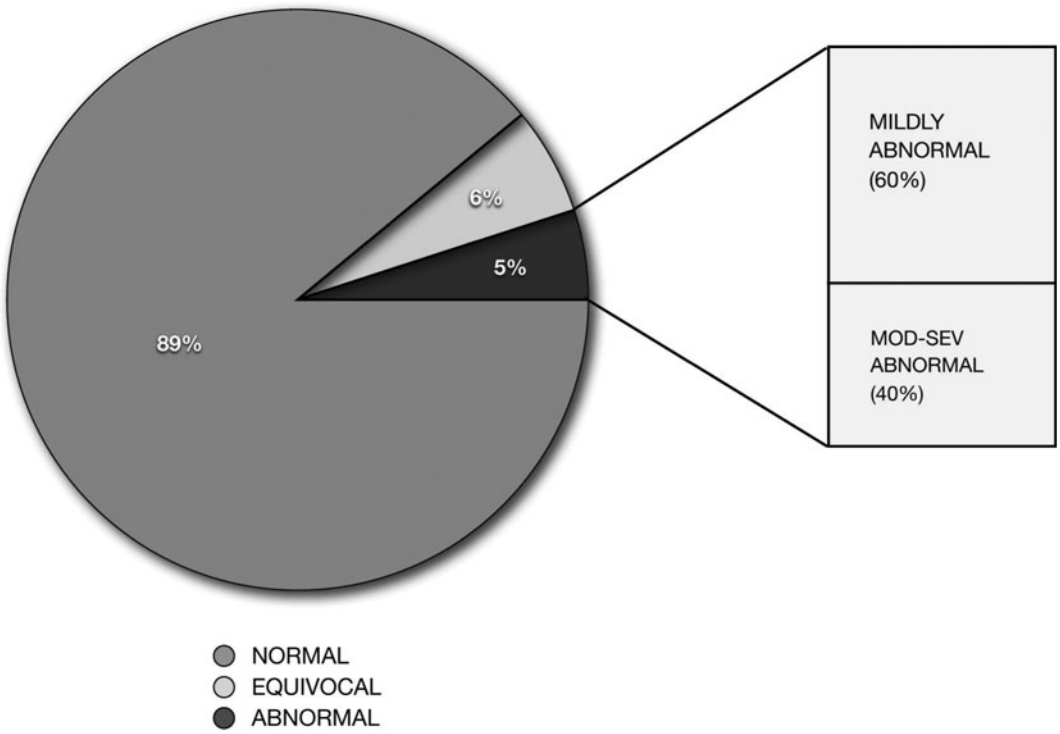

Figure 1. The vast majority of studies (89%) were interpreted as normal. Of the twenty studies interpreted as abnormal, twelve (60%) were judged to be mildly abnormal and eight (40%) moderately or severely abnormal.

Table 3. Post-operative and 1-year follow-up for 382 patients

	Normal or equivocal (n = 362)	Abnormal (n = 20)	*P* value
Surgery not performed (%)	55 (15)	6 (30)	.08
Post-operative cardiac complications			
Atrial arrhythmia (%)	1 (0.3)	1 (5)	NS
Troponin			
Positive (%)	1 (0.3)	0	NS
Borderline (%)	4 (1)	1 (5)	NS
1-Year follow-up			
Death (%)	2 (0.5)	1 (5)	NS
Myocardial infarction (%)	0	0	NS
Revascularization (%)	1 (0.3)	1 (5)	NS

found the incidence of abnormal MPI studies was low: 5% overall; with a 2% incidence of moderate-to-severe abnormalities.

Whether or not pre-operative stress testing is performed prior to bariatric surgery has largely been dependent upon a few notable characteristics of the patient population in question. First, morbidly obese patients are more likely than the general population to have one or more risk factor pre-disposing them to the presence of obstructive coronary artery disease. Secondly, these patients may be limited in their physical capacity and therefore the ability to detect those patients at low risk for cardiovascular events by history alone is limited. Finally, and interrelated with the second reason, morbidly obese patients may report symptoms such as dyspnea, chest pain, and fatigue which may raise suspicion for cardiac etiologies. Therefore, stress testing to better risk stratify patients with morbid obesity prior to bariatric surgery has become a relatively common practice.

Table 4. Follow-up in patients with abnormal MPI studies

Patient Number	Age/sex	MPI abnormality	1-Year follow-up
18	28 F	Ischemia	No complications, events
30	50 F	Ischemia	Cardiac cath: no CAD; no complications, events
41	56 F	Ischemia/scar, ↓LVEF	Surgery not performed
55	39 F	Ischemia	Surgery not performed
61	51 F	Ischemia	No complications, events
103	47 F	Ischemia/scar, ↓LVEF	Cardiac cath: 2vCAD, PCI; no complications
107	54 M	Ischemia	No complications, events
129	46 F	Ischemia	No complications, events
164	36 M	Ischemia, ↓LVEF	No complications, events
196	28 M	Ischemia	Surgery not performed
197	51 F	Ischemia	Cardiac cath: no CAD; no complications, events
208	49 F	Ischemia	No complications, events
217	59 F	Ischemia	No complications, events
222	43 F	Ischemia, TID	Cardiac cath: no CAD; no complications, events
236	46 M	Ischemia	Surgery not performed
240	37 F	Ischemia	Surgery not performed
264	40 M	Ischemia	Surgery not performed
281	53 F	TID	No complications, events
312	50 M	↓LVEF	Deceased
339	48 F	Scar	Mild ↑ troponin post-op

The findings of this study, however, suggest that the patient population in question is at very low risk for cardiovascular events. If this is indeed the case then preoperative stress testing with MPI for the detection of CAD may be unlikely to affect outcome and would be associated with a higher relative likelihood of false positives. Of the four patients with abnormal MPI who underwent diagnostic angiography, in our population, three were found not to have significant obstructive CAD. Additionally, it may be that the likelihood of bariatric surgery precipitating an acute ischemic event is less than has been previously anticipated since eight of the ten patients with MPI abnormalities who underwent surgery without additional intervention had uneventful recoveries after surgery.

Comparison with Other Studies

The result of this study is consistent with findings from several recent studies estimating the rate of perioperative complications following bariatric surgery. Buchwald et al., in a large meta-analysis including 361 studies and over 85,000 patients, reported an overall mortality rate of 0.4% at 30 days and 0.8% for the time interval from 30 days to 2 years post-surgery.[14] In another recent study, Birkmeyer et al. showed the overall rate of serious complications following bariatric surgery was relatively low at 2.7%. In particular, cardiovascular complications contributed only a small portion to the total (0.1%).[15] Our findings are consistent with the very favorable outcomes and lack of cardiovascular perioperative complications reported in these studies.

Stress-Only Imaging

From an imaging standpoint, it is relevant to note that two-thirds of patients were able to undergo stress-only imaging despite their severe obesity. An increasing number of studies have shown a protocol using stress-only images to yield comparable prognostic value while sparing additional radiation exposure relative to the conventional stress-rest protocol.[20,21] While this study was not designed to evaluate the stress-only protocol in this population, the largely normal MPI results, most of which were stress-only studies, were associated with favorable perioperative and 1-year outcomes. Thus, this study further demonstrates the feasibility of a stress-only MPI approach in such patients. Of note, we used attenuation correction in all MPI studies, which facilitates stress-only imaging. The use of stress-only imaging is an important strategy to keep overall radiation exposure as low as reasonably necessary to obtain the required clinical information and may yield extra benefit in this population where there is a tendency to need high doses of radiopharmaceutical to overcome increased body mass.

LIMITATIONS

This study has several limitations. First, as this is a retrospective analysis of patient outcomes based on a chart review, and it is possible that the 1-year event rate has higher than what we found. Furthermore, the frequency of death relative to MI (3 vs 0) suggests the possibility that some non-fatal myocardial infarctions may have occurred that were not detected in follow-up. Secondly, there were no standardized indications for cardiac catheterization which may lead to bias. Thirdly, the relationship between the findings of the MPI studies and 1-year outcomes may have been affected by management decisions derived from the results of the MPI studies. Medications such as aspirin and beta-blockers may have been initiated or withheld prior to surgery depending on interpretation of the MPI studies, which may have affected 1-year outcomes. Finally, there was a very low incidence of adverse cardiovascular outcomes in this patient population. Due to the relatively low number of adverse outcomes, the analysis of the association between MPI results and outcomes is limited. A large, multicenter, randomized prospective study would be helpful in further determine whether a particular subgroup of these patients are at higher risk for adverse outcomes and may derive a greater benefit from this type of approach.

CONCLUSION

This study demonstrates that in a typical pre-bariatric surgery population the incidence of both abnormal result by MPI and combined outcome of 1-year mortality and adverse cardiovascular events is low. Additional studies are needed to determine how such patients should be selected for pre-operative noninvasive risk stratification.

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