Hepatic Resection in the United States

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

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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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HEPATIC RESECTION is commonly performed in the United States for resection of metastatic disease and primary hepatobiliary malignancies.1-8 Despite continued improvements in patient selection, operative technique, and perioperative management, many patients remain at high risk for perioperative morbidity and mortality following hepatic resection. Studies using statewide administrative databases have demonstrated that hospitals that perform high volumes (HVHs) of hepatic resection have improved outcomes relative to lower-volume hospitals (LVHs).7-10 However, the estimate of the volume-outcome effect may be biased by the effect of a single HVH in certain states. Moreover, these studies may lack external validity because states may have differing hospital profiles and referral patterns.11,12

High-volume centers have been shown to have superior outcomes for several other surgical procedures, including complex vascular procedures, cardiac surgery, and other major cancer resections.10,13-17 In response to this evidence of improved outcome at HVHs, there are currently health policy initiatives underway in an effort to concentrate high-risk surgery at centers with a high level of experience.18,19 Despite the active nature of current efforts to regionalize surgery, the majority of studies are from single-state databases, and there are few studies using nationally representative data. To obtain an accurate estimate of the volume-outcome relationship for hepatic resection, we conducted a population-based study using a nationally representative database,
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 comorbidity risk.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.

**METHODS**

**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.

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 an HVH have similar outcomes to high-volume surgeons working in the same hospital.23

**HOSPITAL VOLUME**

**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 chi-squared 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 po-
**RESULTS**

**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...
The in-hospital mortality rate was 3.5% at HVHs 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 lobe resection 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.

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### Table 3. Unadjusted In-Hospital Mortality Rates at High- and Low-Volume Hospitals in the United States According to Indication for Hepatic Resection From 1996 to 1997

<table>
<thead>
<tr>
<th>Indication for Surgery</th>
<th>High-Volume Hospitals*</th>
<th>Low-Volume Hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metastatic disease</td>
<td>2.6</td>
<td>4.9†</td>
</tr>
<tr>
<td>Primary hepatic malignancy</td>
<td>6.3</td>
<td>15.5†</td>
</tr>
<tr>
<td>Benign hepatic neoplasm</td>
<td>0.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Biliary tract malignancy</td>
<td>0.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Benign hepatic disease</td>
<td>0.0</td>
<td>5.1</td>
</tr>
<tr>
<td>Benign biliary disease</td>
<td>0.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Traumatic laceration</td>
<td>30.0</td>
<td>26.5</td>
</tr>
</tbody>
</table>

*High-volume hospitals performed 10 or more procedures per year. †Comparison of high- and low-volume hospitals; P < .05 by χ² test.

### Table 4. Independent Variables Associated With In-Hospital Mortality After Hepatic Resection in the United States

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Risk of In-Hospital Mortality, OR (95% CI)</th>
<th>P Value†</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-volume hospital*</td>
<td>0.6 (0.4-0.9)</td>
<td>.02</td>
</tr>
<tr>
<td>Mild to moderate liver disease</td>
<td>2.0 (1.0-3.8)</td>
<td>.04</td>
</tr>
<tr>
<td>Hepatic lobectomy</td>
<td>2.2 (1.4-3.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Age older than 65 years</td>
<td>2.2 (1.4-3.2)</td>
<td>.001</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td>2.7 (1.3-5.7)</td>
<td>.007</td>
</tr>
<tr>
<td>Primary hepatic malignancy</td>
<td>3.0 (1.7-5.2)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Severe liver disease</td>
<td>72.0 (23.7-218.5)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

†Statistical test for independent association of the variable to in-hospital mortality.

Abbreviations: CI, confidence interval; OR, odds ratio.

*High-volume hospitals performed 10 or more procedures per year.
land, Choti et al8 reported the results of 606 hepatic re-
regression). In a second statewide study from Mary-
ters had a mortality rate of 6.2% compared with 24.4%
adjusting for case-mix. The highest-volume cen-
study, procedural volume was associated with mortality
memorial centers (P = .02), chronic pulmo-
several high- and low-volume centers. In the current study,
base, Glasgow et al7 investigated the outcomes of he-
rior to the Surveillance, Epidemiology, End-Results data-
other factors predict-
clude 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.26,20 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 resec-
tion have focused on the relationship of procedural vol-
outcome using state discharge data and the na-
tional Medicare database.7-10 Using the California Office of Statewide Health Planning and Development database, Glasgow et al12 investigated the outcomes of hepatic resection for hepatocellular carcinoma for the state of California from 1990 to 1994. During their study pe-
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 al16 reported the results of 606 hepatic re-
sections performed between 1990 and 1996. The over-
all in-hospital mortality rate was 5.1% and was

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Increased Length of Stay, Adjusted (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-hospital volume</td>
<td>-5 (-9 to 11)</td>
<td>.09</td>
</tr>
<tr>
<td>Age older than 65 years</td>
<td>9 (2 to 15)</td>
<td>.01</td>
</tr>
<tr>
<td>Female sex</td>
<td>10 (5 to 15)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Biliary malignancy</td>
<td>20 (2.3 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>

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

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 me-
tases in Maryland had a lower mortality rate com-
pared with those undergoing resection of primary hepatic malignant, which was similar to our findings.

In a third study investigating operative mortality af-
ter major cancer resections, including hepatic resection, Begg et al19 reported the results from linking Medicare data to the Surveillance, Epidemiology, End-Results data-
base. 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 resec-
tion, 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 suf-
cient to achieve optimal outcomes.23 For complex sur-
gical 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 poten-
tially 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

Abbreviation: CI, confidence interval.
*Statistical test for independent association of the variable to length of stay.
†High-volume hospitals performed 10 or more procedures per year.
associated with decreased risk of postoperative complications and mortality in patients undergoing hepatic resection in Maryland hospitals.\textsuperscript{35} In this same population, having more ICU nurses at night was associated with fewer respiratory complications and decreased resource utilization.\textsuperscript{36}

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.\textsuperscript{34,19,37} In the first study, Dudley et al\textsuperscript{37} 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\textsuperscript{19} 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 pancreatoduodenectomy. In a third report, Birkmeyer et al\textsuperscript{19} 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\textsuperscript{19} 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.\textsuperscript{38} 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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**REFERENCES**

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Correction

Error in Byline. In the article titled “The State of General Surgery Residency in the United States,” published in the November issue of the ARCHIVES (2002;137:1262-1265), the order of author names in the byline was incorrect. The correct order is given here: Amalia Cochran, MD; Spencer Melby, BS; Hugh M. Foy, MD; Marc K. Wallack, MD; Leigh A. Neumayer, MD.

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