

Noninvasive cardiac risk evaluation before elective abdominal aortic aneurysm surgery — clinical value of the goldman index and echocardiography

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Summary

Cardiac complications comprise as much as 50% of perioperative vascular surgical morbidity and mortality. Using the Goldman multifactorial index for evaluating cardiac risk pre-operatively, 53 consecutive patients who underwent abdominal aortic aneurysm surgery were prospectively studied. Forty patients (75.5%) were also evaluated with echocardiography for assessment of left ventricular function.

There were 14 (23.7%) peri-operative events, of which nine (17.0%) were acute myocardial infarctions — two of whom died (3.8%). The minor complications included three with hypovolaemic renal failure, and one each with acute respiratory failure and cerebrovascular accident. Patients with Goldman cardiac risk index (CRI) classes III and IV were associated with significantly higher risks of peri-operative complications ($p < 0.001$), i.e. 77.8% and 66.7% respectively, compared with class II (22.7%) and class I (nil). Echocardiographic left ventricular shortening fraction (LVFS) of $< 28\%$ helped identify high risk groups in all classes, although its positive predictive value was low (42.3%). Combining LVFS $< 28\%$ with Goldman CRI categories II to IV improved the sensitivity to 91.7% and the positive predictive value to 61.1%.

Careful pre-operative assessment using the simple Goldman index and echocardiography is helpful in identifying higher risk patients who would benefit from pre-operative stabilisation and more rigorous perioperative hemodynamic monitoring preferably including intensive care (ICU) management, so as to reduce cardiac complications.

Key words: Abdominal aortic aneurysm, cardiac risk, echocardiography, vascular surgery, complications.

Introduction

Cardiac complications and deaths account for some 50% of peri-operative vascular surgical morbidity and mortality, particularly among abdominal aortic aneurysm (AAA) patients.¹ Furthermore, peri-operative myocardial infarction is often associated with high mortality rates

(50–70%).² Abdominal vascular patients are thought to be at especially higher risk for developing peri-operative cardiac morbidity i.e. some three times that for the general surgical patients.³ Thus, the prediction of cardiac risk from surgery and anaesthesia is important in planning allocation of medical resources and the evaluation of risk-benefit ratio for operations, anaesthetic management and monitoring techniques.

In an elegant landmark study, Goldman and others⁴ prospectively evaluated and followed 1001 patients who underwent major noncardiac surgery at the Massachusetts General Hospital. Using multivariate analysis, nine independent risk factors for life-threatening complications were identified. By scoring each risk factor, patients could then be stratified into high and low risk categories (i.e. classes I to IV; see Table 1). They found that this cardiac risk index (CRI) was more accurate and objective at predicting perioperative morbidity when compared with the Dripps-American Society of Anaesthesiologists (ASA) classification.^{5,6} The Dripps-ASA physical status was fairly useful for predicting perioperative 'noncardiac' complications,⁷ but it was of limited usefulness in predicting cardiac problems.^{4,8}

Based on these data, we designed our study to prospectively evaluate the cardiac risk of this select AAA group, using the Goldman CRI stratification. Echocardiography was also performed to evaluate left ventricular function as an additional cardiac index.

Table 1
Computation of the Goldman Cardiac Risk Index (CRI)*

Criteria	Points
1. History	
a) Age > 70 years	5
b) Myocardial infarction in previous six months	10
2. Physical examination	
a) S ₃ gallop or jugular vein distension	11
b) Important valvular aortic stenosis	3
3. Electrocardiogram	
a) Rhythm other than sinus or PACs on last preoperative ECG	7
b) > 5 PVCs/min documented at any time before operation	7
4. General status	
PO ₂ < 60 or PCO ₂ > 50 mmHg, K < 3.0 or HCO ₃ < 20 mmol/l, BUN > 50 or creatinine > 3.0 mg/dl, abnormal AST (SGOT), signs of chronic liver disease, or patients bedridden from noncardiac causes	3
5. Operation	
a) Intraoperative, intrathoracic or aortic operation	3
b) Emergency operation	4
Total Possible	53

* Goldman et al⁴

Methods and Materials

Fifty three consecutive patients who were scheduled for abdominal aortic aneurysm (AAA) operation at the Vascular Surgical Unit of the National University of Malaysia, were prospectively studied during the period June 1986 to August 1989.

Clinical Assessment: Each patient was seen before operation (49 patients), or, on occasional cases of semi-urgent operations, as soon as possible post-operatively (four patients) to elicit any history of cardiac risk factors, symptoms and/or events and to perform a detailed pulmonary, cardiac, peripheral pulse and extremity examination. Jugular venous pressure was estimated at the bedside (distension or evaluation was defined as venous pressure > 12 cm above the fourth intercostal space in the midaxillary line). Clinically important aortic stenosis was defined on typical clinical signs and confirmed by echocardiography. All available previous ECGs were reviewed for evidence of significant arrhythmias i.e. frequency and complexity of premature ventricular contractions (PVC), atrial fibrillation-flutter (AF), multifocal atrial tachycardia (MAT) or conduction abnormalities. Just prior to operation another ECG was performed and evaluated. This methodology followed closely that described by Goldman's group.⁴

All available patient records to corroborate historical and physical findings were reviewed to ascertain previous cardiac abnormalities. Pre-operative vital signs, ECG and chest X-ray were performed and officially interpreted. All relevant laboratory data were also tabulated for analysis. All patients had full renal, hepatic, haematological and haemostatic screens including serological tests for syphilis and hepatitis B. Lung function tests and arterial blood gases were also performed where indicated by clinical evidence of chronic lung disease (28 patients).

Echocardiography: Where possible an echocardiogram was performed just prior to surgery with particular attention to left ventricular function. For measurements of the left ventricular, aortic and left atrial dimensions, the optimal minor parasternal axis was selected and measurements obtained at various cycle phases in accordance with established criteria.⁹ Since a large number (28 patients) had concomitant airways disease with hyperinflated lungs, poor acoustic windows often resulted in poor apical axis images (in 26 patients) and sometimes even parasternal views (in five patients) were suboptimal in quality. These were therefore, not admissible for objective evaluation. In this regard, LV ejection fraction utilising the apical LV frames (by Simpson's rule) was not possible in many patients. However, M-mode-derived LV fractional shortening (LVFS) could be obtained in the majority (40 patients) from the minor parasternal axis; this was thus utilised as the most accessible cardiac index. LVFS was defined as follows:—

$$\text{LVFS (\%)} = \frac{\text{LVEDD} - \text{LVESD}}{\text{LVEDD}} \times 100$$

where LVEDD and LVESD were LV internal diameters at end-diastole and end-systole respectively, at the chordal level.

Unstable clinical features: Preoperatively, patients who were deemed unstable and high risk on first examination were deferred elective surgery where possible until their problems stabilised. These included patients with: a) uncontrolled hypertension (11 patients), b) ongoing congestive cardiac failure (eight patients), c) recent myocardial infarction (< six months, one patient), d) severe respiratory symptoms (two patients), e) ongoing stable effort angina (two patients), f) grossly abnormal electrocardiograms especially frequent PVCs (two patients), rapid AF (two patients) or MAT (one patient), g) abnormal liver (three patients) and renal function profiles (22 patients had serum creatinine > 120 $\mu\text{mol/l}$, three had serum creatinine > 200 $\mu\text{mol/l}$).

Pertinent therapy was instituted where possible until such time that the patient was regarded as 'stable'. However, this was not possible in semi-emergency or emergency cases where leaking aneurysm, acute abdomen or circulatory collapse were clinically suspected and diagnosed (four patients). These patients were still regarded as 'elective' since they were already registered for prospective evaluation and stabilization. (All other new emergency cases were excluded from analysis if they presented for the first time without prior cardiovascular assessment.) In a semi-emergency or emergency case, the anaesthetist was alerted to the cardiovascular status of the patient and perioperative ECG and/or hemodynamic monitoring was instituted. Particular care was paid to avert severe fluctuation in blood pressure and volume status during and post-anaesthesia. Most of these high-risk (12) patients were monitored in the intensive care unit immediately post-operation for some two to four days.

Goldman stratification for Cardiac Risk Index (CRI): Each patient (where possible, after stabilisation) was assigned to a CRI class as stratified by Goldman et al,⁴ based on the clinical data just prior to AAA surgery (see Table 2).

Table 2
Classification of Cardiac Risk Index

Cardiac Risk Class	Points Total
I	0 – 5
II	6 – 12
III	13 – 25
IV	≥ 26

Definitions for perioperative complications: Perioperative sequelae were defined as early in-hospital complications occurring during or immediately after surgery or anaesthesia, usually within 10 to 14 days. These were divided into major cardiac and other minor noncardiac complications. Major cardiac complications included: 1) pulmonary oedema, 2) myocardial infarction (AMI), 3) ventricular tachycardia/fibrillation, 4) cardiac death and 5) any death. Minor sequelae included all other nonfatal noncardiac complications.

Cardiac complications were assessed as follows: All patients who were regarded as potential high risk cases i.e. CRI classes III or IV or those with poor LVFS (< 28% on echocardiography) were routinely scrutinised with immediate post-surgical serial ECGs (at least for three consecutive days) and cardiac enzymes (creatinine kinase, lactate dehydrogenase and aspartate transaminase). Where unexpected, but a cardiac or unaccountable hypotensive event was detected by the surgeon or anaesthetist, that patient was also monitored at the ICU with serial ECGs and cardiac enzymes as well. Immediate post-operative cardiac consultation (DKLQ) was given to 15 patients who complained of suspicious chest pain or had any changes by physical examination or ECG that raised the clinical question of a myocardial infarction. For all the others, ECGs and serial cardiac enzymes were reviewed and later documented for confirmation of whatever cardiac event.

The diagnosis of a post-operative myocardial infarction mandated new ST segment depression or elevation or symmetrical T-wave inversion (in at least two contiguous leads, with evolving

changes) that either was associated with chest pain typical of myocardial ischaemia, persisted for at least 72 hours, and could not be explained on the basis of medications or electrolyte imbalance, or was associated with serial changes of serum cardiac enzymes (at least two) that could not be explained on the basis of the surgical course itself.^{4,10,11} New pathological Q-waves were not necessary for the diagnosis of AMI – although this development confirmed the probable transmural nature of the infarction. If abnormalities persisted as new ST segment depressions of one mm or more and symmetrical T-wave inversion for at least seven days without any other explanation, the diagnosis is also considered established.⁴

The diagnosis of pulmonary oedema required classic chest X-ray changes or respiratory distress with extensive rales in both lung fields which improved with diuretic therapy. A cardiac death was diagnosed if a patient died either from an arrhythmia or from refractory low cardiac output secondary to myocardial infarction or dysfunction (not primarily caused by noncardiac conditions such as sepsis, respiratory failure or terminal cancer).⁴ A noncardiac death was defined as death resulting from any other cause regardless of whether there was an associated prior cardiac condition or complication.⁴

Data Analysis

Post-operative pulmonary oedema, myocardial infarction and observed ventricular tachycardia were each associated with a 25% or greater incidence of cardiac death, and thus were defined as life-threatening.⁴ Since other noncardiac complications carried substantially lower chance of death, they were defined as minor. However all sequelae were documented and considered in the data analysis. Cardiac or major complications were also independently analysed.

Each continuous or discrete variable was correlated with cardiac outcome by univariate chi-square analysis. A probability of < 0.05 was considered significant.

In this study, the clinical usefulness of the Goldman CRI and echocardiography was also analysed with the usual computations for sensitivity, specificity and positive predictive value. In particular, echocardiographic LVFS $< 28\%$, as an established index of LV dysfunction,¹² was evaluated for its usefulness in predicting cardiac or clinical sequelae.

Results

Patient characteristics: Fifty three consecutive patients were studied, of whom 49 (92.5%) were men. The ethnic distribution resembled the Malaysian population profile i.e. Malays 23 (43.4%), Chinese 19 (35.9%), Indians six (11.3%) and others five (9.4%). The mean age was 67.0 ± 7.6 years (range 51 to 85 years). This meant a rather elderly population: 86.8% were ≥ 60 years and 62.3% were ≥ 65 years. The common risk factors were tabulated as in Table 3, which compares very similarly with those reported by Jeffrey and others.⁶ Notably highly prevalent risk factors included a history of smoking whether current or past (92.5%), hypertension (67.3%) and chronic respiratory disease (52.8%). A number of patients either had previous myocardial infarctions (all but one > 6 months; 30.2%) or a history of coronary artery disease (26.4%) with some one-fifth (18.9%) having ongoing but stable angina.

Peri-operative complications: Fourteen patients suffered peri-operative complications, of which nine (17.0%) had documented myocardial infarctions – five of which associated with acute pulmonary oedema and two (3.8%) died. Five others had 'minor' complications: three had acute

Table 3
Risk Factors in 53 Patients having Elective AAA Surgery

	Number (%)	Jeffrey et al*
History of smoking	49 (92.5)	97 (98.0)
Hypertension	33 (67.3)	55 (55.6)
History of coronary disease	30 (56.6)	44 (44.4)
Previous myocardial infarction	16 (30.2)	32 (32.2)
Current history of angina	10 (18.9)	27 (27.3)
Previous congestive heart failure	11 (20.8)	10 (10.1)
Chronic respiratory disease	28 (52.8)	46 (46.5)
Diabetes mellitus	7 (13.2)	9 (10.0)
Renal impairment	2 (3.8)	3 (3.3)

AAA: Abdominal aortic aneurysm
(*Jeffrey CC et al³)

renal failure – two from graft anastomotic leak and one from acute on chronic renal impairment, one had a nonfatal stroke with left hemiparesis and another developed acute Type II respiratory failure. None in this group died.

Fatalities: The two who died were women. The first case was a 68-year old woman who presented as an acute abdomen with circulatory collapse during stabilisation prior to elective AAA bypass-graft surgery. Profound hypotension with new hyperacute electrocardiographic evidence of a fresh inferior myocardial infarction was noted over and above her previous Q-wave anterior myocardial infarction. Urgent portable echocardiography showed a markedly dilated left ventricle with poor function, LVEDD 70 mm, LVESD 60 mm, and an LV shortening fraction of only 14.3%. An emergency laparotomy revealed a 10-cm diameter leaking aneurysm with a large retroperitoneal haematoma. Post-operatively she remained in shock with pulmonary oedema and finally succumbed with terminal ventricular tachycardia-fibrillation at the fourth post-operative day. Her pre-operative CRI score was 30 i.e. Goldman class IV. The second patient was 75 year old and presented with a recent-onset abdominal pain and swelling. Ultrasound confirmed a 50-mm diameter aneurysm with a clinical suspicion of intraabdominal bleeding i.e. an acute abdomen. Her pre-operative ECG showed precordial R-wave regression, the chest radiograph showed gross cardiomegaly with a cardiothoracic ratio of 0.62 with interstitial oedema and pulmonary venous redistribution. Urgent laparotomy revealed a curious ruptured left uterine vein with intact aortic aneurysm. At day three post-operation, she collapsed, went into intractable asystole despite prolonged cardiopulmonary resuscitation. Her preterminal ECG revealed an hyperacute inferoposterior infarction.

Goldman Cardiac Risk Index versus Complications: As can be seen in Table 4, many patients who presented for elective AAA surgery were in Goldman CRI classes I and II (76.3%). Some 22.7% were in classes III and IV. Yet nine of the 14 peri-operative events and seven of nine myocardial infarctions occurred in the classes III and IV. In fact 55.6% and 66.7% of patients with classes III and IV, respectively, had a cardiac event when compared to only 9.1% of those in

Table 4
Goldman Cardiac Risk Index (CRI) Class & Complications

CRI Class	Number (%)	Peri-operative Complications		
		Minor (%)	Major (%)	Total (%)
I	19 (35.8)	0	0	0
II	22 (41.5)	3 (13.6)	2 (9.1)	5 (22.7)
III*	9 (17.0)	2 (22.2)	5 (55.6)	7 (77.8)
IV*	3 (5.7)	0	2 (66.7)	2 (66.7)
Total	53 (100.0)	5 (9.4)	9 (17.0)	14 (26.4)

* CRI classes III and IV were associated with significantly higher peri-operative complications when compared with CRI classes I and II ($p < 0.001$)

class II and none in class I. Thus, patients in classes III and IV had a significantly higher risk for any perioperative events including myocardial infarctions when compared with those in classes I and II ($p < 0.001$).

Echocardiographic features: Adequate echographic images were obtained for cursor-steered M-mode echograms for measurements of left ventricular dimensions, in 40 (75.5%) patients. Figure 1 gives an example of a preoperative echogram of a CRI class II with poor LV function and calcific aortic sclerosis but fair aortic valve opening. Figure 2 shows the distribution of the left ventricular shortening fractions (LVFS) and the Goldman CRI classes and the post-operative sequelae. It shows quite clearly that CRI classes III and IV were associated with LVFS $< 28\%$ in many patients, with some seven of eight patients having had a perioperative complication including 5 myocardial infarctions and one cardiac death. However, some 4 patients in CRI class II and one in class I also had an event, all but one of these predicted by a LVFS of $< 28\%$. Thus 11 of the 12 peri-operative events occurred in patients with LVFS $< 28\%$ when compared with those with normal LVFS ($> 28\%$), a significance probability of < 0.02 . Furthermore, all seven patients who had AMI belonged to those patients whose echocardiographic LVFS was $< 28\%$ ($p < 0.05$).

Other significant risk factors associated with peri-operative events: When various characteristics of our patients were compared to determine which predisposed to increased risks of any peri-operative complications, the following factors were identified as significant: functional classes (New York Heart Association) III and IV ($p < 0.01$), the presence of S_3 gallop ($p < 0.01$), jugular venous distension ($p < 0.01$), lung basal rales ($p < 0.02$), radiographic evidence of pulmonary congestion ($p < 0.001$), any ECG evidence of previous Q-wave myocardial infarction ($p < 0.01$), and elevated serum levels of creatinine $> 200 \mu\text{mol/l}$ ($p < 0.01$). For increased risk of myocardial infarctions, only poor NYHA class (III or IV), presence of S_3 gallop, jugular venous distension, and radiographic pulmonary congestion reached significant levels ($p < 0.05$). Using univariate analysis, age or duration of surgery or anaesthesia were not shown to be significant factors.

Sensitivity, specificity and positive predictive value: The Goldman CRI classes III and IV

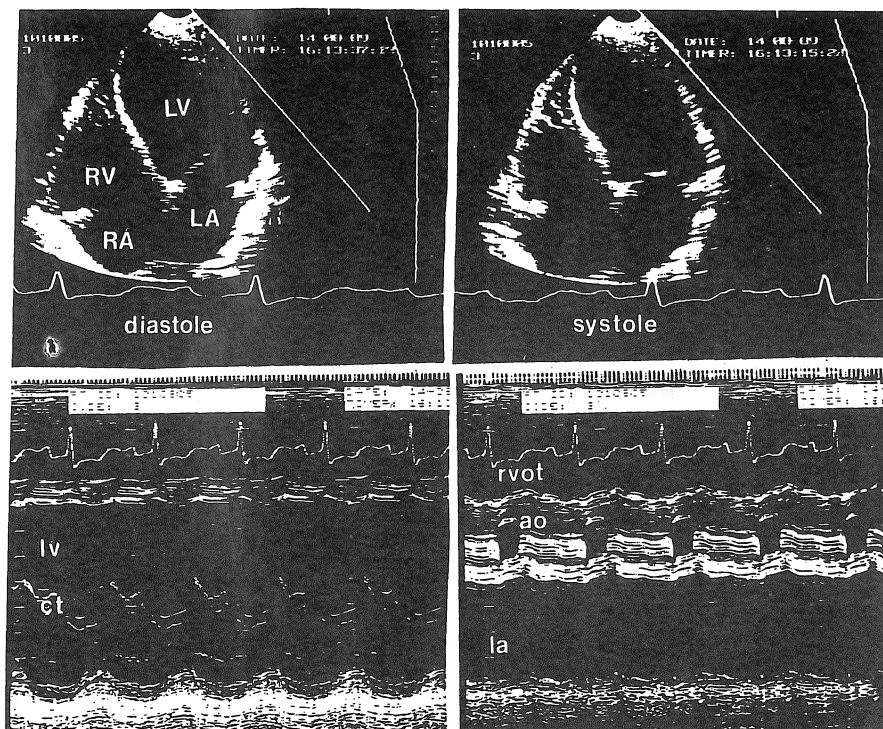


Figure 1: Echocardiographs of a 70-year old man with Goldman CRI class III who developed perioperative non-Q-wave infarction and acute pulmonary oedema. *Top*: Diastolic and systolic frames of the apical 4 chamber view showing very poor LV contraction; RV – right ventricle, RA – right atrium, LV – left ventricle, LA – left atrium. *Bottom*: M – mode images at the left parasternal window showing left ventricular dimensions (left) and aortic valve – left atrium site (right). The left ventricular dimensions are grossly dilated, LVEDD 72mm, LVESD 65mm, LVFS 9.7%; lv – left ventricular chamber, ct – chordae tendinae. The aortic valve (ao) is calcified and sclerotic but still opens fairly well 16mm, and the left atrium (la) dilated 44mm, rvot – right ventricular outflow tract.

identified nine of 14 clinical events i.e. a sensitivity of 64.3%. For myocardial infarctions, these two classes identified seven of nine events, i.e. a sensitivity for AMI of 77.8%. Specificity for any post-operative events was also good, 92.3%. Thus using the CRI classes III and IV as high risk categories, a positive predictive value of 75.0% was obtained for predicting peri-operative events ($p < 0.001$).

Echocardiographic left ventricular shortening fraction (LVFS) of $< 28\%$ (as an index of poor cardiac function) was obtained in 26 of 40 patients, with a sensitivity of 100% for perioperative myocardial infarctions and 91.7% for all events. However, the specificity for this index was low, 48.3% for any perioperative events. Using LVFS $< 28\%$ by itself, resulted in poor positive predictive values i.e. 42.3% for all events and only 26.9% for AMI.

By combining the two indices of CRI classes II to IV and LVFS $< 28\%$, 11 of 18 events could be predicted i.e. a positive predictive value of 61.1%; although the specificity remained low at 46.1%. This was mainly due to the overall lower risk category of CRI class II.

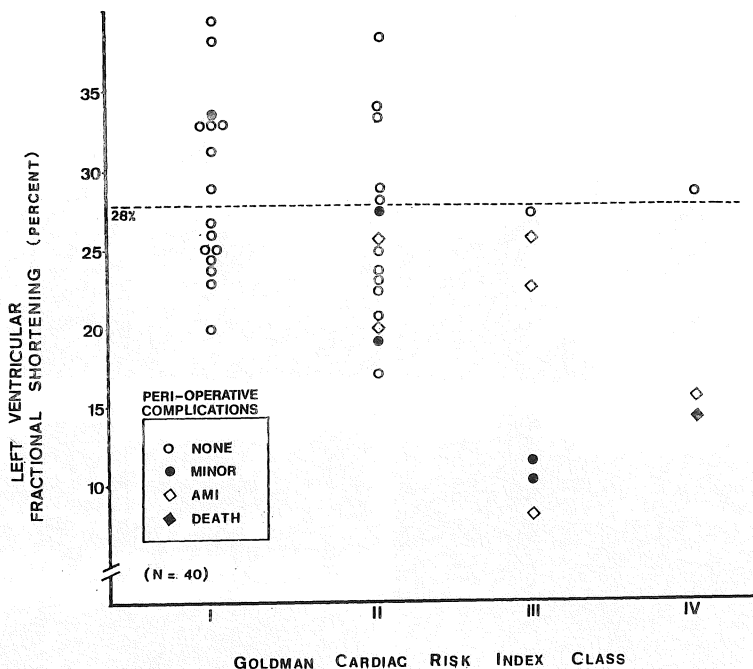


Figure 2: Echocardiographic left ventricular fractional shortening (LVFS) vs. Goldman cardiac risk index (CRI) class among 40 patients who underwent abdominal aortic aneurysm surgery and their peri-operative outcome. The open circle represented uneventful outcome, the dark circle – minor complications, the open diamond – major complication (AMI – acute myocardial infarction), and the dark diamond – cardiac death. The dotted line delineates the LVFS of 28%. Note that almost all but one peri-operative complications occurred among patients with LVFS < 28%, and were distributed in classes II to IV.

Discussion

From our above study of predominantly elderly patients, it can be seen that aortic aneurysm surgery did indeed carry a larger than average risk of peri-operative event. From our data, it is clear that many of the complications (nine of 14, or 64.3%) were cardiac, with two resulting in cardiac deaths (3.8%). It is also obvious that these two deaths were from somewhat emergency surgery following the diagnostic decision of an intra-abdominal catastrophe. Other series in fact reported peri-surgical mortality of around one percent.³ Goldman et al⁴ in their series, found a graded response in incidence of life-threatening complications and cardiac deaths (approaching 78% and 56%, respectively, in CRI class IV).

Our results thus concur with those of Goldman et al⁴ and Jeffrey et al³ in that two distinct categories of risks could be defined, those with very high risk in classes III and IV, and those in the lower risk group in Class I. Class II remained a difficult intermediate group with about 9% incidence of complications. By using another index, i.e. echocardiographic evidence of impaired left ventricular functions (LVFS < 28%), we were able to further identify potential candidates for developing perioperative events. But unfortunately, echocardiography could not be performed with sufficiently consistent quality in all patients because of its inherent acoustic properties of poor penetration of air and lung tissue in this particular group of patients who often had chronic obstructive lung disease and therefore hyperinflated lungs. We could only adequately

measure limited parameters in some three-fourths of the patients. Furthermore, left ventricular dysfunction is a nonspecific global index, especially in those patients who had had previous myocardial infarctions. Also we are aware that using M-mode measurements alone has its limitations and is less than totally accurate when segmental wall motion abnormalities occur. Preferably, estimations using 2D-echographic LV dimensions in one or two axes may yield more accurate results. But as we have explained such evaluation over poor acoustic windows would render this mode quite impractical in many instances. Perhaps with the advent of transesophageal imaging, chest wall acoustic limitations would become unimportant. But this echo modality is still not within reach of most physicians.

In a simple way LVFS < 28% suggests that where there was already substantial myocardial damage, concomitant coronary artery stenoses might lead to severe coronary hypoperfusion and myocardial ischemia during stressful surgical or anaesthetic procedures including that for abdominal aortic surgery. This may be due to the associated substantial myocardial stress resulting from aortic cross-clamping and the major shifts in fluid and electrolytes. When myocardial ischemia occurs, we can expect poorer outcomes because of the greater degree of myocardial jeopardy. We are not sure if acute coronary occlusion from a newly thrombosed atheromatous plaque is the cause of AMI in postsurgical patients. Certainly the homeostatic dynamics in such patients are quite different.¹³ Thus we were not surprised that among the 7 peri-operative infarcted patients who had an earlier echogram, all had LVFS < 28%, four of whom had associated pulmonary oedema and one subsequently died. Poor myocardial function also helped identify those complications associated with minor events i.e. those possibly related to hypovolemic stress. Three patients had oliguric renal failure (two from anastomotic leakage, one from previous chronic renal impairment) and another had a cerebral infarction. Therefore, by combining these two indices, we were able to improve prediction of peri-operative complications to 61.1%. In particular, we were able to subcategorise patients in CRI class II who also had impaired LV function for closer peri-operative observations and monitoring.

It is now known that intensive peri-operative evaluation and treatment can reduce both complications and associated mortality rates.^{14,15} Rao and associates,¹⁴ showed that spectacular morbidity reduction could be obtained from extended ECG, arterial and central venous (including pulmonary wedge pressure) monitoring and aggressive management of their patients over the peri-operative period, i.e., 3–4 days. Such rigorous monitoring helped limit fluctuations which can unduly stress an already compromised myocardium.

Although we have found the Goldman index useful, we are aware that it tended to underestimate the cardiac risks associated with those in the lower CRI classes. For cardiac risk evaluation, some workers have suggested that coronary artery disease has to be actively excluded,¹⁶ since the Goldman index and echocardiography cannot do so definitively. Exercise stress testing whilst quite useful in younger patients, often cannot be adequately performed by an elderly population. Submaximal stress is often not achievable because of inherent poor effort. Further, because of extensive atherosclerosis, patients with peripheral vascular disease are often unable to exercise sufficiently to alter the myocardial oxygen supply-demand equation and develop overt signs and symptoms of ischemia.¹⁷ This, therefore yields equivocal and inconclusive results. Such physical limitations may account for as much as one-third of the patients in question.¹⁸ However, inability to perform two minutes of bicycle exercise in a supine position and to raise the heart rate to above 99 beats/min was an independent important predictor of cardiac complications in noncardiac surgery.¹⁶

Because of these limitations, Boucher et al¹⁷ studied the utility of dipyridamole-thallium-201

imaging in this subset of patients. Dipyridamole increases coronary blood flow several-fold to produce a steal syndrome, ischemic myocardium thus exposed can then be scanned with radionuclide imaging using Thallium-201 for redistribution patterns. This technique allows the clinician to decide whether patients require coronary arteriography and possibly revascularisation prior to noncardiac surgery. Leppo et al¹⁸ reported the prognostic utility for predicting cardiac events in 100 consecutive patients admitted for peripheral vascular surgery. Dipyridamole-thallium scintigraphy was found to be superior to exercise testing or clinical variables in determining peri-operative myocardial infarction and death. However they admitted that even thallium redistribution was 'not a specific marker for such events because surgery can be safely performed in patients with coronary disease when appropriate precautions are taken'. Besides, even when patients opted for coronary arteriography and revascularisation, procedural risks and mortality remain high; in their series, six events out of 11.¹⁸

In conclusion, we believe the Goldman multifactorial index has been well-validated as a useful approach for the global assessment of risk in not only unselected general surgical patients but also in abdominal aortic aneurysm surgical patients. In this subset of high risk patients, additional testing with echocardiography for left ventricular function can usefully supplement the multifactorial index in predicting and forestalling peri-operative cardiac complications. Although, dipyridamole-thallium imaging may be superior, because of its cost and relative scarcity of this facility in Malaysia, its usefulness is quite limited in the logistical sense. Finally, careful pre-operative estimation of cardiac risks can help reduce peri-operative morbidity and mortality by allowing identification of at-risk patients who would need meticulous attention for electrocardiographic, arterial, central venous, and pulmonary wedge pressure monitoring, including preferably intensive care monitoring for at least three to four days post-operatively.

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References

1. Hertzner NR. Fatal myocardial infarction following peripheral vascular operations: a study of 951 patients followed six to 11 years postoperatively. *Cleve Clin Q* 1982; 49:1-11.
2. Steen PA, Tinker JH, Tarhan S. Myocardial reinfarction after anaesthesia and surgery. *JAMA* 1978; 239: 2566-70.
3. Jeffrey CC, Kunsman J, Cullen DJ, Brewster DC. A prospective evaluation of cardiac risk index. *Anaesthesiology* 1983; 58: 462-4.
4. Goldman L, Caldera DL, Nussbaum SR et al. Multifactorial index of cardiac risk in non-cardiac surgical procedures. *N Engl J Med* 1977; 297: 845-50.
5. Dripps RD, Lamont A, Eckenhoff JE. The role of anaesthesia in surgical mortality. *JAMA* 1961; 178: 261-6.
6. New classification of physical status. *Anaesthesiology* 1963; 24: 111.
7. Vacanti CJ, vanHouten RJ, Hill RC. A statistical analysis of the relationship of physical status to postoperative mortality in 68,388 cases. *Anesth Analg (Cleve)* 1970; 49: 564-6.
8. Lewin I, Lerner AG, Green SH et al. Physical class and physiological status in the prediction of operative mortality in the aged sick. *Ann Surg* 1971; 174: 217-31.

9. Devereux RB, Lutas EM, Casale PN et al. Standardization of M-mode echocardiographic left ventricular anatomic measurements. *J Am Coll Cardiol* 1984; 4: 1222-30.
10. Pasternak RC, Braunwald E, Sobel BE. Acute myocardial infarction. In: Braunwald E (ed.) *Heart Disease: A Textbook of Cardiovascular Medicine*. 3rd Edition. WB Saunders Co., Philadelphia. 1988; 38: 1241-2.
11. Goldberg RJ, Gore JM, Alpert JS, Dalen JE. Non-Q-wave myocardial infarction. Recent changes in occurrence and prognosis in a community-wide perspective. *Am Heart J* 1987; 113: 273-7.
12. Corya BC, Rasmussen S, Knoebel SB, Feigenbaum H. M-mode echocardiography in evaluating left ventricular function and surgical risk in patients with coronary artery disease. *Chest* 1977; 72: 181-5.
13. Goldman L, Wolf MA, Braunwald E. General anaesthesia and noncardiac surgery in patients with heart disease. In: Braunwald E (ed.) *Heart Disease: A Textbook of Cardiovascular Medicine*, 3rd Edition. WB Saunders Co, Philadelphia. 1988; 53: 1693-705.
14. Zeldin RA. Assessing cardiac risk in patients who undergo noncardiac surgical procedures. *Can J Surg* 1984; 27: 402-4.
15. Rao TL, Jacobs KH, El-tr AA. Reinfarction following anaesthesia in patients with myocardial infarction. *Anaesthesiology* 1983; 59: 499-505.
16. Gerson MC, Hurst JM, Hertzberg VS et al. Cardiac prognosis in noncardiac geriatric surgery. *Ann Intern Med* 1985; 105: 832-7.
17. Boucher CA, Brewster DC, Darling RC, Okada RD, Strauss HW, Pohost GM. Determination of cardiac risk by dipyridamole-thallium imaging before peripheral vascular surgery. *N Engl J Med* 1985; 312: 389-94.
18. Leppo J, Plaja J, Gionet M, Tumolo J, Paraskos JA, Cutler BS. Noninvasive evaluation of cardiac risk before elective vascular surgery. *J Am Coll Cardiol* 1987; 9: 269-76.