Hepatic Resection in the United States

Indications, Outcomes, and Hospital Procedural Volumes From a Nationally Representative Database

Justin B. Dimick, MD; John A. Cowan, Jr, MD; James A. Knol, MD; Gilbert R. Upchurch, Jr, MD

Background: Hepatic resection has become common in the United States for both primary and secondary hepatic tumors.

Hypothesis: Variation in outcomes after hepatic resection is related to patient characteristics, the indication for operation, and hospital procedural volume.

Design: Observational study using a nationally representative database.

Patients: All patients in the Nationwide Inpatient Sample for 1996 and 1997 with a primary procedure code for hepatic resection (N = 2097).

Main Outcome Measures: Outcomes included in-hospital mortality and length of stay. Risk-adjusted analyses were performed using hierarchical multivariate models.

Results: Overall mortality for the 2097 patients was 5.8%. The most common indications for hepatic resection were secondary metastases (52%), primary hepatic malignancy (16%), biliary tract malignancy (10%), and benign hepatic tumor (5%). High-volume hospitals had a mortality rate of 3.9% vs 7.6% at low-volume hospitals (P < .001). In the multivariate analysis adjusting for patient case-mix, high-volume hospitals had a 40% lower risk of in-hospital mortality compared with low-volume hospitals (odds ratio, 0.60; 95% confidence interval, 0.39-0.92; P = .02). Other predictors of mortality in the multivariate analysis included age older than 65 years, hepatic lobectomy (vs wedge resection), primary hepatic malignancy (vs metastases), and the severity of underlying liver disease.

Conclusions: Hospital procedural volume is an important predictor of mortality after hepatic resection. Patients who require resection of primary and secondary liver tumors should be offered referral to a high-volume center.

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The extent of hepatic resection was determined using the primary ICD-9-CM code for each patient (code 503 for lobectomy and code 5022 for wedge resection). Patients who underwent percutaneous (code 5011) or open-wedge (code 5012) biopsy were excluded. Those undergoing hepatic resection for traumatic laceration were included in the description of indications for surgery but excluded from the final multivariate analysis. Individuals with traumatic liver laceration who underwent liver repair (codes 5061 and 5069) and did not undergo resection were excluded from all analyses. These groups are not subject to the same perioperative risk as those undergoing standard hepatic resection and were excluded to create a homogenous population for study.

Unadjusted and risk-adjusted analyses were conducted. Risk adjustment included demographic characteristics (age, sex, and race), 10 comorbid diseases, nature of admission (elective, urgent, or emergent), extent of surgical resection (wedge resection vs lobectomy), and the indication for surgery. The Romano modification of the Charlson comorbidity score was used with ICD-9-CM codes from an index hospitalization to account for comorbid disease.22-24 The comorbid diseases included in the Romano-Charlson risk adjustment score included myocardial infarction, chronic obstructive pulmonary disease, chronic renal failure, diabetes mellitus, diabetes with chronic complications, mild liver disease, moderate to severe liver disease, peripheral vascular disease, malignancy, metastatic cancer, cerebrovascular disease, and dementia.22-24 Each comorbid disease was coded as a dichotomous variable and entered individually into the multivariate model. Not all hospitals reported the nature of admission, and data for this variable were available for 1828 (87%) of 2097 patients in the database.

**HOSPITAL VOLUME**

The number of hepatic resections performed at each hospital during 1996 and 1997 was calculated using an anonymous hospital identification number available in the NIS database. We initially divided hospitals into 3 groups by volume, but there was no difference between medium- and low-volume hospitals. Hospital volume was therefore best modeled as a dichotomous variable that for some surgical procedures low-volume surgeons practicing in the same hospital.25

The Nationwide Inpatient Sample (NIS), from 1996 to 1997.

**OUTCOME VARIABLES**

The primary outcome variable was vital status at discharge (in-hospital mortality). Length of stay was a secondary end point and was used to compare the relative use of resources between HVHs and LVHs. The reason for hepatic resection was determined using the primary diagnostic ICD-9-CM code. Indications for surgery were assigned to one of the following categories: primary hepatic malignancy, secondary hepatic malignancy, benign hepatic neoplasm, biliary malignancy, benign hepatic disease, benign biliary disease, traumatic liver laceration, or other.

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**Table 1. Demographic Characteristics and Comorbid Diseases for Patients Undergoing Hepatic Resection in the United States From 1996 to 1997**

<table>
<thead>
<tr>
<th>Patient Characteristic</th>
<th>High-Volume Hospitals</th>
<th>Low-Volume Hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No. of patients</td>
<td>1011 (48)</td>
<td>1086 (52)</td>
</tr>
<tr>
<td>Age, mean ± SD, y</td>
<td>54 ± 17</td>
<td>57 ± 19</td>
</tr>
<tr>
<td>Female sex</td>
<td>529 (52)</td>
<td>562 (52)</td>
</tr>
<tr>
<td>Nonwhite race</td>
<td>154 (15)</td>
<td>214 (20);†</td>
</tr>
<tr>
<td>Elective admission</td>
<td>780 (77)</td>
<td>628 (58);†</td>
</tr>
<tr>
<td>Urgent admission</td>
<td>67 (7)</td>
<td>97 (9)</td>
</tr>
<tr>
<td>Emergent admission</td>
<td>97 (10)</td>
<td>159 (15);†</td>
</tr>
<tr>
<td>Hepatic lobectomy</td>
<td>481 (48)</td>
<td>452 (42);‡</td>
</tr>
<tr>
<td>Malignancy</td>
<td>281 (28)</td>
<td>402 (37);‡</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>90 (9)</td>
<td>105 (10)</td>
</tr>
<tr>
<td>Mild to moderate liver disease</td>
<td>75 (7)</td>
<td>86 (8)</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>23 (2)</td>
<td>58 (5);‡</td>
</tr>
<tr>
<td>History of myocardial infarction</td>
<td>24 (2)</td>
<td>11 (1);‡</td>
</tr>
<tr>
<td>Severe liver disease</td>
<td>8 (&lt;1)</td>
<td>13 (1)</td>
</tr>
<tr>
<td>Chronic renal disease</td>
<td>2 (&lt;1)</td>
<td>3 (&lt;1)</td>
</tr>
</tbody>
</table>

†High-volume hospitals performed 10 or more procedures per year.
‡Comparison of high- to low-volume hospitals. P<.05 by χ² or Wilcoxon rank sum test.

**DATA SOURCE**

The NIS is a 20% stratified random sample of all hospital discharges in the United States. It is maintained by the Agency for Health Care Policy and Research as part of the Healthcare Cost and Utilization Project.20 The data for this study were derived from 1996 and 1997 versions of the NIS. During this time, hepatic resection was performed at 221 hospitals in 19 states in 1996 and 231 hospitals in 22 states in 1997.

All patients who were discharged from these hospitals in 1996 and 1997 with an International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) primary procedure code for hepatic wedge resection or hepatic lobe resection (codes 503 and 5022) were included in the study (N=2097).21 For all included patients, data regarding age, sex, race, the nature of admission, the indication for surgery, the extent of the procedure, vital status at discharge, length of stay (LOS), and hospital charges were abstracted directly from the database. Secondary ICD-9-CM diagnostic codes were abstracted to ascertain the presence of several comorbid diseases.22-24

**OUTCOME VARIABLES**

The primary outcome variable was vital status at discharge (in-hospital mortality). Length of stay was a secondary end point and was used to compare the relative use of resources between HVHs and LVHs. The reason for hepatic resection was determined using the primary diagnostic ICD-9-CM code. Indications for surgery were assigned to one of the following categories: primary hepatic malignancy, secondary hepatic malignancy, benign hepatic neoplasm, biliary malignancy, benign hepatic disease, benign biliary disease, traumatic liver laceration, or other.

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**STATISTICAL ANALYSIS**

Descriptive statistics were conducted for characteristics of all patients undergoing hepatic resection during 1996 and 1997 (Table 1). Univariate comparisons of hospital volume, patient characteristics, and outcome variables were performed using the χ² test, Wilcoxon rank sum test, t test, simple logistic regression, and simple linear regression where appropriate. Multiple logistic regression of in-hospital mortality was used to test its association with hospital volume after adjusting for poten-
HOSPITAL AND PATIENT CHARACTERISTICS

During 1996 and 1997, 2097 patients underwent hepatic resection at hospitals included in the NIS. For 1996, hepatic resection was performed in 221 hospitals; 20 (9%) of these hospitals were classified as HVHs, and 201 (91%) were classified as LVHs. In 1997, hepatic resection was performed in 251 hospitals, of which 25 (10%) were HVHs and 226 (90%) were LVHs. Although only approximately 10% of hospitals from 1996 and 1997 met the criteria for high volume, nearly half (48%) of all patients underwent surgery at these centers (Table 1).

Baseline characteristics for the patients undergoing hepatic resection revealed several differences between HVHs and LVHs (Table 1). Patients at LVHs and HVHs were similar with respect to age and sex, but those at LVHs were more likely to be of a race other than white (24% vs 18%; *P*=.001). Patients at LVHs also had a higher frequency of urgent admission (10.2% vs 7.1%; *P*<.001) and emergent admission (17.2% vs 10.2%; *P*<.001). Even though more urgent/emergent procedures were performed at LVHs, a slight majority (58%) of emergent trauma resections were performed at HVHs (*P*<.001). In addition, patients at LVHs were more likely to have a history of a malignancy (37.0% vs 27.8%; *P*=.009) and chronic obstructive pulmonary disease (5.3% vs 2.3%; *P*<.001). Indications for surgery were generally similar between HVHs and LVHs, although a slightly higher proportion of patients underwent resection for trauma or benign biliary disease at LVHs. Alternatively, HVHs performed slightly more resections for benign hepatic neoplasms (Table 2). Overall, the most common indications for hepatic resection were secondary metastases (52%), primary hepatic malignancy (16%), and benign hepatic tumor (10%) (Figure 1).

IN-HOSPITAL MORTALITY

Overall in-hospital mortality was 5.8% for hepatic resection during the 2-year study period, 1996 and 1997; HVHs had a significantly lower mortality rate than LVHs (3.9% vs 7.6%; *P*<.001). This effect represents an unadjusted relative risk of 0.51 (95% confidence interval [CI], 0.34-0.73) for having surgery at a high-volume center. In a simple logistic regression analysis, increasing age was associated with a higher in-hospital mortality rate (odds ratio [OR], 1.01; 95% CI, 1.00-1.02; *P*=.03). There was a stepwise increase in mortality associated with increasing age, with age changed to a categorical variable (Figure 2). Using a dichotomous age variable with a cutoff point of 65 years, patients 65 years and older had a 7.8% in-hospital mortality rate that was significantly higher than younger patients (8.9% vs 2.9% in patients under 60 years; *P*<.001).
greater than the mortality rate of 4.7% for patients younger than 65 years (P < .003). When examining both hospital volume and the dichotomous age variable in a univariate analysis, it was clear that the effect of hospital volume persisted for patients older than and younger than 65 years. Specifically, for patients younger than 65 years, the in-hospital mortality rate was 3.5% at HVHs compared with 5.9% at LVHs (P = .04). For patients older than 65 years, the in-hospital mortality rate was 4.7% at HVHs and 10.1% at LVHs (P = .006).

Nature of admission was an important predictor of in-hospital mortality, with mortality rates of 4.1% for elective admission, 7.5% for urgent admission, and 12.9% for emergent admission (P < .001). Of 252 patients with emergent resections, 101 (40%) were performed after traumatic laceration. After excluding the trauma patients, nature of admission was no longer predictive of increased mortality.

Extent of resection was associated with mortality; hepatic lobectomy (7.6%) had a significantly higher mortality rate than did hepatic wedge resection (4.4%) (P = .002). Sex was also associated with mortality; women had an increased in-hospital mortality rate of 7.2% compared with 4.6% for men (P = .01). Indication for hepatic resection was one of the most important variables predicting in-hospital mortality (Table 3). Patients having surgery for traumatic lacerations were obviously at the highest risk of mortality (27.2%), followed by excision of primary hepatic malignancy (11.0%), whereas other indications were associated with much lower mortality rates. High-volume centers had significantly lower mortality rates for both resection of hepatic metastases (P = .05) and primary hepatic malignancy (P = .008) (Figure 3). Other univariate risk factors for increased in-hospital mortality included race (P = .001), chronic obstructive pulmonary disease (P < .001), metastatic disease (P < .001), history of mild liver disease (P = .001), and history of moderate to severe liver disease (P < .001).

In a multivariate analysis adjusting for case-mix, undergoing hepatic resection at an HVH was associated with a 40% reduction in mortality (OR, 0.60; 95% CI, 0.39-0.92; P = .02) (Table 4). Independent risk factors for increased in-hospital mortality include mild to moderate liver disease (OR, 2.0; 95% CI, 1.0-3.8), hepatic lobectomy (OR, 2.2; 95% CI, 1.4-3.3), age 65 years or older (OR, 2.2; 95% CI, 1.4-3.2), chronic pulmonary disease (OR, 2.7; 95% CI, 1.3-5.7), primary hepatic malignancy (OR, 3.0; 95% CI, 1.7-5.2), and severe liver disease (OR, 72.0; 95% CI, 23.7-218.5). The multivariate model was not rejected after goodness-of-fit testing, and the area under the receiver operator characteristic curve was calculated as 0.840, demonstrating the good predictive capacity of the model.

### LENGTH OF STAY

The overall median LOS was 7 days (interquartile range [IQR], 5-10) for patients undergoing hepatic resection in 1996 and 1997. After hepatic resection, HVHs had a median LOS 1 day shorter than that of LVHs (7 days [IQR, 5-9] vs 8 days [IQR, 5-11]), which was statistically significant (P = .002) but represents only a modest clinical difference. Those patients undergoing hepatic lobectomy had an LOS 1 day longer than that of patients having wedge resection (7 days [IQR, 5-9] vs 8 days [IQR, 6-12]) (P < .001). Patients aged 65 years or older had a median LOS 1 day longer than those younger than 65 years.
land, Choti et al 8 reported the results of 606 hepatic re-
(7 days [IQR, 5-10] vs 8 days [IQR, 6-11]) (P < .001). Other risk factors for increased LOS in the univariate analysis include female sex (P < .001), urgent admission (P < .001), emergent admission (P < .001), malignancy (P < .001), metastatic disease (P = .02), chronic pulmonary disease (P = .02), and severe liver disease (P < .001).

In addition, relative to resection for metastases, all other indications for surgery had a univariate association with LOS (P < .05), and this variable was therefore included in the multivariate analysis.

In the case-mix–adjusted multivariate analysis, several patient characteristics were associated with an increased LOS. However, the association between hospital volume and LOS only approached statistical significance in this analysis (Table 5). Age older than 65 years remained associated with a 9% (95% CI, 3%-15%) increase in LOS, and female sex was associated with a 10% (95% CI, 5%-15%) increase in LOS. Having hepatic lobectomy vs wedge resection was associated with a 21% (95% CI, 15%-28%) increase in LOS. Other factors predictive of increased LOS include biliary malignancy (20%; 95% CI, 2%-41%), urgent admission (24%; 95% CI, 13%-36%), benign hepatic disease (27%; 95% CI, 3%-57%), emergent admission (51%; 95% CI, 37%-67%), and severe liver disease (116%; 95% CI, 66%-182%).

**COMMENT**

Hepatic resection is increasingly performed for excision of secondary metastases, primary liver tumors, and biliary malignancy in the United States. Information on outcomes of this high-risk surgical procedure is, for the most part, limited to large case series from tertiary medical centers. 20,21 The current study provides population-based outcomes from a nationally representative sample of several hundred hospitals that perform hepatic resection. In addition, we were able to describe differences in outcomes associated with hospital procedural volume across several high- and low-volume centers. In the current study, having surgery at an HVH was associated with a 40% risk reduction in mortality, which may be significant enough to consider regionalization of this high-risk general surgical procedure.

Previous population-based studies of hepatic resection have focused on the relationship of procedural volume to outcomes using state discharge data and the national Medicare database. 7,10 Using the California Office of Statewide Health Planning and Development database, Glasgow et al 22 investigated the outcomes of hepatic resection for hepatocellular carcinoma for the state of California from 1990 to 1994. During their study period, 507 patients underwent hepatic resection with an overall mortality rate of 14.8%. Similar to the current study, procedural volume was associated with mortality after adjusting for case-mix. The highest-volume centers had a mortality rate of 6.2% compared with 24.4% in the lowest-volume centers (P < .001 by logistic regression). In a second statewide study from Maryland, Choti et al 9 reported the results of 606 hepatic resections performed between 1990 and 1996. The overall in-hospital mortality rate was 5.1% and was significantly different between LVHs (7.9%) and HVHs (1.5%) (P < .01). However, the external validity of these findings is questionable because one high-volume provider in Maryland performed 44% of all hepatic resections during the study period. Approximately one half of the resections in this group were performed for hepatic metastases. Patients having resection for metastases in Maryland had a lower mortality rate compared with those undergoing resection of primary hepatic malignancy, which was similar to our findings.

In a third study investigating operative mortality after major cancer resections, including hepatic resection, Begg et al 3 reported the results from linking Medicare data to the Surveillance, Epidemiology, End-Results database. This investigation focused on differences in 30-day mortality rates across hospital volume categories. For 801 patients undergoing hepatic resection, there was a stepwise increase in mortality rates from high-volume (1.5%) to medium-volume (3.2%) and low-volume (3.7%) hospitals (P = .04).

The relationship between volume and outcome for high-risk surgical procedures, including hepatic resection, is well documented. 7,19 However, the differences in structure and care processes between high- and low-volume centers that contribute to this relationship are unknown. 11 Surgical training and competency (including individual surgeon volume) are necessary but not sufficient to achieve optimal outcomes. 33 For complex surgical procedures, the preoperative, intraoperative, and postoperative stages of management are all important in determining the ultimate outcome. Postoperative complications, for example, vary dramatically among medical centers and cannot be entirely attributable to surgical technique. 30,31 Because complications are associated with increased mortality and cost, any factor that aids in prevention or treatment of complications may potentially contribute to the observed volume-outcome effect. 32,34 One structural aspect of postoperative care shown to be important for hepatic resection is intensive care unit (ICU) physician and nurse staffing. Having daily rounds by an ICU physician has been shown to be

**Table 5. Independent Variables Associated With Length of Stay After Hepatic Resection in the United States**

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Increased Length of Stay, Adjusted Percentage Increase (95% CI)</th>
<th>P Value *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female sex</td>
<td>10 (3.1 to 57)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Age older than 65</td>
<td>9 (2 to 15)</td>
<td>.01</td>
</tr>
<tr>
<td>Biliary malignancy</td>
<td>20 (2.5 to 41)</td>
<td>.03</td>
</tr>
<tr>
<td>Hepatic lobectomy</td>
<td>21 (15 to 28)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Urgent admission</td>
<td>24 (13 to 36)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Benign hepatic disease</td>
<td>27 (3.1 to 57)</td>
<td>.02</td>
</tr>
<tr>
<td>Emergent admission</td>
<td>51 (37 to 67)</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Severe liver disease</td>
<td>116 (66 to 182)</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Abbreviation: CI, confidence interval. *Statistical test for independent association of the variable to length of stay.

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associated with decreased risk of postoperative complications and mortality in patients undergoing hepatic resection in Maryland hospitals. In this same population, having more ICU nurses at night was associated with fewer respiratory complications and decreased resource utilization.

Some advocates of regionalization suggest that it may not be necessary to understand the relationship of volume to outcome. If patients who need high-risk surgery are selectively referred to HVHs, the benefits of regionalization could be realized without exploring the relationship. Three recent reports have focused on estimating the number of lives that could be saved by referring patients to HVHs for several high-risk elective surgical procedures. In the first study, Dudley et al applied the best existing estimate of the volume-outcome effect for several procedures to the California population. In their analysis, they concluded that more than 600 deaths in California and 4000 deaths in the United States could be avoided each year by selective referral to HVHs. In a second study focused on the Medicare population, Birkmeyer et al calculated the number of lives saved by regionalization for 10 high-risk surgical procedures. They estimated that between 800 deaths (5% mortality reduction) to 4300 deaths (25% mortality reduction) could be avoided after elective surgery by implementing regionalization. These authors concluded that regionalization of care for common, intermediate-risk procedures, such as cardiovascular procedures, would save more lives than regionalization of uncommon, high-risk procedures, such as pancreatectoduodenectomy. In a third report, Birkmeyer et al estimated the potential benefits of “universal adoption” of the Leapfrog group’s selective referral guidelines. The Leapfrog group is a health policy advocacy group formed by several Fortune 500 companies in an effort to improve the quality of care provided to their employees. One of their guidelines included selective referral based on minimum volume standards for several complex surgical procedures. Birkmeyer et al estimate that 2600 lives could be saved in urban areas by referring patients to HVHs.

There are several limitations to the current study. The NIS was created by merging administrative data sets from several states. Some argue that administrative data should not be used to assess the quality of care because they do not provide enough physiologic variables for robust case-mix adjustment. In the present study, adjustment was made for several comorbid diseases, indication for hepatic resection, nature of admission (elective, urgent, and emergent), and patient demographics. Several of these variables were associated with increased in-hospital mortality and were entered into the multivariate analysis. After adjusting for case-mix in this fashion, there was no change in the magnitude of the volume-outcome interaction. This was consistent with several previous studies, all with varying methods of case-mix adjustment, that demonstrated that differences in outcomes between HVHs and LVHs are not attributable to variation in patient characteristics. There is no doubt that using a physiologic risk-adjustment tool, such as the APACHE III (Acute Physiology and Chronic Health Evaluation III) score, would provide more accurate comparisons, especially for patients with urgent or emergent admissions. However, the large-scale nature of the present study precludes such data acquisition. Another limitation is that the NIS does not include all US hospitals. The participating hospitals, representing 20% of all hospitals, were stratified according to geographic region, urban or rural location, teaching status, ownership, and bed size to accurately represent care across the entire nation.

This population-based study from a nationally representative database provides information on the outcomes of patients who underwent hepatic resection at US hospitals for a recent 2-year period. The overall operative mortality rate noted in the present study is higher than that reported in large case series from tertiary centers of excellence and provides valuable information to patients and physicians regarding the relative safety of undergoing hepatic resection given certain hospital and patient risk profiles. These findings have important implications for health policy makers and health care providers. Efforts to regionalize complex general surgical procedures should include hepatic resection, especially for high-risk indications such as resection of primary hepatic malignancies or resection of metastatic disease.

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Corresponding author and reprints: Gilbert R. Upchurch, Jr, MD, 1500 E Medical Center Dr, Taubman Center 2210, Ann Arbor, MI 48109-0329 (e-mail: riversu@umich.edu).

REFERENCES
