Clinical and Angiographic Predictors of Operative Mortality from the Collaborative Study in Coronary Artery Surgery (CASS)

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SUMMARY Fifteen institutions participating in the Collaborative Study in Coronary Artery Surgery (CASS) have performed isolated coronary artery bypass surgery upon 6630 patients (1061 women and 5569 men) for coronary artery disease. The overall operative mortality (OM) was 2.3% (range 0.3–6.4%). Mortality increased with age, from 0 in the group 20–29 years old to 7.9% in the group 70 years and older. OM was higher for women in each age group, ranging from 2.8% for ages 30–39 years to 12.3% for age 70 years and older (0.8% and 5.8% for men). Clinical manifestations of congestive heart failure were associated with increased OM. Mortality was 1.4% in one-vessel, 2.1% in two-vessel and 2.8% in three-vessel disease (diameter narrowing ≥70%). Among 1019 patients with left main coronary artery (LMCA) stenosis, OM ranged from 1.6% in patients with mild stenosis and a right-dominant system to 25% in patients with severe (≥90%) stenosis and left dominance. OM varied with ejection fraction (EF) (1.9% for EF ≥50% to 6.7% for EF < 19%) and left ventricular wall motion score (1.7% for least abnormal to 9.1% for most abnormal). For elective surgery, OM was 1.7%, for urgent surgery 3.5%, and for emergency surgery 10.8%. Mortality was 40.0% among 30 patients with severe LMCA stenosis who underwent emergency revascularization. Advanced age, female sex, symptoms of heart failure, LMCA stenosis, impaired left ventricular function and nonelective surgery are associated with a higher OM. These factors should be considered in the selection of patients for coronary artery surgery.

SINCE THE INTRODUCTION of coronary artery bypass graft (CABG) surgery over 10 years ago, there has been a progressive decline in operative mortality (OM). In the early years of bypass surgery, OM was 2–12%. Now, OMs of 1% or less are usually reported, although these very low figures usually refer to selected groups of patients. Although not a great deal of information is available, because of the reluctance to report less-than-excellent results, OM probably varies considerably among institutions. The present report describes the risks for CABG surgery performed at 15 major medical centers in the United States and Canada. As a large collaborative study, it reflects the practice of coronary surgery in these countries during the last half of the 1970s.

The Collaborative Study in Coronary Artery Surgery (CASS) is a multiinstitutional research program consisting of a randomized trial of the medical and surgical treatment of coronary artery disease (CAD) and a large registry that lists all patients who underwent diagnostic evaluation, including coronary arteriography, for the presence of suspected CAD between August 1975 and December 1978. CABG surgery has been performed on 6630 patients at the participating institutions. The extensive data file of CASS contains detailed information on the historical, physical and angiographic characteristics of these patients. The purpose of this study is to identify the clinical and angiographic characteristics associated with OM in this large series. Statistical methods are limited to univariate techniques in this initial report. The results of this analysis should be useful when balancing the potential benefits and risks of surgical treatment for patients with CAD.

Materials and Methods

Between August 1975 and December 1978, 19,907 patients from 15 institutions were entered into the CASS registry. A randomized trial of 390 medically treated and 390 surgically treated patients is a subset of this total registry. During the period of registration, patients who underwent diagnostic coronary arteriography for suspected CAD who did not have other types of cardiac disease and who gave informed consent were entered in the CASS study.

Clinically important CAD was defined as ≥70% diameter stenosis in at least one major coronary artery segment or ≥50% stenosis of the left main coronary artery (LMCA). By this definition, 12,079 men and 2278 women in the registry had clinically important CAD, 1182 men and 715 women had minimal or moderate CAD (<70% stenosis), and 1685 men and 1847 women had normal coronary arteries. Angiographic data were incomplete in 121 cases. Among the registry group, 6630 patients have had CABG surgery and constitute the study population. Another 509 patients had one or more additional procedures for complications of CAD at the time of bypass surgery. These procedures were mitral valve replacement (38
patients), aneurysmectomy or ventricular plication (357 patients) and other cardiac surgery (161 patients). Only the results of initial isolated CABG surgery are included in this report.

Each patient was interviewed at the time of hospitalization for coronary angiography by the responsible physician or by carefully trained data technicians. The baseline historical, physical and laboratory data, and the results of coronary arteriography and left ventriculography were collected and recorded on data forms. The details of the surgery and any complications of the diagnostic or surgical procedures were also recorded.

The severity of angina was graded according to the classification of the Canadian Cardiovascular Society (CCS). Categories were added for patients who experienced angina that was unrelated to exercise and for those with unstable angina (defined as onset of symptoms within 2 months of entry or a change in the pattern of preexisting angina).

A history of myocardial infarction was recorded if the patient had been informed by a physician of a definite myocardial infarct for which hospitalization exceeded 5 days.

Death was defined as related to surgery if it occurred after the onset of the surgical procedure and before discharge from the hospital.

Data from each site were transmitted to the data coordinating center by computer terminals (Datapoint Model 110) programmed to detect errors. This method of automated data transmission has resulted in a very low error rate in data entry.

Numerous clinical, laboratory and angiographic variables were screened for their importance in the prediction of OM. Initial characteristics were selected for their relationship to recognized cardiovascular risk factors, severity and extent of CAD and possible relationship to left ventricular (LV) dysfunction. Other factors that might be expected to relate to increased OM, such as advanced age and the presence of chronic pulmonary disease, were also considered. The total group of characteristics as related to OM was subjected to univariate analysis and those found to be statistically significant (chi-square, \( p < 0.05 \)) were selected for further analysis.

All clinical variables recorded on CASS patients that might be related to LV failure were evaluated because of the known relationship of poor LV function to OM. The clinical characteristics predictive of OM are listed in Table 1. In addition, a congestive heart failure (CHF) score was developed that included the number of positive responses to a history of CHF, use of digitalis, use of diuretics, and the presence of pulmonary rales on the admission physical examination (possible score 0–4).

### Angiographic Analysis

Selective coronary arteriography was carried out by either the brachial or femoral technique. Multiple views of each vessel were obtained. By July 1976, two-thirds of the participating angiographic laboratories used hemiaxial views routinely (more than 75% of cases) to gain improved definition of the proximal portion of the left coronary artery system. Hemiaxial views were used occasionally in the remaining laboratories during the course of this study. The results of the coronary angiograms were recorded on a specially designed and carefully tested form, which divided the coronary vessels into 27 segments and identified dominance and the presence and source of collateral vessels. The morphology of the obstructing lesion and the distal vessel were recorded. Coronary stenoses were read as the percent narrowing of the maximal luminal diameter for each segment. Several training sessions were held for CASS angiographers in an effort to assure uniformity of reporting. These training sessions were also directed at improving techniques of coronary arteriography, film processing and other details of cardiac imaging. Regular assessment of the quality of cardiac angiography was carried out by four control laboratories. All complications of angiographic procedures were recorded and have been reported.

The LV end-diastolic pressure (LVEDP) was
measured before angiography. LV cineangiography was carried out in the 30° right anterior oblique (RAO) view in all studies and in many instances in the 60° left anterior oblique view as well. For the purpose of this report, only the analyses of the RAO view were used. The RAO ventriculogram was divided into five segments: anterobasal, anterolateral, apical, diaphragmatic and posterobasal. The systolic motion of each of these segments was recorded and scored numerically: normal — 1; moderate hypokinesia — 2; severe hypokinesia — 3; akinesia — 4; and dyskinesia — 5. When a segment was believed to represent a true ventricular aneurysm it was assigned a score of 6. A completely normal left ventricle was therefore scored as 5. It was theoretically possible to record a score of 30. The wall motion score was available in 6365 patients. The LV ejection fraction (EF) determined by the length-area method for single-plane cineangiograms and reported as a percent was available for 5024 patients.

A myocardial jeopardy index was developed to relate the functional status of LV wall segments to the presence or absence of proximal stenosis (≥ 70%) in the major artery that supplied those segments. LV wall segments that move normally or are hypokinetic are assumed to be composed of viable myocardial tissue and are at risk of infarction if the artery supplying the segments is stenotic. Akine tic or dyskinetic regions are assumed to represent nonfunctional tissue, which is therefore not at risk of infarction. In the RAO projection, the anterobasal, anterolateral and apical segments are taken as one unit that is assumed to be supplied by the left anterior descending coronary artery. The diaphragmatic and posterobasal segments constitute a second unit that is assumed to be supplied by the right coronary artery in a right-dominant system or by the circumflex artery in a left-dominant system. If, for example, the anterior unit contracts normally and there is a 70% stenosis of the left anterior descending artery, one unit of myocardium is at risk and one point is scored. By considering the segmental motion and degree of stenosis for each of two units, a score of from 0–2 is obtained. In the case of LMCA stenosis in a left-dominant system, where both the anterior and inferior myocardial units are functional, the maximum of two points is scored because both units are at risk of infarction.

Surgical Priority

The priority of surgery was assigned by the surgeon at the time of operation. In most cases, emergency procedures were performed on the day of coronary arteriography. Urgent procedures were usually performed 1–6 days after arteriography when delay of operation was judged to be unwarranted. Procedures were otherwise categorized as elective.

Statistical Analysis

Patient characteristics were screened univariately using the chi-square statistic. A relative risk (RR) was computed for characteristics found to be significant at the 0.05 level. The RR is the ratio of the OM for the group of patients with a characteristic to the OM for the group without the characteristic. It is, therefore, an index of the association of a characteristic and OM. A RR greater than 1 indicates the particular characteristic is associated with an increased OM. The extent of the risk for various characteristics may be estimated by examining the magnitude of the respective RRs. The chi-square test and, in some cases, Fisher’s exact test were used to compare values between groups. A chi-square test for trend was applied in the instance of ordered variables.

Analysis of Data by Site

Fifteen sites contributed data for this analysis. As expected, OM varied between sites. OM also varied between individual sites and the group as a whole. We report OM by site, realizing that differences in OM may be due in part to differences in patient selection at each site. It is the CASS policy to preserve the anonymity of individual site performance. To present the data within these guidelines, we have displayed surgical mortality by percent, omitted the number of patients operated at each site, and ranked institutions in order of mortality rate.

Results

During the study, 6630 patients underwent CABG surgery for the treatment of CAD after registration in CASS. The OM was 2.3%. OM in the 15 hospitals varied from 0.3–6.4% (fig. 1). In another group of 509 patients who had additional cardiac procedures, OM was 8.3% for aneurysmectomy, 7.6% for plication and 23.7% for mitral valve replacement. The 20 clinical and angiographic characteristics univariately predictive of increased OM are listed in table 1.

Age and Sex

Surgery was performed on 5569 men and 1061 women. The OM was 1.9% for men and 4.5% for women (p < 0.001). The OM by age and sex is presented in figure 2. OM was significantly higher for women ages 40–59 years. OM was not significantly different between men and women older than age 60 years. The trend toward higher mortality with increasing age was significant for men, but did not reach significance for women (chi-square for trend, p < 0.001 for men).

Risk Factors for CAD

Some risk factors for CAD were examined for possible association with OM. Hypertension, diabetes, elevated serum cholesterol (> 250 mg/dl), cigarette smoking, and family history of CAD were included in the analysis. None of these factors was related to OM.

Previous Myocardial Infarction

There were 3497 patients who had a history of a myocardial infarction before the time of their registration in CASS. For this group, the OM was 2.4% (p > 0.05). Previous myocardial infarction as deter-
mined from the patient history does not increase the risk of CABG surgery.

Angina Pectoris

The presence and severity of angina pectoris were evaluated for association with OM. The results are shown in table 2. Patients with CCS class I angina had an OM of 2.4%, while those with class IV angina had an OM of 4.3%. The trend toward increased OM in patients with more severe functional limitation is significant (chi-square for trend, \( p < 0.001 \)). Patients with an unstable chest pain syndrome had a small but significant \( (p < 0.001) \) increase in OM. There was no increased risk associated with angina unrelated to exertion.

Congestive Heart Failure

Clinical characteristics related to LV failure were examined for their influence on OM. The results of this analysis are presented in table 3. OM ranged from 1.6% with a CHF score of 0 to 10.0% in the 40 patients with a score of 4 (chi-square for trend, \( p < 0.001 \)). The single characteristic of pulmonary rales, present in 199 patients, was associated with an OM of 7.5%. Cardiac enlargement on the chest roentgenogram or a cardiothoracic ratio \( \geq 0.50 \) were associated with OM of 3.5% and 3.2%, respectively.

Angiographic Variables

The relationship of EF to OM is shown in table 4. The OM was 1.9% for 3913 patients with an EF \( \geq 50\% \) and tended to increase in patients with an EF \( \leq 50\% \), but this trend was not significant. For those with an abnormal EF, the OM varied from 1.7–6.7%. It should be noted that only 107 patients with an EF \( \leq 30\% \) underwent CABG surgery.

The relationship of the LV wall motion score as derived from the qualitative assessment of the motion

**TABLE 2. Angina Pectoris and Operative Mortality**

<table>
<thead>
<tr>
<th>Angina class</th>
<th>n</th>
<th>Operative mortality (%)</th>
<th>Relative risk</th>
<th>Chi-square test</th>
</tr>
</thead>
<tbody>
<tr>
<td>No angina</td>
<td>477</td>
<td>1.3</td>
<td>0.53</td>
<td>NS</td>
</tr>
<tr>
<td>Class I</td>
<td>248</td>
<td>2.4</td>
<td>1.05</td>
<td></td>
</tr>
<tr>
<td>Class II</td>
<td>1390</td>
<td>1.4</td>
<td>0.54</td>
<td>( p &lt; 0.001^* )</td>
</tr>
<tr>
<td>Class III</td>
<td>2541</td>
<td>1.8</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>Class IV</td>
<td>1373</td>
<td>4.3</td>
<td>2.40</td>
<td></td>
</tr>
<tr>
<td>Unrelated to exertion</td>
<td>600</td>
<td>2.7</td>
<td>1.17</td>
<td>NS</td>
</tr>
<tr>
<td>Unstable angina</td>
<td>2748</td>
<td>3.5</td>
<td>2.32</td>
<td>( p &lt; 0.001 )</td>
</tr>
</tbody>
</table>

The severity of angina was rated according to the classifications of the Canadian Cardiovascular Society.

\(^*\)Chi-square test for trend applied to groups in order of angina classes I–IV.
of five segments of the RAO ventriculogram to OM is also shown in table 4. There is a significant (p < 0.01) increase in OM as the wall motion score increases. When the wall motion score was ≥ 20 the OM was 9.1%. Only 22 patients with a score of ≥ 20 were subjected to CABG surgery without an additional procedure, such as aneurysmectomy.

The relationship of LVEDP to OM is presented in table 4. When the LVEDP was normal, the OM was 1.6% and when ≥ 24 mm Hg, the OM was 5.9%. This trend of increasing OM with increasing LVEDP was highly significant (p < 0.001).

The relationship of coronary anatomy to OM has been reported. Often, attention has been focused on the presence of left main coronary disease (LMCD). Coronary disease has usually been subdivided into one-, two- and three-vessel involvement. The large number of patients in this study permits a more detailed analysis of coronary anatomy, LV function and OM. The OM for major subsets of patients is presented in tables 5 and 6. When patients were classified into one-, two- and three-vessel disease, the OM was 1.4%, 2.1% and 2.8% respectively. Patients with LMCD are included in this analysis. LMCD with right-dominant or balanced circulation is considered two-vessel disease and LMCD with left-dominant circulation is considered three-vessel disease. When patients with left main coronary artery stenosis ≥ 50% were excluded, the overall OM was 2.1% (table 5). Left main coronary artery stenosis of 50–74% does not increase OM. When LMCD becomes severe (≥ 90%),
the OM increases more than threefold to 7.9%. The trend is significant (p < 0.001).

OM was inversely related to the myocardial jeopardy index (table 5). When surgery was performed on patients who had akinetic or dyskinetic segments supplied by stenotic vessels (index 0), the OM was 3.8%. In patients with viable anterior and inferior walls supplied by stenotic vessels (index 2), the OM was 1.9% (chi-square for trend, p < 0.01).

The relationship between the severity of LMCD, the dominant circulation, and operative risk is shown in table 6. When LMCD is not severe (50–74%), OM is low and dominance is not important (Fisher's exact test, p = 0.34). When LMCD is severe (≥ 90%), OM with right-dominant circulation is 5.7% and with left-dominant circulation is 25.0% (Fisher's exact test, p < 0.05). Fortunately, the combination of severe LMCA stenosis and left dominant circulation is uncommon.

At the time of surgery each operative procedure was given a priority of elective, urgent or emergency. The majority of procedures (78.7%) were elective, 16.6% were urgent, 3.2% were classified emergency and 1.5% were not classified. The OM for these categories was 1.7%, 3.5%, and 10.8%, respectively (chi-square for trend, p < 0.001). Because many patients with LMCD receive emergency surgery, we examined the relationship between surgical priority, the presence and severity of LMCD, and OM (fig. 3). Emergency surgery was associated with increased risk in all groups. The OM for emergency surgery was 5.1% in the absence of significant LMCD and 40.0% in the 30 patients who had severe LMCD (stenosis ≥ 90%) (p < 0.001). Patients with LMCD ≥ 90% operated upon electively or urgently had an OM of 4.4% and 2.2%, respectively.

Table 6. Left Main Coronary Artery Stenosis and Operative Mortality

<table>
<thead>
<tr>
<th>Stenosis (%)</th>
<th>n</th>
<th>Operative mortality (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50–74</td>
<td>432</td>
<td>1.6</td>
</tr>
<tr>
<td>75–89</td>
<td>237</td>
<td>2.5</td>
</tr>
<tr>
<td>≥ 90</td>
<td>210</td>
<td>5.7</td>
</tr>
<tr>
<td>Total</td>
<td>879</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Left dominance

| 50–74        | 32  | 3.1                     |
| 75–89        | 35  | 8.6                     |
| ≥ 90         | 16  | 25.0                    |
| Total        | 83  | 9.6                     |

Balanced

| 50–74        | 30  | 0.0                     |
| 75–89        | 16  | 6.3                     |
| ≥ 90         | 11  | 18.2                    |
| Total        | 57  | 5.3                     |

Five hundred nine other patients underwent 556 other cardiac surgical procedures, including LV aneurysm resection, aneurysm plication, mitral valve replacement and other cardiac procedures. These patients had significantly higher OM compared with those who underwent CABG surgery alone (p < 0.001) (table 7). These patients were not included in the analysis of OM associated with CABG surgery.

**Discussion**

Clinical characteristics and angiographic factors associated with an increased OM in aortocoronary bypass surgery have been reported. The pattern of angina, symptoms of heart failure, stenosis of the LMCA, and abnormal indexes of LV function have been found to be important predictors of surgical mortality. The age and sex of the patient, the extent of the disease in the coronary vessels, and the presence of hypertension or diabetes are commonly thought to have less influence on survival. Studies have been hampered by inadequate numbers of patients to properly evaluate each of these factors. A comprehensive analysis of preoperative clinical and laboratory findings has not always been available, especially in regard to the definition of specific subsets of coronary

Table 7. Additional Cardiac Surgical Procedures and Operative Mortality

<table>
<thead>
<tr>
<th>Operative procedure</th>
<th>n*</th>
<th>Operative mortality (%)</th>
<th>Relative risk</th>
<th>Chi-square test</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV aneurysm resection</td>
<td>252</td>
<td>8.3</td>
<td>3.13</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>LV aneurysm plication</td>
<td>105</td>
<td>7.6</td>
<td>2.73</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Mitral valve replacement</td>
<td>38</td>
<td>23.7</td>
<td>8.61</td>
<td>p &lt; 0.001</td>
</tr>
<tr>
<td>Other cardiac surgery</td>
<td>161</td>
<td>12.4</td>
<td>4.70</td>
<td>p &lt; 0.001</td>
</tr>
</tbody>
</table>

*Five hundred nine patients underwent 556 procedures. Abbreviation: LV = left ventricular.
artery pathology. The CASS study has the advantage of a large number of patients entered prospectively into a registry that contains detailed data on these essential clinical and angiographic variables. While variability of interpretation and recording of clinical and angiographic data are potential sources of error in collaborative studies, the CASS protocol was specifically designed to reduce these errors.4 No registry patient who had CABG surgery was excluded from the analysis. The participating institutions are located in various geographic regions of North America. In view of these considerations, the CASS data may be representative of the surgical management of CAD in the United States and Canada during the last half of this decade.

Surgery in the older patient is generally undertaken at some increased risk, but the extent to which age influences coronary surgery mortality is not well defined. Among the 78 patients over age 65 years who received coronary bypass grafts alone, Ashor and colleagues reported two early deaths (2.6%).6 Meyer et al., reporting on patients 70 and older having coronary artery surgery through mid-1974, found an early mortality rate of 12.6%.7 Gann et al. reported a smaller group of patients over 70 years of age operated upon from 1969–1975 with an OM of 6.7%.6 In the latter two studies hospital mortality increased when aortocoronary bypass was combined with other cardiac surgery.

Advanced age has not been an apparent risk factor in several studies. Loop et al. compared 60 patients who died of cardiac-related causes after surgery performed in the period 1967–1973 to a group of patients who survived surgery performed in 1973.9 Age was not a predictor of OM.

The present CASS report shows a clear and impressive relationship between OM and advanced age in men. Men ages 60–69 years had an OM nearly three times greater than men ages 50–59 years. Operative mortality increased again for men over 70 years old. The same trend occurred for women, the OM increasing nearly three times between the sixth and seventh decades of life. The increasing risk for surgery as age increases was statistically significant for men but not for the smaller group of women.

Many reports have indicated the risk of coronary artery surgery is greater for women than for men. Hospital mortality was 7.3% in women and only 2.2% in men undergoing bypass grafting at the Cleveland Clinic before 1971.10 Bolooki et al. compared the results in 34 women who had surgery before 1974 with 51 men operated in 1972.11 Mortality was higher in women (8.8% vs 2.0%) despite some evidence that preoperative ventricular function was more abnormal in the men. Reul et al. reported an early mortality nearly twice as high for women as for men (9.2% vs 4.8%) through the end of 1974.12 There was increased mortality among women having two or more saphenous vein grafts from 1971–1975 in a series reported by Golding and Groves.13

In some recent studies, the patient's sex has not been a predictor of increased risk. Langou et al. found, for example, that OM was not related to sex in an analysis of 172 patients.14 Tyras et al. described their experience in 1541 patients, of whom 241 were women.15 The women were older and had more severe angina, but as a group had fewer previous myocardial infarctions and less depressed ventricular function than the men. There was no significant difference in OM (3.7% in women vs 2.4% in men). In the last 2.5 years of that study, the mortality rate for women was lower than that for men (1.4% vs 2.0%).

The present study shows a higher OM for women ages 40–59 years compared with men. In patients younger than 30–39 years, OM was higher in women, but the difference was not significant. OM increased in men in the sixth decade and increased in women in the seventh decade, so that after age 60 years, OM is similar in men and women. Because of the interrelationship between age, sex and OM, both must be considered when estimating surgical risk.

The severity of angina as it relates to the risk of surgery has been examined previously. Mortality was similar in patients with all classes of angina in the report of Oldham et al.16 Hammermeister et al.17 reported no significant difference in severity of either angina or exercise capacity among survivors and nonsurvivors. In the series of 400 patients reported by Cannom et al., however, severe angina was associated with an OM of 14.1%, but all patients with mild symptoms survived.18 Langou et al. also found that severe angina was predictive of increased OM.14 Loop et al. reported that the presence of rest or preinfarction angina and severe exertional pain slightly increased the probability of death.9

CABG surgery in patients with unstable angina has been associated with an OM in the range of 10–20% in some studies.19, 20 Mortality in this group has been lower in recently reported surgical series, however. In the National Cooperative Study of unstable angina, OM was 5% for the 141 patients randomized to surgical therapy.21

There is a significant trend toward higher mortality in the CASS patients with more disabling angina, with a RR for the most severely compromised (class IV) of 2.40. The group with unstable angina is also at slightly higher risk compared with those without an unstable chest pain syndrome. We conclude that the pattern and severity of angina have a modest influence on surgical mortality.

Most investigators have not found diabetes mellitus, hypertension or elevation of blood lipids to be risk factors for aortocoronary bypass surgery.9, 14 Engelman et al., in a sample of 177 patients, found hypertension, but not diabetes, to decrease survival.22 Diabetes mellitus, hypertension and elevated serum cholesterol were not associated with increased mortality in the CASS analysis. We conclude that the presence of these factors does not place the patient at increased risk for coronary artery surgery.

There is a demonstrated relationship between the extent of CAD and survival in medically treated patients.23 How the extent of CAD relates to OM when patients who have poor LV function and LMCD are excluded is not clear. Conley et al. reported an OM of 1% in patients with one- and two-vessel disease
and 6.6% in those with three-vessel disease. Chaitman et al. also reported higher early mortality in patients with three-vessel disease. In the multivariate discriminant analysis by Loop et al., the number of vessels diseased was of minor predictive value.

There is considerable evidence that stenosis of the LMCA adversely affects the OM. The early fatality rate for the subgroup of patients with LMCA stenosis assigned to surgery was 14% in the Veterans Administration Cooperative Study. As in the case of unstable angina, mortality rates have been dramatically reduced in some series of patients with LMCD reported more recently.

In the present study, because of the large sample size, we included an analysis of several anatomic subgroups with widely differing OMs. The most striking difference occurred in LMCD with ≥90% stenosis. Patients with a left-dominant circulation had an OM more than four times greater than those with a right-dominant circulation. In contrast, when LMCD is not severe (50–74% stenosis), the OM is low in patients with either right- or left-dominant circulation. This relationship between left-dominant circulation, severe LMCD and increased risk, although intuitively rational, has not been well recognized because only a very few patients have this highly lethal anatomy (0.2% in this study). When patients are categorized into one-, two-, or three-vessel involvement, the severity or extent of disease has less influence on OM.

Reduced LV performance has been considered the most important risk factor for OM. CHF (including an increased end-diastolic pressure) was the most heavily weighted of all the variables associated with an increased probability of death in one study. Kouchoukos et al. reported a mortality rate of 29% in patients with symptoms of CHF when only 1.9% of those without such symptoms died from surgical causes. Many reports describe an association of higher mortality and abnormal ventricular function assessed by hemodynamic or angiographic techniques. Oldham et al. found left ventricular end-diastolic pressures greater than 18 mm Hg and EFs < 25% to be significantly more frequent in non-survivors. Collins et al. also found patients with the lowest EFs to be at the highest risk for bypass surgery. Using a measurement of segmental ventricular wall motion, Keon et al. showed increasing mortality with the number of segments judged abnormal. Patients with the most severe LV dysfunction had an early mortality of 28.4%, while mortality was 1.2% for patients with normal ventricular performance.

The risk of surgery for patients with impaired ventricular function appears to be declining. Tyers et al. compared their experience operating on patients with reduced EF during 1971–1973 with that in 1974. Although the number of patients at risk was small, the mortality rate was significantly lower during 1974. This improvement was attributed to changes in anesthetic and surgical techniques and to the use of the intraaortic balloon pump.

Patients in the CASS registry who had angiographically abnormal LV function determined by wall motion scores had a greater mortality rate. The small number of patients with severely dysfunctional ventricles (wall motion score > 20) were at particularly high risk. Clinical manifestations of heart failure (CHF score or pulmonary rales) have similar RRs as the angiographic indicators of ventricular dysfunction (EF ≤ 19% or wall motion score > 20).

The results of this study support observations that OM increases as LV function worsens. The wall motion score appears to be more useful than the EF in selecting patients at increased risk for surgical treatment. The long-term survival of patients with severely damaged ventricles treated both medically and surgically must be evaluated. Some studies suggest that the outlook for such patients is poor with either type of treatment.

The myocardial jeopardy index described here provides a method of analyzing the functional relationship of ventricular performance and the degree of stenosis in the major coronary arteries. A high score indicates that stenotic vessels are supplying well-functioning regions of myocardium. This condition is shown to be associated with a low surgical risk. Bypass of stenotic vessels for the purpose of revascularizing akinetic or dyskinetic segments, on the other hand, carries a higher risk.

The striking relationship between priority for surgery and OM in patients with and without LMCD is of interest. Obviously, many factors enter into a decision to undertake urgent or emergent cardiac surgery. We can only evaluate the relationship between coronary anatomy, surgical priority and OM. Increased OM is associated with emergency surgery in all patient groups and is highest in patients with severe LMCD. Although there are situations where delay is not feasible, these findings suggest that emergency procedures should be avoided in favor of a period of intensive medical care in preparation for surgery.

Although OM in coronary artery surgery has declined, the mortality figures reported from different institutions vary. A range of OM was present among the sites participating in this study. The variability in reports of OM may be attributable to differences in the experience of the surgical teams, methods of anesthesia or techniques of myocardial preservation. Some of the variability in OM may be due to differences in the type of patient selected for surgery. Although the overall CASS mortality is low, we have constructed subsets with enough patients so that characteristics associated with increased OM emerge. A univariate analysis identifies several predictors of increased OM. The age and sex of the patient, symptoms of severe or unstable angina, heart failure, the distribution of lesions in the coronary arteries, ventricular performance and the timing of surgery have bearing on OM. These factors should be kept in mind when reports of surgical therapy are evaluated. They are also useful when considering a patient for surgery.
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Cooperating Clinical Sites

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