Risk Factors for Mortality After Surgery in Patients With Cirrhosis

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See editorial on page 1609; CME quiz on page 1596.

**Background & Aims:** Current methods of predicting risk of postoperative mortality in patients with cirrhosis are suboptimal. The utility of the Model for End-stage Liver Disease (MELD) in predicting mortality after surgery other than liver transplantation is unknown. The aim of this study was to determine the risk factors for postoperative mortality in patients with cirrhosis. **Methods:** Patients with cirrhosis (N = 772) who underwent major digestive (n = 586), orthopedic (n = 107), or cardiovascular (n = 79) surgery were studied. Control groups of patients with cirrhosis included 303 undergoing minor surgical procedures and 562 ambulatory patients. Univariate and multivariable proportional hazards analyses were used to determine the relationship between risk factors and mortality. **Results:** Patients undergoing major surgery were at increased risk for mortality up to 90 days postoperatively. By multivariable analysis, only MELD score, American Society of Anesthesiologists class, and age predicted mortality at 30 and 90 days, 1 year, and long-term, independently of type or year of surgery. Emergency surgery was the only independent predictor of duration of hospitalization postoperatively. Thirty-day mortality ranged from 5.7% (MELD score, <8) to more than 50% (MELD score, >20). The relationship between MELD score and mortality persisted throughout the 20-year postoperative period. **Conclusions:** MELD score, age, and American Society of Anesthesiologists class can quantify the risk of mortality postoperatively in patients with cirrhosis, independently of the procedure performed. These factors can be used in determining operative mortality risk and whether elective surgical procedures can be delayed until after liver transplantation.

Patients with cirrhosis are believed to be at increased risk of mortality and morbidity after surgery, but the duration of risk for increased mortality has not been demonstrated. In patients with cirrhosis undergoing various surgical procedures, risk factors for mortality have been shown to include Child-Turcotte-Pugh (CTP) score of 7 or greater, elevated serum creatinine concentration, cardiopulmonary comorbidity, and American Society of Anesthesiologists (ASA) physical status class of IV or V. However, the quantitative risk of mortality at specific times after surgery has not been characterized. Many patients with cirrhosis are candidates for liver transplantation, but, at present, there is no way to determine whether elective procedures in these patients should be delayed until after liver transplantation. The increased interest in surgery in patients with liver disease relates in part to the advent of liver transplantation, which offers the prospect of long-term survival for patients who would not previously have been considered for major surgery.

The Model for End-stage Liver Disease (MELD)—derived from the international normalized ratio (INR), serum total bilirubin, serum creatinine concentration, and etiology of liver disease—was originally developed to assess the short-term prognosis of patients with cirrhosis receiving a transjugular intrahepatic portosystemic shunt. The MELD subsequently was validated as a predictor of mortality in patients with many types of liver disease, even if the etiology was not considered. Since February

*Abbreviations used in this paper: ASA, American Society of Anesthesiologists; CTP, Child-Turcotte-Pugh; INR, international normalized ratio; IQR, interquartile range; MELD, Model for End-stage Liver Disease.*

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2002, the MELD system has been used with excellent results to prioritize allocation of organs for liver transplantation in the United States.7

The utility of the MELD for predicting mortality in patients with cirrhosis undergoing surgery other than liver transplantation has not been well studied. We and others have shown that the MELD score can be used to determine which patients with cirrhosis are at low risk of mortality after hepatic resection for hepatocellular carcinoma.8,9 Several other reports have concluded that patients with a higher MELD score are at increased risk of mortality or morbidity after surgery.10–13 These studies, however, addressed only postoperative morbidity and not mortality,13 were restricted to cardiac surgery alone,10 or addressed only 30-day mortality.12 One study indicated that the MELD was not predictive of mortality after hepatic resection, but the majority of patients in the cohort may not have had cirrhosis.14 In the present study, we investigated short-term and long-term mortality risks in patients with cirrhosis who underwent various surgical procedures, excluding liver transplantation.

Patients and Methods

Study Population

Using the Surgical Procedure Index database at the Mayo Clinic in Rochester, Minnesota, we retrospectively searched for the records of patients with cirrhosis from any cause who underwent major digestive, orthopedic, or cardiac surgical procedures. Patients were stratified into 2 study populations based on decade of treatment (1980–1990 vs 1994–2004). A total of 825 patients were identified. All patients who had laparoscopic cholecystectomy (n = 46) and those in whom all MELD parameters were not measured within 24 hours before surgery (n = 7) were excluded. The patients who underwent laparoscopic cholecystectomy were excluded because the risk associated with this procedure in patients with cirrhosis had been addressed previously in much larger studies.13,15 The final study group included 772 patients: 426 consecutive patients who had surgery in the decade 1980 through 1990 (“Era A”) and who were part of an earlier database, portions of which have been previously analyzed;4 and 346 consecutive patients who had surgery in 1994 through 2004 (“Era B”). To account for possible differences in patient population and abstraction method, all analyses were stratified by era.

All included patients had cirrhosis documented by histologic or intraoperative findings, or the diagnosis was based on the findings of at least 2 of the following: (1) gastroesophageal varices on endoscopy; (2) serum albumin ≤3.4 g/dL, INR ≥1.3, or serum bilirubin ≥2 mg/dL; and (3) radiologic imaging (ultrasonography or computed tomography) suggesting portal hypertension from cirrhosis. The diagnosis of cirrhosis by the ICD-9 CM code was confirmed by review of the medical records.

Patient information obtained included demographic features; etiology of cirrhosis; laboratory test results; type of surgical procedure; ASA class16; and dates of admission, surgery, and discharge (to determine duration of hospitalization). Follow-up was censored at the last known date of follow-up or date of death or liver transplantation. The study was approved by the Mayo Foundation Institutional Review Board.

Major Surgical Procedures

Patients who underwent surgery typically had platelet counts greater than 60,000/μL and INR of less than 1.5 (or, before 1991, prothrombin time within 4–6 seconds of reference values) at the time of surgery. Surgical procedures were performed with the patient under monitored general anesthesia. Patients were divided into 3 groups by the type of surgical procedure: digestive (n = 586), orthopedic (n = 107), and cardiovascular (n = 79). Major digestive surgery was defined as laparotomy with operative intervention on a visceral organ. Digestive procedures were further divided arbitrarily into 2 groups: digestive A (n = 372) and digestive B (n = 214), described in Table 1.

Control Groups

Two disease control groups were included; MELD score (median and interquartile range [IQR]) and age (median and IQR) of each group were matched with the major surgery group. One group, the “outpatient control group,” included ambulatory patients with cirrhosis seen between 2002 and 2005 without any of the above surgical procedures (N = 562); of these, only 59 patients were listed for liver transplantation, and 166 were not candidates for transplantation based on age or comorbid conditions. The other group (“minor surgery control group”) included patients with cirrhosis hospitalized between 1980 and 1990 for surgical procedures under general anesthesia, such as appendectomy, herniorrhaphy, and other procedures considered “minor” (N = 303).4 MELD parameters were obtained at the time of diagnosis of cirrhosis in the outpatient group and on the day of hospitalization in the minor surgery group. Patients from the control groups were censored at the date of last follow-up, death, or liver transplantation. The Charlson comorbidity index was used to account for comorbid conditions such as cardiopulmonary disease in all patient and control groups.17

Calculation of the MELD Score

The MELD score was calculated from the INR, serum total bilirubin (bili) in mg/dL, and serum creatinine (cr) in mg/dL obtained on the day of or within 24 hours before the incident operation in the surgery group as follows6:
Table 1. Patient Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All (N = 772)</th>
<th>Era A (n = 233)</th>
<th>Era B (n = 139)</th>
<th>Era A (n = 102)</th>
<th>Era B (n = 112)</th>
<th>Era A (n = 50)</th>
<th>Era B (n = 57)</th>
<th>Era A (n = 41)</th>
<th>Era B (n = 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median age, y</td>
<td>63</td>
<td>61</td>
<td>64</td>
<td>62.5</td>
<td>64</td>
<td>63.5</td>
<td>65</td>
<td>67</td>
<td>60.5</td>
</tr>
<tr>
<td>Median MELD score</td>
<td>8</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>7.5</td>
<td>7</td>
<td>6</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>ASA class IV or V</td>
<td>142 (18)</td>
<td>55 (24)</td>
<td>6 (4)</td>
<td>31 (30)</td>
<td>14 (13)</td>
<td>7 (14)</td>
<td>3 (5)</td>
<td>17 (41)</td>
<td>9 (24)</td>
</tr>
<tr>
<td>Men</td>
<td>430 (56)</td>
<td>123 (53)</td>
<td>89 (64)</td>
<td>46 (45)</td>
<td>62 (55)</td>
<td>28 (56)</td>
<td>24 (42)</td>
<td>31 (76)</td>
<td>27 (71)</td>
</tr>
<tr>
<td>Etiology of cirrhosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcoholic</td>
<td>182 (24)</td>
<td>56 (24)</td>
<td>26 (19)</td>
<td>28 (27)</td>
<td>14 (13)</td>
<td>24 (48)</td>
<td>14 (25)</td>
<td>12 (29)</td>
<td>8 (21)</td>
</tr>
<tr>
<td>Viral</td>
<td>141 (18)</td>
<td>28 (12)</td>
<td>46 (33)</td>
<td>16 (16)</td>
<td>18 (16)</td>
<td>7 (14)</td>
<td>11 (19)</td>
<td>8 (20)</td>
<td>7 (18)</td>
</tr>
<tr>
<td>Cholestatic</td>
<td>142 (18)</td>
<td>51 (22)</td>
<td>17 (12)</td>
<td>21 (21)</td>
<td>22 (20)</td>
<td>9 (18)</td>
<td>13 (23)</td>
<td>5 (12)</td>
<td>4 (11)</td>
</tr>
<tr>
<td>Other</td>
<td>307 (40)</td>
<td>98 (42)</td>
<td>50 (36)</td>
<td>37 (36)</td>
<td>58 (52)</td>
<td>10 (20)</td>
<td>19 (33)</td>
<td>16 (39)</td>
<td>19 (50)</td>
</tr>
<tr>
<td>Emergency surgery</td>
<td>79 (10)</td>
<td>37 (16)</td>
<td>2 (1)</td>
<td>17 (17)</td>
<td>13 (12)</td>
<td>6 (12)</td>
<td>0 (0)</td>
<td>3 (7)</td>
<td>1 (3)</td>
</tr>
</tbody>
</table>

ASA, American Society of Anesthesiologists; MELD, Model for End-stage Liver Disease.

Values are median or number of patients (%).

Surgery includes hepatobiliary (n = 209), portosystemic shunts (n = 86), esophagus and stomach (n = 51), and duodenum and pancreas (n = 26). Patients in the hepatobiliary group included 82 who had hepatic resection for hepatocellular carcinoma and were reported previously.

Surgery includes small and large intestine (n = 170) and spleen (n = 44).

Surgery includes knee replacement (n = 52), hip arthroplasty (n = 28), femur (n = 18), and spine (n = 9).

Surgery includes coronary artery bypass graft (n = 27), aortic aneurysm repair (n = 18), and other/valve replacement (n = 34).

ASA class definitions: I, healthy patients undergoing surgery; II, mild systemic disease; III, severe systemic disease; IV, severe systemic disease that is a constant threat to life; and V, moribund patients not expected to survive 24 hours with or without surgery.

MELD = 9.57 × ln(cr) + 3.78 × ln(bili) + 11.20 × ln(INR) + 6.43.

Statistical Analysis

Univariate and multivariable proportional hazards models were used to determine the relationship between preoperative variables and postoperative survival. P < .05 was considered statistically significant. The time-dependent coefficient method of Therneau and Grambsch was used to examine the effect of risk score over time (eg, the effect of the MELD on 30-day, 90-day, and 1-year mortality), and smoothing splines were used to assess the linear relationship between continuous covariates and risk.

Results

Demographics

Patient characteristics are shown in Table 1; follow-up was complete in all groups. The etiology of cirrhosis included alcoholic liver disease; viral hepatitis; cholestatic liver disease (primary biliary cirrhosis and primary sclerosing cholangitis); and other causes such as autoimmune hepatitis, nonalcoholic steatohepatitis, and cryptogenic. Patients in the outpatient and minor surgery control groups did not differ from each other according to the Charlson index (mean ± standard deviation, 5.3 ± 3.5 and 5.6 ± 3.4, respectively). The major surgery group had a significantly higher Charlson index score (6.1 ± 3.6) than the outpatient (P < .001) and minor surgery groups (P = .03). Median [IQR] age for the major surgery group (median, 61 years [51–69 years]) was similar to those of the outpatient (median, 57 years [48–64 years]) and minor surgery (median, 56 years [47–64 years]) control groups.

Mortality After Surgery

Patients undergoing major surgery (median [IQR] MELD score, 8 [5–11]) had an increased risk of mortality independent of age, MELD score, and Charlson index up to 90 days, as compared with the outpatient (median [IQR] MELD score, 9 [7–12]) and minor surgery (median [IQR] MELD score, 8 [5–12]) control groups (P = .03) (Figure 1A). Mortality at 1 year and beyond was not different among the groups (Figure 1B and 1C).

Risk Factors for Mortality

Univariate analyses. The ASA class for patients in the major surgery group was II in 67 patients (who typically received a diagnosis of cirrhosis only at surgery), III in 563 patients, IV in 132 patients, and V in 10 patients. The median survival for patients with ASA class V was only 2 days; 9 of the 10 patients died within 2 weeks, and the other died at 85 days. These 10 patients had a range of MELD scores (mean, 21) and ages; all underwent emergency surgery and were excluded from further analysis of other risk factors.

Univariate analysis of determinants for postoperative mortality is shown in Table 2. For each variable, the effect of time (up to 30 days, 90 days, 1 year, and after 1 year) was examined by using time-dependent coefficient plots (as in Figure 2). The table is thus stratified by these intervals of follow-up. There was a significant difference in mortality between patients with ASA classes III and IV.
variable in the univariate model. A single point increase in the MELD score was associated with a 14% increase in mortality in the first 30 and 90 postoperative days, a 15% increase in mortality in the first postoperative year, and a 6% increase in mortality for subsequent years. The relationship between MELD score and relative risk, shown as smoothing splines in Figure 2A–C, was almost perfectly linear for MELD scores greater than 8; less than 8, each point change in the MELD score had only approximately one fourth as large an effect. From 1 to 20 years after surgery, the excess risk was essentially constant (Figure 2D), and the relationship between MELD and increased mortality was similar to that described in the original model.5

Multivariable analysis. The multivariable analysis (Table 2) was also stratified by time after surgery. Although several variables (including serum creatinine concentration, CTP score, and individual components of the score) were significant by univariate analysis, only 3 co-variables in the multivariable model—MELD score, age, and ASA class—were significant predictors of mortality throughout follow-up. No patients younger than 30 years died within 90 days postoperatively; age greater than 70 years was associated with higher mortality. Male sex added to the increased risk of mortality only during the first year. Emergency surgery was not an independent predictor of mortality but was the only independent predictor of duration of hospitalization \((P < .001)\). Median MELD score was significantly higher for those undergoing emergency surgery than for those undergoing elective surgery \((12.2 \text{ vs } 7.9, \text{ respectively}; P < .001)\). Within the first 90 days postoperatively, the increase in mortality related to ASA class of IV was equivalent to 5.5 MELD points; an increase in age beyond 70 years was equivalent to 3 MELD points. The type of surgical procedure and whether it was emergency or elective were not independently predictive of long-term mortality.

The relationship between mortality after surgery and increasing MELD score is shown in Table 3 and Figure 3. The median survival among all patients with digestive, orthopedic, or cardiovascular surgery was 4.8 years for MELD scores of 0 to 7 \((n = 351)\), 3.4 years for scores of 8 to 11 \((n = 257)\), 1.6 years for scores of 12 to 15 \((n = 106)\), 64 days for scores of 16 to 20 \((n = 35)\), 23 days for scores of 21 to 25 \((n = 13)\), and 14 days for a MELD score of 26 or greater \((n = 10)\). The c-statistic for 30-day mortality was 0.78 and for 90-day mortality was 0.82; addition of age and ASA class improved the c-statistic slightly to 0.80 and 0.84, respectively. These increases in c-statistic with addition of age and ASA class were statistically significant but unlikely to be clinically important.

Discussion

In patients with cirrhosis, the risk of mortality is related to the severity of liver disease, the comorbid conditions, the type of surgery, and probably the skill of
Univariate analysis

Disease.

ASA, American Society of Anesthesiologists; CI, confidence interval; CTP, Child–Turcotte–Pugh; HR, hazard ratio; MELD, Model for End-stage Liver Disease.

NOTE. Multivariate models include MELD score, age, ASA, and each of the other variables individually.

The increased risk of mortality in patients undergoing major surgery as compared with control groups may continue for up to 90 days after surgery. The mortality rate in the outpatient control group was higher than previously described for patients listed for liver transplantation but is similar to that for cohorts of unselected patients with cirrhosis. The mortality rate is lower in patients listed for transplantation because patients at highest risk for mortality undergo transplantation, thus decreasing the overall mortality rate in the group. The stratification of risk for postoperative mortality is independent of the type of surgical procedure performed, including whether the procedure is elective or emergent. Of the 3 variables, ASA class V is the strongest predictor of 7-day postoperative mortality, and MELD score is the strongest predictor of mortality beyond 7 days and long-term. However, addition of age and ASA class to the MELD score may further increase the predic-

### Table 2. Univariate and Multivariable Determinants of Postoperative Mortality

<table>
<thead>
<tr>
<th>Factor</th>
<th>30 days</th>
<th>90 days</th>
<th>1 year</th>
<th>After 1 year</th>
</tr>
</thead>
<tbody>
<tr>
<td>MELD score &gt; 8</td>
<td>1.14 (1.10–1.18)</td>
<td>.001</td>
<td>1.14 (1.10–1.18)</td>
<td>.001</td>
</tr>
<tr>
<td>CTP score &gt; 7</td>
<td>1.86 (1.03–3.37)</td>
<td>.04</td>
<td>2.20 (1.35–3.58)</td>
<td>.002</td>
</tr>
<tr>
<td>Age a</td>
<td>1.34 (1.07–1.68)</td>
<td>.01</td>
<td>1.38 (1.14–1.68)</td>
<td>.001</td>
</tr>
<tr>
<td>ASA class IV</td>
<td>3.47 (2.05–5.86)</td>
<td>.001</td>
<td>4.08 (2.62–6.37)</td>
<td>.001</td>
</tr>
<tr>
<td>Surgery type b</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>3.69 (0.98–13.92)</td>
<td>.054</td>
<td>2.81 (0.96–8.22)</td>
<td>.06</td>
</tr>
<tr>
<td>Digestive A</td>
<td>2.35 (0.72–7.66)</td>
<td>.16</td>
<td>1.95 (0.77–4.92)</td>
<td>.16</td>
</tr>
<tr>
<td>Digestive B</td>
<td>2.17 (0.62–7.60)</td>
<td>.23</td>
<td>1.92 (0.72–5.14)</td>
<td>.20</td>
</tr>
<tr>
<td>Orthopedic</td>
<td>1.00</td>
<td>—</td>
<td>1.00</td>
<td>—</td>
</tr>
<tr>
<td>Emergency surgery</td>
<td>3.20 (1.81–5.65)</td>
<td>.001</td>
<td>3.09 (1.88–5.06)</td>
<td>.001</td>
</tr>
<tr>
<td>Year of surgery</td>
<td>1.00 (0.91–1.09)</td>
<td>.98</td>
<td>1.04 (0.96–1.12)</td>
<td>.35</td>
</tr>
<tr>
<td>Etiology of disease c</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcoholic</td>
<td>0.73 (0.40–1.32)</td>
<td>.03</td>
<td>0.78 (0.47–1.29)</td>
<td>.34</td>
</tr>
<tr>
<td>Cholestatic</td>
<td>0.25 (0.09–0.70)</td>
<td>.01</td>
<td>0.27 (0.12–0.63)</td>
<td>.02</td>
</tr>
<tr>
<td>Viral/other</td>
<td>1.00</td>
<td>—</td>
<td>1.00</td>
<td>—</td>
</tr>
<tr>
<td>Male sex</td>
<td>1.79 (1.03–3.11)</td>
<td>.04</td>
<td>1.76 (1.10–2.80)</td>
<td>.02</td>
</tr>
</tbody>
</table>

NOTE. Multivariate models include MELD score, age, ASA, and each of the other variables individually.

ASA, American Society of Anesthesiologists; CI, confidence interval; CTP, Child–Turcotte–Pugh; HR, hazard ratio; MELD, Model for End-stage Liver Disease.

aHazard ratio for age corresponds to a 10-year increase.

bOrthopedic surgery is the reference group for procedure type.

Viral/other is the reference group for etiology.
The significance of this study is that mortality risk in the individual patient at specific time points after surgery can now be determined (obtained by entering the variables at: http://www.mayoclinic.org/meld/mayomodel9.html). Thus, both the patient and physician can make more rational decisions regarding candidacy for surgery.

Patients with cirrhosis who undergo surgery are at risk for mortality because of liver failure, postoperative bleeding, infection, and renal failure as a result of the circulatory dysfunction.20,21 The MELD score may be superior to the CTP score in assessing risk of mortality because it includes the key components of the CTP score, serum total bilirubin (which reflects global hepatic function), and INR (or prothrombin time), but, unlike the CTP score, it also includes a measure of renal function, serum creatinine. Quantitative tests of liver function such as galactose elimination capacity and aminopyrine breath test22 are not superior to the CTP score. The MELD score weighs variables according to risk of mortality, has only objective variables, and is not subject to “floor” effects or “ceiling” effects.6 In contrast, variables in the CTP score were selected empirically, cut-off values are arbitrary, and similar weight is given to each of the 5 parameters in the score. Similar to the CTP score, the MELD system has been validated extensively in many different patient groups with varying severity of liver disease.6,23 Whereas the CTP score has a range only between 5 and 15 and only 3 classes (A, B, and C), the MELD system has a much wider range of scores, usually between 6 and 40. Therefore, a finer calibration of mortality risk is possible with MELD. The CTP score can only help predict whether the patient is in a low-risk, intermediate-risk, or high-risk group, but it cannot determine the specific risk for mortality at defined time points.

Factors specific to certain surgical procedures may also affect risk. Abdominal surgery may be associated with decreased or impaired hepatic arterial blood flow, and perioperative mortality rates as high as 76% have been reported for patients with CTP class C.24 In contrast, in patients undergoing cardiac surgery, mortality has been related to other factors in addition to CTP class,25 such as increased duration of cardiopulmonary bypass and need for perioperative pressor support.26 Similar to the findings in other studies, we found that emergency surgery is associated with a higher mortality risk, but it was not predictive of mortality by multivariable analysis. This is because patients undergoing emergency procedures had a

Figure 2. Analysis of MELD score. Smoothing spline curves illustrate relationship between MELD score and relative risk of postoperative mortality at (A) 30 days, (B) 90 days, and (C) 1 year. (D) Coefficient of mortality for MELD vs postoperative time. Dotted curves represent 95% confidence limits.
higher MELD score, reflecting worsening hepatic and renal function. The advantage of the MELD score is that it can be used to determine risk of mortality independent of the type of surgery or intervention. Emergency surgery does not influence long-term mortality independent of MELD score.

Patients with ASA class V were most likely to die within 7 days after surgery. The ASA classification incorporates measures of cardiopulmonary function that are critical to determination of immediate survival, measures that have been shown to be associated with a high risk of mortality in patients with acute or chronic liver failure. Therefore, postoperative mortality within 7 days may be related to factors not reflected in the MELD score, such as cardiopulmonary comorbidity. Similarly, increasing age may be associated with increasing cardiopulmonary comorbidity. The series of events leading to surgery and the surgical procedure itself may result in mortality related to liver failure beyond 7 days, a risk best assessed by the MELD score.

Patients with cirrhosis should have an ASA class of at least III—that is, the presence of severe systemic illness. Patients who were initially classified as ASA class II in this study were those in whom cirrhosis was diagnosed only at surgery. Therefore, it is not surprising that there was no difference in mortality risk between ASA class II and class III. The range of ASA classification in patients known to have cirrhosis preoperatively (class III–V) is small (in the present study, ASA class was III or IV in more than 90% of the surgical patients); ASA class alone, therefore, would allow only coarse discrimination of surgical risk over specific time periods. Moreover, there is a subjective element in the determination of ASA class that may limit wide applicability of the classification by less experienced anesthesiologists. Similarly, because only extremes of age (<30 years or >70 years) significantly affected mortality, age alone cannot be used as a predictor of mortality in most patients. Therefore, age and ASA class other than V must only be considered as modifiers of the MELD score.

Because survival models typically have lower predictive accuracy when applied to independent data sets, the present data must be validated, especially because the results were derived from a retrospective study. Patients included in the study were treated at a single center by a team of experienced surgeons, anesthesiologists, intensive care physicians, and hepatologists. Therefore, the universal applicability of these factors in determining postoperative risk must be determined. Moreover, there was likely a selection bias regarding which patients underwent surgery, which depended on the perceived mor-

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**Table 3. Relationship Between MELD Score and Postoperative Mortality**

<table>
<thead>
<tr>
<th>MELD score</th>
<th>7 Days</th>
<th>30 Days</th>
<th>90 Days</th>
<th>1 Year</th>
<th>5 Years</th>
<th>10 Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–7 (n = 351)</td>
<td>1.9 (314)</td>
<td>5.7 (301)</td>
<td>9.7 (287)</td>
<td>19.2 (253)</td>
<td>50.7 (123)</td>
<td>72.6 (57)</td>
</tr>
<tr>
<td>8–11 (n = 257)</td>
<td>3.3 (236)</td>
<td>10.3 (219)</td>
<td>17.7 (200)</td>
<td>28.9 (170)</td>
<td>58.5 (83)</td>
<td>78.1 (35)</td>
</tr>
<tr>
<td>12–15 (n = 106)</td>
<td>7.7 (94)</td>
<td>25.4 (78)</td>
<td>32.3 (69)</td>
<td>45.0 (56)</td>
<td>69.5 (24)</td>
<td>87.3 (10)</td>
</tr>
<tr>
<td>16–20 (n = 35)</td>
<td>14.6 (29)</td>
<td>44.0 (19)</td>
<td>55.8 (15)</td>
<td>70.5 (10)</td>
<td>94.1 (2)</td>
<td>94.1 (2)</td>
</tr>
<tr>
<td>21–25 (n = 13)</td>
<td>23.0 (7)</td>
<td>53.8 (4)</td>
<td>66.7 (3)</td>
<td>84.6 (2)</td>
<td>92.3 (1)</td>
<td>100 (0)</td>
</tr>
<tr>
<td>≥26 (n = 10)</td>
<td>30.0 (6)</td>
<td>90.0 (1)</td>
<td>90.0 (1)</td>
<td>100 (0)</td>
<td>100 (0)</td>
<td>100 (0)</td>
</tr>
</tbody>
</table>

MELD, Model for End-stage Liver Disease.

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**Figure 3.** Relationship between MELD and mortality. Curves show postoperative mortality at (A) 30 days and (B) 90 days as a function of preoperative MELD score. The curves may be used to determine the risk for mortality at these time points in an individual patient.
tality and risk and patient preferences. The number of patients who required surgery but were not operated on because of perceived increased risk for mortality, and the reasons that they were denied surgery, could not be determined in this retrospective analysis. Patients with cirrhosis undergo surgery only if conservative measures fail. Therefore, there is no ideal control group—that is, a group of matched patients who require surgery but are treated nonsurgically. Consequently, the conclusions from the present study may not be applicable to all patients who require surgery.

The major advantage of quantifying probability of mortality is in making decisions regarding elective surgical procedures. Surgical procedures may be broadly classified as those that are lifesaving, such as emergency procedures and cardiovascular and cancer surgery, and those indicated to improve quality of life, such as orthopedic procedures. In both situations, ASA class, MELD score, and age may be used to counsel patients and their families regarding risk of mortality at defined times after surgery. Mortality risk in patients with ASA class V is so high that surgery may not be a viable option.

In patients who are candidates for liver transplantation, MELD score may be used to plan management. In patients with a MELD score less than 11, postoperative mortality is low enough that most patients may find the risk of surgery acceptable (Table 3, Figure 3). Nonetheless, in our opinion, these patients should preferably have surgery at institutions with a center for liver transplantation. In patients with a MELD score of 20 or higher, the risk of mortality is so high that elective procedures may be postponed until after liver transplantation. If patients with a MELD score of 20 or higher have cardiac conditions that need correction before liver transplantation, the cardiac surgery and liver transplantation could be a combined procedure.26 Patients with MELD scores between 12 and 19 should have most of their evaluation for transplantation completed before surgery so that they can proceed to urgent liver transplantation if required. The MELD score at which elective surgery should be postponed until after liver transplantation may vary depending on surgical expertise and organ availability within the center or region.

We conclude that, in patients with cirrhosis undergoing major surgical procedures, the risk of mortality within 7 days of surgery is best assessed by ASA class, whereas mortality after 7 days is best determined by MELD score. Both of these variables and age may be used to counsel patients and their families before surgery is performed.

References


