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National trends in the use of surgery for benign hepatic tumors in the United States

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Abstract

Background—The widespread use of diagnostic imaging has led to an increase in the incidence and diagnosis of benign liver tumors. The objective of this study was to define the overall use and temporal trends of operative procedures for benign liver tumors using a nationally representative cohort.

Methods—All patients who underwent liver surgery for benign liver tumors between 2000 and 2011 were identified from the Nationwide Inpatient Sample database. Trends in annual volume of liver procedures were analyzed using the average annual percent change (AAPC) assessed by joinpoint analysis.

Results—There were 2,489 open (94.5%) and 144 (5.5%) minimally invasive surgical (MIS) procedures. Partial hepatectomy accounted for 43.8% of all cases ($n = 1,153$). Surgery for patients with benign liver tumors increased from 156 in 2000 to 272 in 2011 (AAPC, 5.8%; 95% CI, 3.2–8.6%). There was decline in the relative use of open operative procedures from 98.1% in 2000 to 92.3% in 2011 (AAPC, –0.4%; 95% CI, –0.7 to –0.1%). In contrast, the proportion of MIS procedures increased from 1.9% in 2000 to 7.7% in 2011 (AAPC, 7.4%; 95% CI, 1.9–13.3%). The median duration of stay among all patients was 5 days (interquartile range, 4–7; 5 days [open] vs 3 days [MIS]; $P < .001$). Inpatient mortality was 0.6% ($n = 15$ [open] vs $n = 0$ [MIS]; $P = .43$) and did not change during the study period ($P > .05$).

Conclusion—Overall volume of surgical management of benign liver tumors has increased substantially over the past decade. There has been a relative shift away from open procedures toward MIS procedures.

Benign liver tumors are relatively common lesions that can be observed in 20–50% of the population at the time of autopsy.^{1–4} Benign liver tumors are classified generally into cystic or solid tumors based on their radiologic features. Cystic tumors tend to be more frequent and can occur in 5 to 15% of the population.^{5,6} Although benign solid lesions probably occur with less overall frequency, these lesions can be often found in women of childbearing

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age.⁷ Over the past decade, the incidence of benign liver tumors has increased,^{8,9} probably related in part to the widespread use of abdominal imaging such as ultrasonography, CT, and MRI.^{10–13} With the discovery of more and more benign liver lesions, the clinician is faced increasingly with the need to make therapeutic decisions regarding the management of these lesions. Although advanced imaging techniques and an improved understanding of the natural history of many benign liver tumors has facilitated therapeutic decision making, the management of these lesions can still be challenging.^{14–17}

The current indications for an operative approach to benign liver tumors include progressive symptoms and suspicion of malignant change.^{18,19} In the setting of benign disease, the overall indication and utilization of surgery may be somewhat subjective and variable. Benign liver tumors are often discovered incidentally on cross-sectional imaging obtained for other reasons. Many patients may also present with nonspecific pain in the setting of a benign liver lesion. Management of patients with benign liver lesions can therefore be challenging and controversial, because the indications for operative intervention may be more ambiguous (eg, pain, diagnostic uncertainty, patient anxiety).²⁰ In this setting, the utilization of surgery for benign liver tumors may vary. Furthermore, the expanding utilization of cross-sectional imaging and subsequent increased discovery of benign liver lesions, as well as the increased use of minimally invasive surgical (MIS) approaches, may impact the relative use of surgery for benign liver lesions. Previous studies on surgery of benign liver lesions have not investigated temporal trends in the utilization of surgery for benign liver lesions. Rather, past data have focused almost exclusively on the morbidity and mortality associated with surgery for benign liver lesions.^{21,22} In addition, most series that assessed the use of operative procedures for benign liver tumors were conducted in a single center over a short period of time.^{23–25} Given this, we sought to characterize the use of operative procedures for benign liver tumors over the last decade using a representative, population-based dataset. Specifically, the objective of the current study was to define the overall and temporal trends in the utilization of surgery, as well as examine in-hospital outcomes, for benign liver tumors using data from the National Inpatient Sample (NIS) database.

MATERIALS AND METHODS

Data sources and samples

We conducted a retrospective analysis using the NIS database to examine the utilization of surgery for benign liver tumors between January 2001 and December 2011. The NIS database is maintained by the Agency for Healthcare Research and Quality as part of the Healthcare Cost and Utilization Project (HCUP) that contains deidentified data on patients enrolled in Medicare, Medicaid, private insurances, and the uninsured. NIS is the largest publicly available all-payer inpatient care database in the United States.²⁶ The NIS contains comprehensive data on 8 million hospital stays gathered from 1,000 hospitals, which represents approximately 20% of stratified sample of all US community hospitals. Data in NIS is obtained from states that participate in HCUP, which represent over 97 percent of the US population. The NIS collects >100 variables, ranging from patient demographics, diagnosis codes, procedure type, and hospital features.

All patients who were discharged with an International Classification of Disease, Ninth Revision, Clinical Modification (ICD-9-CM) diagnostic code for liver benign tumors and biliary passage (2,115) and congenital cystic liver disease (75,162) were included in our study. Patients with ICD-9-CM diagnosis codes for hemangioma (22,804) and lymphangioma (2,281) were included only if patients had procedure codes for liver resection. Liver operative procedure codes were identified using ICD-CM procedure code: partial hepatectomy (50.22), hepatic lobectomy (50.3), hepatic wedge resection (5,012), liver ablation (50.23–50.26), and “other” liver procedures such as enucleation (50.29). MIS was defined as a composite of laparoscopic and robotic procedures using ICD-9-CM coding (laparoscopy, 54.21; robotic, 17.4, 17.41, 17.42, 17.43, and 17.49), as well as laparoscopic ablation of liver lesions (5,025).^{27,28} Information regarding laparoscopic procedures was available for all time periods; however, data for robotic information was only available from October 2008 onward. For all patients, demographic-specific data on age, sex, race, primary payer, hospital teaching status, admission type, and hospital location were abstracted when available. Patient comorbidities (hypertension, diabetes, chronic lung disease, obesity, chronic kidney disease, and congestive heart failure) were defined according to ICD-9-CM codes. Mortality (in-hospital mortality) and duration of stay were extracted directly from the database. Trends in mortality, duration of stay, and procedures type were determined for 3 time intervals (2000–2003, 2004–2007, and 2008–2011). In-hospital perioperative complications were defined using the corresponding ICD-9-CM diagnostic codes and included infection, wound complication, bleeding complication, myocardial infarction, postoperative respiratory complications, cerebrovascular accident, venous thromboembolism, acute renal failure, urinary tract infection, liver failure, digestive complication, postoperative shock, and reoperation.

Statistical analysis

Characteristics of patients, hospitals, and in-hospital outcomes were summarized using standard measures of frequencies and percentage or median and interquartile ranges (IQR), as appropriate. Chi-square analysis was used to assess temporal trends in characteristics of patients, hospitals, and inpatient outcome within a given time period. We utilized joinpoint trends analysis to calculate annual percentage change (APC) statistics that characterize the magnitude and direction of trends in annual volumes and relative utility of operative procedures between 2000 and 2011.²⁹ Through joinpoint analysis, we calculated APC and average APC (AAPC) between 2000 and 2011. For this study, a maximum of 1 joinpoints (2 line segments) were allowed for each analysis. Joinpoint Regression Program was used for the joinpoint analysis (Version 4.0.4, May 2013; Surveillance Research Program, National Cancer Institute, Bethesda, MD), and other statistical analyses employed STATA version 12.0 (StataCorp, College Station, TX).

RESULTS

Patient and hospital characteristics from 2000 to 2011

During the 12-year period, a total of 2,633 hepatic procedures were performed for benign liver tumors. The characteristics of the patients and hospitals are shown in Table I. Median age of the study population was 45 years (IQR, 35–56) and 82.3% ($n = 2,157$) of patients

were female. The majority of patients were Caucasian ($n = 1,542$; 73.7%). Although patient age and race were similar across time periods in the study cohort, there was an increase in the proportion of female patients ($P = .04$). Most cases were performed as an elective operation ($n = 2,010$; 85.7%) in an urban hospital ($n = 1,656$; 97.2%). Liver resection was conducted the most in the South region, with more cases being done in the South region over time ($P < .01$). The majority of hepatic procedures were performed at a teaching hospital ($n = 1,519$; 89.1%), with a slight increase over time (2004–2007, 87.1% vs 2008–2011, 90.4%; $P = .04$). The most common comorbidities were hypertension ($n = 663$, 25.2%), followed by diabetes ($n = 217$, 8.2%) and obesity ($n = 155$, 5.9%). Of note, obesity and chronic kidney disease increased during the study period ($P < .05$). Overall incidence of any complications during the hospitalization was 29.9% (30.5% [open] vs 20.1% [MIS]; $P = .008$) and did not change over the time periods examined ($P = .11$). The median duration of stay among all patients was 5 days (IQR, 4–7; 5 days [open] vs 3 days [MIS]; $P < .001$). Inpatient mortality was 0.6% ($n = 15$ [open] vs $n = 0$ [MIS]; $P = .43$) and did not change during the study period ($P > .05$).

Operative approach

At the time of the operation, the vast majority of cases were performed as an open procedure ($n = 2,489$; 94.5%); the remaining 144 cases (5.5%) were MIS (Table II). Patients who underwent an MIS procedure were often older (45 years [open] vs 50 years [MIS]; $P = .004$) and more likely to have Medicare coverage (14.4% [open] vs 22.6% [MIS]; $P = .02$). Other patient and hospital characteristics were comparable in the open versus MIS groups. The most common hepatic operation was a partial hepatectomy, accounting for 43.8% of all cases ($n = 1,153$) followed by hepatic lobectomy ($n = 660$; 25.1%). Hepatic wedge resection and liver ablation accounted for 7.9% ($n = 207$) and 1.9% ($n = 50$) of cases, respectively. Among open procedures, partial hepatectomy was the most common hepatic procedure ($n = 1,110$; 44.6%) with hepatic lobectomy accounting for one-fourth of all open procedures ($n = 648$; 26.0). Hepatic wedge resection ($n = 188$; 7.6%) and liver ablation ($n = 15$; 0.6%) were conducted less often among open cases. Among all MIS cases, partial hepatectomy was most commonly performed ($n = 43$, 29.9%), whereas approximately one-third of MIS cases involved liver ablation ($n = 40$, 27.8%).

Trends in individual operative procedures as well as the proportion of each procedure were then evaluated to assess general shifts in utilization of surgery for benign liver tumors (Fig 1). Of note, the number of hepatic procedures performed for patients with benign liver tumors increased from 156 in 2000 to 272 in 2011 (AAPC, 5.8%; 95% CI, 3.2–8.6%). Although the number of open procedures for benign liver tumors increased from 153 in 2000 to 251 in 2011 (AAPC, 4.4%; 95% CI, 2.2–6.8%), there was a decline in the relative use of open procedures from 98.1% in 2000 to 92.3% in 2011 (AAPC, –0.4%; 95% CI, –0.7 to –0.1%; Fig 2). The annual volume of MIS procedures increased from 3 in 2000 to 21 in 2011 (AAPC, 11.6%; 95% CI, 5.0–18.6%). Similarly, the proportion of MIS procedures among all patients undergoing a liver operation for a benign liver tumor increased from 1.9% in 2000 to 7.7% in 2011 (AAPC, 7.4%; 95% CI, 1.9–13.3%; Fig 2). After excluding liver ablation, the total number of MIS procedures increased from 31 in period 2000–2003 to 37 in period 2008–2011 (AAPC, 5.0; 95% CI, –4.7 to 15.6; $P = .35$). The total number of

partial hepatectomies increased from 54 in 2000 to 142 in 2011 (AAPC, 7.9%; 95% CI, 5.3–10.6%); similarly, the proportion of cases that were characterized as a partial hepatectomy also increased from 34.6% in 2000 to 52.2% in 2011 (AAPC, 3.1%; 95% CI, 1.3–4.9%). In contrast, the number of hepatic wedge resections decreased from 18 in 2000 to 14 in 2011 (AAPC, –4.6%; 95% CI, –8.0 to –1.0%) as reflected in the relative decline from 11.5% in 2000 to 5.1% in 2011 (AAPC, –8.5%; 95% CI, –10.4 to –6.5%). There was no trend in the use of hepatic lobectomy (AAPC, 0.9%; 95% CI, –3.1 to 5.1%) or the relative use of hepatic lobectomy (AAPC, –1.9%; 95% CI, –4.5 to 0.6%) over the study period.

Trends among various subgroups

Relative utilization of open and MIS were assessed in various subgroups (Table III). Although there was a decline in the relative use of open versus MIS procedures across all subgroups, the increase in relative utility of MIS was most pronounced among younger patients (age < 65 years [AAPC, 8.4%; 95% CI, 0.1–17.3%]). Also, relative use of an open approach decreased most among teaching (AAPC, –0.9%; 95% CI, –1.7 to –0.2%) and urban (AAPC, –0.9%; 95% CI, –1.5 to –0.2%) hospitals.

DISCUSSION

Benign liver tumors are common lesions that may be present in up to 20% of the population at autopsy.^{6,30} With the expanding use of abdominal imaging, benign liver tumors are being identified increasingly³¹ and continue to represent a management challenge.²² Benign liver tumors are classified into solid or cystic tumors according to features on radiographic imaging.¹ The most common solid benign liver tumors include hemangiomas, focal nodular hyperplasia, and hepatic adenoma, whereas simple cysts represent the most common nonsolid lesion.³² Although benign liver tumors can have varied natural histories and need to be managed using an individualized approach, the main indication for operative resection of most benign liver tumors is the presence of significant clinical symptoms or potential malignant transformation.^{33–36} Although malignant transformation of benign hepatic tumors is an uncommon phenomenon, it can occur. In particular, patients with multiple, large adenomas have a greater chance for malignant transformation.^{37,38} Most previous studies on the topic of operative management of benign liver tumors come from a single-institution or cases series derived from multiple academic centers.^{39,40} These data may not reflect the management of benign liver lesions at the national, population-based level. In addition, no previous study has specifically examined trends in the utilization of surgery for benign liver tumors as an operative indication. The current study is important because we utilized a nationally representative cohort to assess both the overall use of operative procedures for benign liver tumors as well as the relative utility of MIS in a nationally representative cohort. Specifically, we demonstrated that the volume of operative procedures for benign liver tumors has increased significantly over the past decade. In addition, the relative use of MIS has increased compared with open procedures in managing benign liver tumors. Although surgery for benign liver tumors has increased, morbidity and mortality remained the same over time with up to one-third of patients experiencing a complication.

Over the time periods examined, there was a significant increase in the total volume of operative procedures performed for benign liver tumors. Several investigators have previously suggested that an increasing proportion of patients with benign liver tumors receive therapeutic procedures.^{41,42} Unlike previous work, data from the current study specifically quantified the increase in operative procedures for benign liver tumors using a nationally representative dataset.^{19,43,44} In doing this, we noted that the number of hepatic procedures performed for patients with benign liver tumors increased by >50% from 2000 to 2011 with an AAPC of 5.8% (Fig 1). Furthermore, the increase in operations was most attributable to an increase in the proportion of patients who underwent a partial hepatectomy (from 34.6% in 2000 to 52.2% in 2011). The reason for the increase in the utilization of operative intervention for benign liver tumors is clearly multifactorial and was beyond the scope of the current study. Possible explanations include increased detection of benign lesions with the ubiquitous use of cross-sectional imaging, as well as the proliferation of the MIS approach to hepatopancreatobiliary (HPB) surgery.^{2,27} Other investigators have suggested that the increasing acceptance of laparoscopy may, in part, explain the increase use of the operative approach for benign liver tumors.⁴⁵ For example, in a review by Toro et al,⁴² the authors reported that laparoscopy had increased the use of hepatic resection for benign liver tumors. Our data were consistent with this finding; there was a marked increase in the use of MIS procedures relative to open procedures for operative management of benign liver tumors over the time periods examined. Several investigators have reported that an MIS approach can be performed safely for even large, complicated, benign lesions.^{23,46–48} Whether a less invasive operative approach should change the indication for surgery remains, however, controversial. Although some surgeons have advocated that an MIS approach should allow for the expansion of the indications for surgery of benign liver tumors, others have disagreed.²¹ Data from the current study demonstrate that the expansion of the MIS approach parallels the increase in surgery for benign liver tumors, suggesting that the two may indeed be related. Although we cannot comment on whether the indications for operative management were appropriate or not, the data serve to emphasize that HPB surgeons need to remain vigilant regarding the indications for operations, regardless of advances in MIS.

Interestingly, although we noted that the overall utilization of surgery for benign tumors increased over the last decade, the incidence of perioperative complications remained the same. In fact, although mortality was very low at <1%, the incidence of perioperative complication was about 30% or 1 in 3 patients. These data are consistent with other reports that have noted that hepatic resection of benign liver tumors can be performed safely with a low mortality, but with a modest amount of morbidity.^{19,49} In fact, most large series that have reported on perioperative outcomes for patients undergoing HPB operative procedures for either a benign or malignant indication have reported a morbidity in the range of 30–40%.^{27,50} In addition, patients undergoing an operation for a benign procedure had a median hospital stay of 5 days, which again was comparable with previous data on duration of stay reported for liver resection for malignant indication.²² Of note, in the current study, the incidence of complications, as well as median duration of stay, was lower among patients with benign liver tumors who underwent an MIS versus open approach. These population-based data were consistent with previously published data from highly specialized academic

centers, which have reported lower morbidity with MIS versus open operative procedures.^{45,51,52} Collectively, the data suggest that surgery for benign liver tumors was associated with a low mortality, but a modest morbidity.

Avoiding unnecessary operations for patients with asymptomatic benign liver tumors should be the standard, even though the MIS liver surgery is safe and feasible.⁵³ Most benign liver lesions can be managed appropriately with simple observation. In fact, as imaging becomes more sensitive and specific for hepatic masses, asymptomatic benign appearing lesions can be followed with greater confidence.⁵⁴ The risk of hemorrhage, rupture, or malignant transformation is very low with the exception of hepatic adenomas, which have an increased risk of these complications based on their size.⁵⁵ On occasion, the distinction between a benign and malignant lesion can be difficult to discern based on cross-sectional imaging alone, leading to diagnostic uncertainty and the need for resection. However, the indication for surgery of most benign lesions largely involves the presence of severe or progressive symptoms. Kneuert et al²⁰ reported on 255 patients who underwent surgery for benign liver lesions and who completed a quality-of-life survey. In that series, the most common presenting symptoms included abdominal pain (70.9%), nausea/vomiting (5.0%), and early satiety (5.0%). The operation involved less than a hemihepatectomy (68.2%), and a laparoscopic approach was utilized in 40.8% of patients. After the operation, the proportion of patients who reported moderate to extreme pain decreased from 46.9% to 15.6% and 6.8% at 6 months and 1-year, respectively ($P < .001$). Patient self-reported mean pain scores also decreased over time (1.65 [preoperative] vs 0.63 [6 months] vs 0.28 [1 year]; $P < .001$). Patients with “moderate to extreme” pain preoperatively were more likely to report an improvement in pain scores (odds ratio, 1.96; 95% CI, 1.05–3.66; $P = .03$). As such, the authors concluded that only those patients with significant preoperative symptoms derive the most benefit from operative intervention.

Our study had several limitations that should be considered. First, benign liver tumors and comorbidities were identified using ICD-9-CM codes in the NIS database. As such, we could not stratify the analyses by more specific categories of benign liver tumors, such as hemangioma, focal nodular hyperplasia, and hepatic adenoma. Although the NIS provides data to quantify nationwide use of inpatient procedures, the NIS does not allow quantification of outpatient procedures for liver benign tumors. As such, those patients who may have undergone a minor procedure such as laparoscopic cyst fenestration may have been omitted; however, the number of such cases is likely to be low. Although the number of MIS cases was relatively small, MIS surgery for benign liver disease not the main focus of the current study. Rather, we sought to define overall surgical trends in the use of operative intervention for benign liver lesions, highlighting the relative use of an MIS approach. Finally, we were unable to characterize the reason or “appropriateness” of any procedure for a benign indication. However, the purpose of the current study was to define temporal trends in nationwide operative procedures associated with benign liver tumors in the United States, irrespective of the clinical indication.

In conclusion, the overall volume of operative procedures for the management of liver benign tumors has increased substantially over the past decade. There has been a relative shift away from open procedures and toward MIS procedures. Future studies are warranted

to assess the indication and therapeutic guidelines for benign liver tumors so as to define which patients are most likely to benefit from an operative approach.

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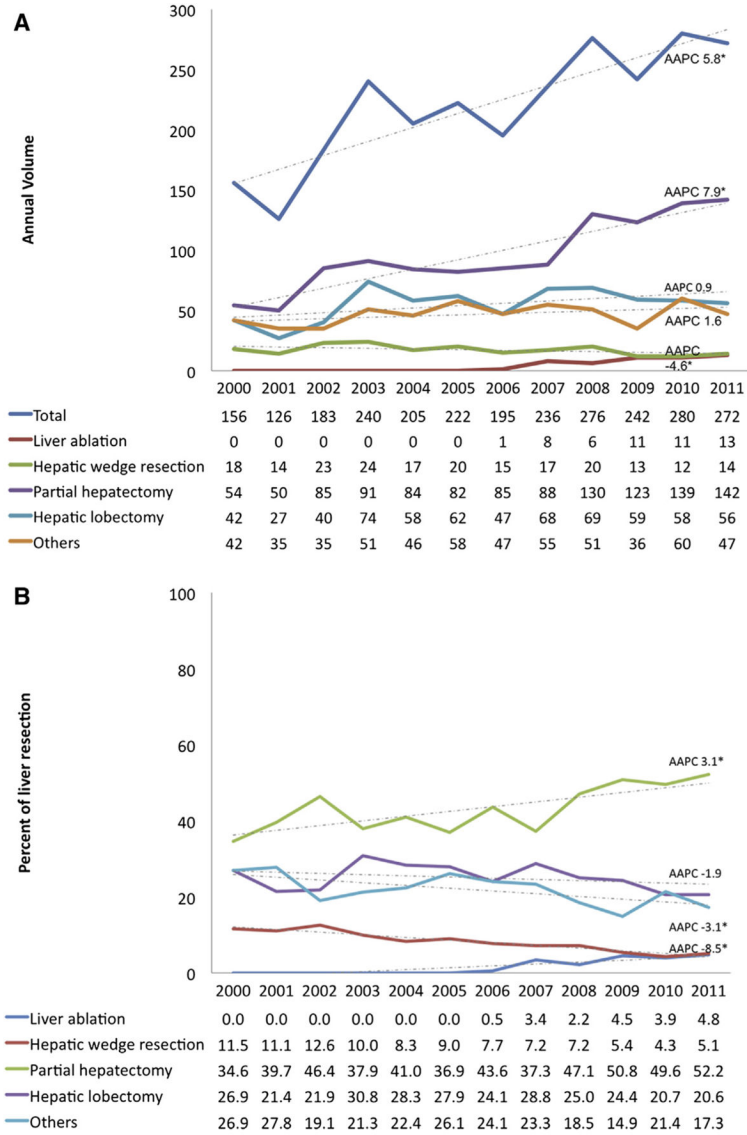


Fig 1. Trends in (A) annual volume and (B) proportion of hepatic resection for benign liver tumors. (Color illustration of this figure is available online.)

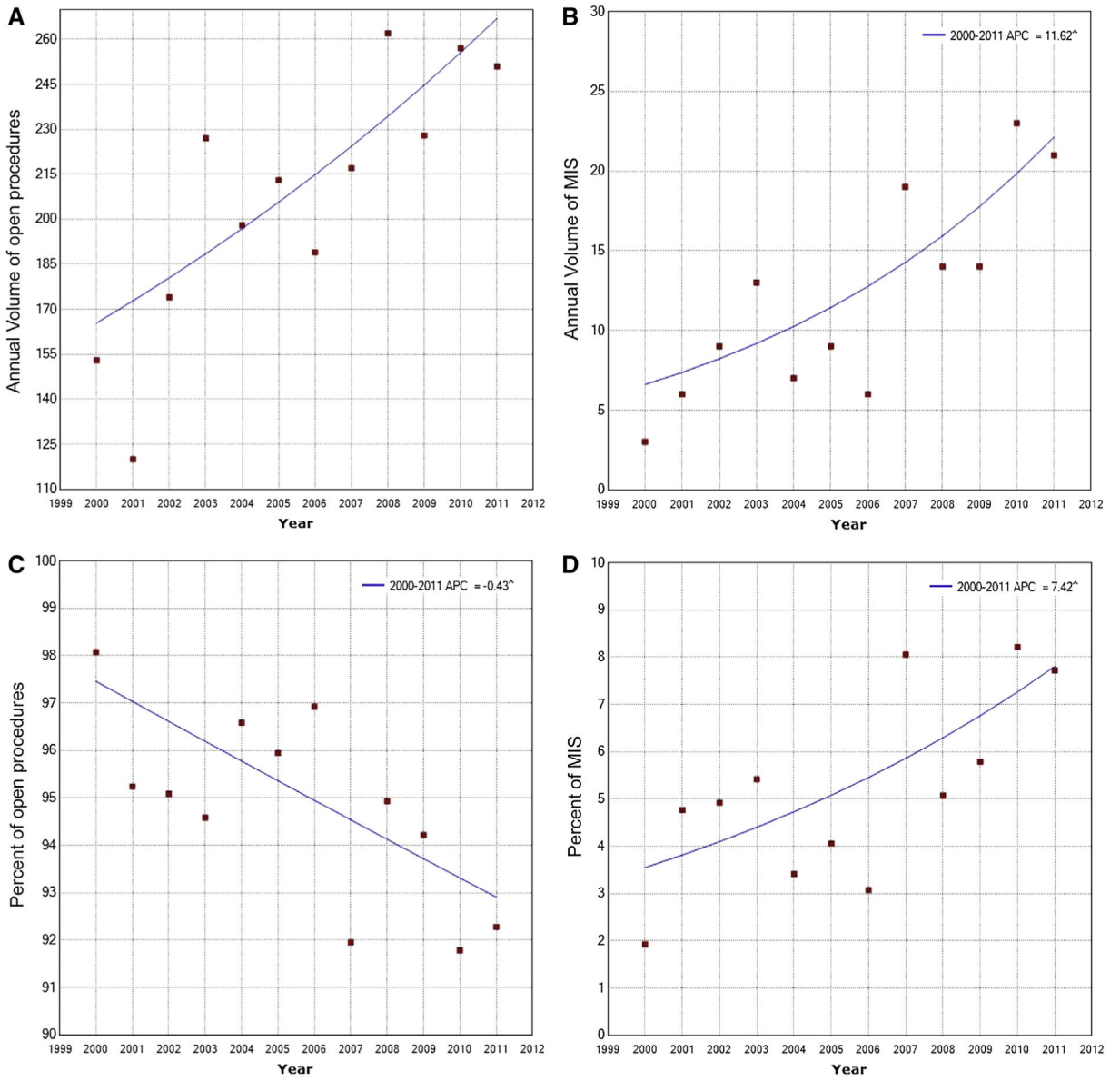


Fig 2. Trends in annual volume of (A) open procedures and (B) minimally invasive surgery (MIS) procedures and proportion of (C) open procedure and (D) MIS procedures of hepatic resection for benign liver tumors.

Characteristics of patients who had hepatic procedures for benign liver tumors in the United States

Table 1

Characteristic	Overall (n = 2,633)	Period 1 (2000–2003; n = 705)	Period 2 (2004–2007; n = 858)	Period 3 (2008–2011; n = 1,070)	P value
Gender					.04
Female	2,157 (82.3)	557 (79.1)	709 (83.2)	891 (83.6)	
Age (y), median (IQR)	45 (35–56)	45 (35–54)	46 (36–56)	45 (34–56)	.55
Race					.81
Caucasian	1,542 (73.7)	278 (73.7)	473 (73.2)	691 (74.1)	
African American	226 (10.8)	53 (10.3)	65 (10.1)	108 (11.6)	
Hispanic	180 (8.6)	44 (8.6)	63 (9.8)	73 (7.8)	
Other	144 (6.9)	38 (7.4)	45 (7.0)	61 (6.5)	
Comorbidities					
Hypertension	663 (25.2)	167 (23.7)	210 (24.5)	286 (26.7)	.30
Diabetes	217 (8.2)	53 (7.5)	64 (7.5)	100 (9.4)	.23
Chronic lung disease	58 (2.2)	22 (3.1)	17 (2.0)	19 (1.8)	.15
Obesity	155 (5.9)	25 (3.6)	45 (5.2)	85 (7.9)	<.001
Admission type (n = 2,345)					.17
Elective	2,010 (85.7)	358 (84.8)	720 (84.3)	932 (87.2)	
Nonelective	335 (14.3)	64 (15.2)	134 (15.7)	137 (12.8)	
Hospital location (n = 1,704)					.28
Urban	1,656 (97.2)	NA	631 (96.6)	1,925 (97.5)	
Rural	48 (2.8)	NA	22 (3.4)	26 (2.5)	
Geographic region (n = 1,723)					<.001
Northeast	364 (21.1)	NA	114 (17.5)	250 (23.4)	
Midwest	432 (25.1)	NA	144 (22.0)	288 (26.9)	
South	493 (28.6)	NA	190 (29.1)	303 (28.3)	
West	434 (25.2)	NA	205 (31.4)	229 (21.4)	
Hospital teaching status, (n = 1,704)					.04
Teaching	1,519 (89.1)	NA	569 (87.1)	950 (90.4)	
Nonteaching	185 (10.9)	NA	84 (12.9)	101 (9.6)	
Any complication	788 (29.9)	200 (28.4)	235 (27.4)	353 (33.0)	.11

Characteristic	Overall (n = 2,633)	Period 1 (2000–2003; n = 705)	Period 2 (2004–2007; n = 858)	Period 3 (2008–2011; n = 1,070)	P value
Duration of stay, median (IQR)	5 (4–7)	5 (4–7)	5 (4–7)	5 (3–7)	.36
Inpatient mortality	15 (0.6)	6 (0.9)	3 (0.4)	6 (0.6)	.42

IQR, Interquartile range; NA, not applicable.

Table II

Volume and proportion of inpatient hepatic procedures for benign liver tumors, 2000–2011

	Overall	Period 1 (2000–2003)	Period 2 (2004–2007)	Period 3 (2008–2011)
Total (<i>n</i>)	2,633	705	858	1,070
Hepatic wedge resection	207 (7.9)	79 (11.2)	69 (8.0)	59 (5.5)
Partial hepatectomy	1,153 (43.8)	280 (39.7)	339 (39.5)	534 (49.9)
Hepatic lobectomy	660 (25.1)	183 (26.0)	235 (27.4)	242 (22.6)
Other procedure*	613 (23.3)	163 (23.1)	215 (25.0)	235 (21.9)
Open, <i>n</i> (%)	2,489 (94.5)	674 (95.6)	817 (95.2)	998 (93.2)
MIS, <i>n</i> (%)	144 (5.5)	31 (4.3)	41 (4.8)	72 (6.8)

* Other procedure includes liver ablation, cauterization of hepatic lesion and enucleation of hepatic lesion.

MIS, Minimally invasive surgery.

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Temporal trends in liver resection for benign liver tumors stratified by patients and hospital characteristics, 2000–2011

Table III

Characteristic	Period 1 (2000–2003)	Period 2 (2004–2007)	Period 3 (2008–2011)	2000–2011 AAPC	95% CI
Age <65 (n = 1,893)					
Open	592 (96.1)	730 (95.4)	869 (93.8)	-0.3	(-0.8, 0.2)
MIS	24 (3.9)	35 (4.6)	57 (6.2)	8.4*	(0.1, 17.3)
Female (n = 2,157)					
Open	537 (96.4)	673 (94.9)	834 (93.6)	-0.4	(-0.9, 0.1)
MIS	20 (3.6)	36 (5.1)	57 (6.4)	9.7	(-0.1, 20.5)
Teaching hospital (n = 1,519)					
Open	NA	542 (95.3)	885 (93.2)	-0.9*	(-1.7, -0.2)
MIS	NA	27 (4.8)	65 (6.8)	14.9	(-0.6, 32.8)
Urban hospital (n = 1,656)					
Open	NA	598 (94.8)	954 (93.1)	-0.9*	(-1.5, -0.2)
MIS	NA	33 (5.2)	71 (6.9)	11.3	(-2.9, 27.6)

AAPC, Annual percent change; MIS, minimally invasive surgery;

* P<0.05.