Clinical Reports

A Simple Classification of the Risk in Cardiac Surgery

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A new risk classification for patients undergoing cardiac surgery has been used for the last two years by the anaesthesiologists of the Montreal Heart Institute. The following factors known to be associated with a greater operative morbidity and mortality were selected: (1) poor left ventricular function, (2) congestive heart failure, (3) unstable angina or recent (less than 6 weeks) myocardial infarction, (4) age over 65 years, (5) severe obesity (Body Mass Index > 30), (6) reoperation, (7) emergency surgery, (8) other significant or uncontrolled systemic disturbances. Patients with none of the above factors were classified as normal risks; those presenting with one of those selected factors were classified as increased risks, and those with more than one factor were said to carry a high risk.

In a prospective study of 500 consecutive open-heart surgery patients classified according to this method, we found that the operated population at normal risk (50 per cent of cases) had a mortality of 0.4 per cent, the patient group with increased risk (32 per cent of cases) had a mortality of 3.1 per cent, and the high risk group (18 per cent of cases) had a 12.2 per cent mortality. Furthermore, 50 deaths following open-heart surgery were assessed retrospectively using the classification; 58 per cent of these patients were classified as high risk, 34 per cent had an increased risk, and only eight per cent were found to be in the normal risk group. Thus, this new risk classification has proven to be a reliable and useful tool for preoperative assessment of patients undergoing open-heart surgery and for teaching purposes.

Key Words
RISK: estimate; ANAESTHESIA: cardiovascular; SURGERY: cardiovascular.

Although the American Society of Anesthesiologists (ASA) Classification of Physical Status was not introduced as a method to assess surgical risk,[1] a large proportion of anaesthesiologists use it to that very end in their clinical practice.[2] This is a logical attitude since estimates of physical status have repeatedly been shown to correlate with early and late mortality.[1,3] Goldman pointed out that the ASA Classification is the best predictor of surgical deaths from noncardiac causes; cardiac disease itself is a better predictor of mortality from cardiac causes in noncardiac surgical procedures.[4,5]

Numerous studies have been made in recent years to identify predictive factors for mortality following cardiac surgery.[6–10] Left ventricular dysfunction, congestive heart failure, advanced age, emergency surgery, left main coronary artery stenosis and female sex in coronary surgery were among the factors associated with a higher operative mortality.

Despite these studies, clinical experience shows that preoperative assessment of surgical mortality and morbidity remains difficult and that predictions should be made with caution.[11]

A new preoperative classification of the surgical risk has been developed at the Montreal Heart Institute[12] and has been used routinely by the anaesthesiologists of that institution for over two and a half years. The object of the present study was to prospectively evaluate the ability of the new

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TABLE I Risk Factors and Risk Classification for Open-Heart Surgery

Risk Factors:
1 Poor left ventricular function (ejection fraction <0.3)
2 Unstable angina or recent myocardial infarction
3 Evidence of heart failure
4 Age over 65 years
5 Severe obesity (Body Mass Index >30).
6 Emergency surgery
7 Reoperation
8 Other significant and uncontrolled systemic disturbances

Patient classification:
Normal risk: Patient with none of above factors
Increased risk: Patient with one of above factors
High risk: Patient with more than one of above factors

TABLE II Surgical Procedures in 500 Consecutive Patients Assessed by the New Risk Classification

	Patients	
Surgical Procedures	*No.*	*%*
Congenital defect repair	17	3.4
Coronary surgery	350	70.0
Coronary bypass	320	64.0
Left ventricular aneurysm	30	6.0
Valve surgery	113	22.6
Open mitral commissurotomy	11	2.2
Mitral valve replacement	45	9.0
Aortic valve replacement	38	7.6
Multiple valve surgery	19	3.8
Combined valvular and coronary surgery	20	4.0
TOTAL	500	100.0

method to predict early mortality (death during the operation or subsequent death in the hospital).

Material and Methods

Preoperative risk classification of the Montreal Heart Institute

The various factors shown to be associated with a greater surgical mortality and morbidity in previous studies were selected for this classification (Table I). Poor left ventricular function was defined by an ejection fraction less than 0.3 or by an end-diastolic left ventricular pressure above 18 torr at rest.

Unstable angina included crescendo angina during the month prior to surgery, persistent angina despite intravenous dilator therapy, nocturnal or rest anginal pains and subendocardial infarction. Many patients with subendocardial infarction present with persistent anginal pains despite aggressive medical therapy; since a large proportion of these cases evolve towards a transmural infarction, early coronary surgery is often considered. The risk in those cases is equivalent to that of unstable angina.[13] Recent (less than six weeks) transmural infarction has been combined together with unstable angina as a single factor because both conditions reflect an evolving coronary process. Normally, patients with a recent myocardial infarction are not considered as candidates to early surgery. Those who are operated on are patients who present with severe complications of their infarction (acute mitral insufficiency from ruptured chordae tendinae or ruptured ventricular septum). These patients present with many risk factors (recent infarction, heart failure, emergency procedures). Recently we have operated with success on a few patients (not included in the present study) with a recent myocardial infarct who presented with severe persistent angina despite optimal medical therapy (unstable angina, threatening extension). Those patients were classified as high risks (2 factors: unstable angina and recent infarction).

Obesity was considered severe enough to be a major risk factor when the Body Mass Index (weight (kg)/height^2 (m.)) was greater than 30.[14] Various other severe and uncontrolled systemic disturbances [renal insufficiency, pulmonary artery hypertension (systolic pressure > 50 mmHg), history of recurrent severe arrhythmias, cachexia, etc.] were also taken into account and grouped as a single risk factor.

Normal risk patients were defined as those with none of the selected risk factors; patients presenting with one of the factors were classified as increased risks, whereas those with more than one factor were defined as high risk patients.

A check-list of the risk factors and the new risk classification were printed on the anaesthetic chart. The preoperative risk evaluation of each patient was made by the anaesthesiologists at the time of the preoperative visit.

A prospective evaluation of the classification was made in 500 consecutive patients undergoing open-heart surgery who were classified according to the

TABLE III Incidence of Risk Factors in 500 Consecutive Patients

	Coronary Surgery (370 Patients)		*Other Surgical Procedures (130 Patients)*	
Risk factors	*No.*	*%*	*No.*	*%*
Unstable angina or recent M.I.	78	21	0	0
Poor left ventricular function	34	9.1	7	5.4
Age >65	37	10	15	11.5
Severe obesity	36	9.7	15	11.5
Reoperation	21	5.7	15	11.5
Heart failure	5	1.3	7	5.4
Emergency surgery	10	2.7	2	1.5
Other significant and uncontrolled systemic factors	22	5.9	32	24.4

TABLE IV Other Significant and Uncontrolled Systemic Disturbances

	Coronary Surgery (370 Patients)		*Other Surgical Procedures (130 Patients)*	
Risk factors	*No.*	*%*	*No.*	*%*
Pulmonary hypertension	4	1.1	19	14.6
Chronic lung disease	7	1.8	3	2.3
Chronic renal failure	4	1.1	2	1.5
Poor hepatic function	1	0.3	1	0.7
Cerebro-vascular insufficiency	2	0.5	—	
Severe arterial hypertension	2	0.5	—	
Severe arrhythmias	2	0.5	—	
Active endocarditis	—		4	3.0
Poor nutritional status	—		3	2.3
TOTAL	22	5.9	32	24.4

new method in 1980. The surgical procedures performed in this series of patients are described in Table II.

During the period of the study the anaesthetic and surgical management of the patients did not undergo significant changes.

Since the population of patients with coronary disease was likely to be different from that of patients without coronary disease, the 370 patients who underwent coronary surgery (isolated coronary bypass procedures, resection of left ventricular aneurysm with or without coronary bypass, combined coronary and valvular surgery) were assessed separately to define their risk profile and their predictors of mortality as compared to patients submitted to other open-heart procedures.

TABLE V Early Mortality According to Operative Risk Classification in 500 Consecutive Patients

Risk Classification	*No. of Patients*	*No. of Early Deaths*	*(%)*	
Normal	251	1	0.4	$p < 0.0001$*
Increased	159	5	3.1	
High	90	11	12.2	
TOTAL	500	17	3.4	

*The difference between the three groups is highly significant.

The influence of sex, of left main coronary disease and of complex surgical procedures on early mortality was also analyzed.

In addition a retrospective evaluation of the method was made in 50 patients who died early following cardiac surgery using the criteria of the present classification method.

Analysis of the data was performed with the Chi-square test. A probability (p) value of 0.05 or less was considered to indicate statistical significance.

Results

Incidence of the various risk factors in our population of patients

The incidence of the various risk factors in our total series of 500 cases is listed in Table III under two headings depending on whether the patient underwent coronary surgery or another surgical procedure.

Unstable angina occurred only in the group of patients who underwent coronary surgery. Poor ventricular function and emergency surgery were also seen more often in this group of patients as compared to patients submitted to other surgical procedures. On the other hand, reoperation and congestive heart failure were more frequent among patients submitted to noncoronary procedures (mostly valve surgery). While both groups were similar in regard to the incidence of older patients and severe obesity, we recorded a much higher incidence of 'Other Severe and Uncontrolled Disturbances' among patients submitted to noncoronary surgery. These various other factors are listed in

Table IV; none of the nine recorded systemic disturbances occurred frequently in either group except for pulmonary hypertension which was present in 14 per cent of patients who underwent noncoronary surgery (valve surgery in all cases).

Preoperative risk evaluation versus operative mortality

Table V relates early mortality to the preoperative risk evaluation of the patients. Half of the 500 patients were in the normal risk group; the only death in this group (mortality rate 0.4 per cent) occurred in a patient who suffered irreversible brain damage during surgery, most probably as a result of air embolism. One hundred and fifty nine patients (32 per cent) presented with one risk factor and were classified as increased risk patients: the mortality in this group was 3.1 per cent (5 deaths). There were 90 patients (18 per cent) classified as high risks (more than one factor); early mortality among them was 12.2 per cent (11 deaths). The difference in mortality between the three groups is significant ($p < 0.0001$). The overall early mortality of this series was 3.4 per cent (17 deaths/500 patients).

Surgical mortality in men versus women in patients with coronary disease (Table VI)

The population of patients who underwent isolated coronary bypass procedures included 260 men and 60 women. The operative mortality was higher in women (3 deaths/60 patients = 5 per cent) than in men (4 deaths/260 patients = 1.5 per cent); the difference was not statistically significant. As a group, women with coronary disease presented with more risk factors than men: 25 per cent of the women belonged to the high risk category while 10.8 per cent of the men were classified as high risks ($p < 0.01$). The three deaths recorded in women occurred in patients classified as high risks. Thus, in our series of patients operated on for coronary disease: (1) there were more men than women, (2) women were generally sicker than men since a higher proportion of them belonged to the high risk class, (3) surgical mortality was higher in women than in men, (4) our classification could predict these women who were at greater risk of surgical mortality since the three recorded deaths occurred in patients classified as high risks.

TABLE VI Early Mortality Following Isolated Coronary Surgery in 320 Patients; Relationship to Preoperative Risk Evaluation and Sex

Risk Classification	Men			Women		
	No.	*Death*	*%*	*No.*	*Death*	*%*
Normal	150	1	0.6	24	0	—
Increased	82	2	2.4	21	0	—
High	28	1	3.5	15	3	20
TOTAL	260	4	1.5	60	3	5

Left main coronary artery stenosis

Our population of 320 patients who underwent isolated coronary bypass procedures included 44 patients with a significant (>50 per cent) left main coronary artery stenosis (Table VII). The mortality rate in this group was 4.5 per cent as compared to a rate of 1.8 per cent in patients without left main stenosis ($p > 0.05$). No deaths were recorded in the 18 patients with left main stenosis who were classified as normal risks, one death was recorded in the 15 patients classified as increased risks (6.6 per cent mortality) and one death occurred in the eleven patients classified as high risks (9.1 per cent mortality rate). Twenty-five per cent of the patients with a left main coronary artery stenosis belonged to the high risk class as compared to a 11.5 per cent incidence in patients without a left main stenosis.

Complexity of the surgical procedure (Table VIII)

The highest mortality in our series occurred in the group of patients submitted to more complex surgical procedures (multiple valve replacement, combined coronary and valve surgery, resection of left ventricular aneurysm with coronary bypass). The mortality in this group was 8.7 per cent (6 deaths/69 patients) as compared to 2.5 per cent among the 431 patients who underwent single surgical procedures ($p < 0.01$). It should be noted that in the complex procedures group, no deaths were recorded among the 17 patients classified as normal risks. The mortality was significantly higher ($p < 0.01$) among high risk patients submitted to multiple procedures as compared to that of the high risk patients undergoing single procedures (17.6 vs 9.6 per cent). Forty-one per cent of the patients who underwent complex surgical procedures belonged to the high risk class as compared to an incidence of

TABLE VII Early Mortality Following Isolated Coronary Surgery in 320 Patients; Relationship to Left Main Coronary Artery Disease

Risk Classification	*Without Left Main Stenosis*			*With Left Main Stenosis*		
	No. of pts	*Deaths*	*%*	*No. of pts*	*Deaths*	*%*
Normal	156	1	0.6	18	0	—
Increased	88	1	1.1	15	1	6.6
High	32	3	9.3	11	1	9.1
TOTAL	276	5	1.8	44	2	4.5

TABLE VIII Early Mortality by Risk Classification and Type of Surgical Procedures

	Normal Risk			*Increased Risk*			*High Risk*			*Total*			
	Patients	*Deaths*	*%*	*Patients*	*Deaths*	*%*	*Patients*	*Deaths*	*%*	*Patients*	*Deaths*	*%*	
Single procedures	234	1	0.4	135	4	3.0	62	6	9.7	431	11	2.6	*
Multiple procedures	17	0	—	24	1	4.2	28	5	17.9	69	6	8.7	*
TOTAL	251	1	0.4	159	5	3.1	90	11	12.2	500	17	3.4	

*: $p < 0.01$.

SINGLE PROCEDURES INCLUDE: coronary bypass, open mitral commissurotomy, mitral or aortic valve replacement, congenital surgery.

MULTIPLE PROCEDURES INCLUDE: multiple valve replacement, combined coronary and valvular surgery, resection of left ventricular aneurysm with coronary bypass.

Early mortality: death during the operation or subsequent death in the hospital.

TABLE IX Risk Profile and Risk Factors Among 50 Early Deaths Following Heart Surgery Studied Retrospectively

	Classification		
	Normal	*Increased*	*High*
No. of patients (%)	4 (8%)	17 (34%)	29 (58%)
No. of risk factors			
Age >65	—	5	8
Emergency surgery	—	0	12
Reoperation	—	2	9
Unstable angina	—	3	7
Poor left ventricular function	—	2	8
Severe obesity	—	2	6
Heart failure	—	0	6
Other	—	3	6

14 per cent in the patients submitted to a single procedure.

Retrospective study of 50 surgical deaths

The classification was used in a retrospective review of 50 cases of surgical deaths following cardiac surgery (Table IX). None of our selected risk factors were found to be present (normal risk) in four (8 per cent) of the fifty cases. One factor (increased risk) was recorded in each of 17 patients (34 per cent of the cases). More than one risk factor (high risk) were present in the remaining 29 patients (58 per cent of the total). All our risk factors were found to be present at least twice in this series either as an isolated factor or in association with other factors. The most frequently recorded factors were old age, emergency surgery and reoperation.

Discussion

The ASA Physical Status Classification is extensively used as a scale of risk in most types of surgery. Its application to cardiac surgery is difficult due to the definitions of its classes III and IV. In cardiac surgery the surgical indication is based in a large proportion of cases upon the presence of a significant incapacity. Class III which is defined as a severe but not incapacitating systemic disease does not apply to these patients. Class IV refers to a severe and incapacitating systemic disease which is a constant threat to life. The first part of this

definition (presence of an incapacitating disease) would apply to most of our patients. The second part (presence of a constant threat to life) implies a need for urgent or semi-urgent measures; this does not necessarily apply to the numerous patients with an incapacitating disease who undergo elective surgical procedures after waiting weeks or months for their admission to the hospital.

Furthermore, classes III and IV of the ASA classification project a poor prognosis image. Yet numerous cardiac lesions which produce severe incapacity are operated upon at minimal risk. For example the operative mortality of open-mitral valve commissurotomies is close to zero in many institutions despite the presence of severe incapacity. Similarly, patients with stable angina who are otherwise healthy and have a good ventricular function undergo coronary surgery at low surgical risk (one to two per cent mortality in most centres).

Many factors (age, heart failure, poor left ventricular function, emergency procedures, etc.) have been shown to correlate with increased mortality in cardiac surgery,[6–10] but we are not aware of a simple, unified, satisfactory method integrating those factors to clinically assess the risk in cardiac surgery.

Our objective was to devise a simple method of preoperative risk evaluation of patients undergoing cardiac surgery. For this reason we did not try to establish relative values for each of our risk factors though we were well aware that some of them (e.g. heart failure) might be associated with a higher mortality than others. Thus the classification was simply based on the absence or presence of one, or more than one, risk factor preoperatively.

Severe obesity is a well known factor of morbidity and mortality in surgery.[14] This is why it was included in our list of factors, even though it is usually not mentioned as a major risk factor in cardiac surgery. In our prospective series, one of the 500 patients with a Body Mass Index of 31 died of a massive pulmonary embolus on the 4th postoperative day.

In patients undergoing isolated CABG surgery a higher mortality was found in women as compared to men. These results, though not significant in our small series are in agreement with other reported series.[7–9] Our classification also disclosed that a greater proportion of women with coronary disease presents with a high risk as compared to men. The method predicted the risk accurately since all three deaths among women occurred in the high risk patients.

Our results also indicate a higher mortality in patients presenting with a significant left main coronary artery stenosis. While not statistically significant these results are in agreement with those of others.[6,7,10]

We share the experience of numerous groups that with careful surgical and anaesthetic management many of these patients can be operated on with a very low mortality. No deaths occurred in 18 patients with left main lesions who were classified as normal risks. However, experience shows that more of those patients are operated upon as emergency procedures because of complications of coronary angiography (severe arrhythmias, persistent severe anginal pain), that more of them present with unstable angina, recent infarction, obesity etc. In our study, a higher proportion of sicker patients was present preoperatively in the population of patients with left main coronary artery stenosis. We found more than twice as many high risk patients in the left main stenosis group than in patients without left main stenosis (25 vs 11.5 per cent).

The highest early mortality in this series was recorded in patients who underwent more complex and multiple surgical procedures. Overall, a larger ratio (41 per cent) of these patients belonged to the high risk group as compared to patients who were submitted to single procedures. Again our classification was able to predict the mortality accurately in these patients with complex procedures: while there were no deaths among the normal-risk patients, surgical mortality was 4.2 per cent in patients with one risk factor and 17.9 per cent in those with more than one risk factor.

A higher than expected incidence of pulmonary hypertension was found in our patients. Retrospectively, this could have been considered as a major risk factor and included as a separate factor in our list, since in patients with valvular disease it is associated with increased morbidity and mortality.

Our results also indicate that early mortality in patients classified as normal risks is significantly lower than we thought when we first published our method.[12]

With regard to early surgical mortality in cardiac surgery, it is often said that mortality varies from

centre to centre,[15] is low in many institutions,[16] is in part determined by the expertise of the medical and paramedical team, and that technical errors are responsible for most early deaths. Although this may well be true, our results indicate that the preoperative physical condition of the patients is a major determinant of the overall surgical results. Patient selection for surgery in various institutions may thus be responsible, at least partly, for the discrepancies in surgical mortality reported in the literature.

Urzua *et al.* have recently shown[17] that 'clinical judgment, that much maligned attribute, can serve as an estimate of perioperative risk which may be just as reliable as more objective indices of risk'.[18] While not denying the value of clinical expertise, we believe that objective and well defined criteria improve the accuracy and quality of the decision-making process of the experienced clinician.

Our own experience has shown this classification to be a useful clinical tool and, at the same time, it has been a helpful teaching instrument for the residents in our department.

It will be of interest to assess this method in regard to significant postoperative complications in patients surviving open-heart surgery.

Conclusion

The preoperative risk classification of patients undergoing open-heart surgery at the Montreal Heart Institute has proven to be a reliable method of identifying patients at increased risk of perioperative mortality. A close correlation has been shown between the preoperative risk evaluation and early mortality following cardiac surgery.

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Résumé

Une nouvelle classification du risque opératoire est en usage à l'Institut de Cardiologie de Montréal depuis deux ans. Cette classification est basée sur la présence ou l'absence pré-opératoire des facteurs suivants: mauvaise fonction ventriculaire, signes cliniques ou radiologiques d'insuffisance cardiaque, angine instable ou infarctus récent, âge supérieur à 65 ans, obésité importante (i.e. Index de Masse Corporelle supérieur à 30), réintervention, chirurgie effectuée en urgence, autre atteinte systémique importante ou non contrôlée. Les malades qui ne présentaient aucun de ces facteurs de risque avant l'intervention étaient classifiés dans le groupe du risque habituel; ceux qui présentaient un de ces facteurs étaient classifiés dans celui du risque accru et ceux qui présentaient plus qu'un de ces facteurs étaient définis comme des risques élevés.

La classification a été évaluée prospectivement chez cinq cent patients consécutifs soumis à une chirurgie à cœur-ouvert. Un malade sur deux appartenait à la catégorie du risque habituel; la mortalité dans ce groupe a été de 0.4 pour cent. Une mortalité de 3.1 pour cent a été enregistrée chez les malades appartenant au groupe du risque accru (34 pour cent de nos 500 patients). Chez les patients répondant aux critères du risque élevé (18 pour cent des cas) nous avons observé une mortalité de 12.2 pour cent.

Cinquante malades décédés après une chirurgie à cœur-ouvert ont été classifiés de façon rétrospective avec notre classification. Huit pour cent de ces malades appartenaient à la classe du risque habituel, 34 pour cent à celle du risque accru et 58 pour cent à celle du risque élevé.

La nouvelle classification s'est donc avérée utile et fiable pour l'évaluation pré-opératoire du risque en chirurgie cardiaque et pour l'enseignement de nos résidents.