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Safety, utilization, and cost of image-guided percutaneous liver biopsy among cancer patients

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Abstract

Image-guided percutaneous liver biopsy(PLB) is a diagnostic tool for lesions in the liver. Hemorrhage is the most common complication. We selected patients with a diagnostic claim for cancer who had undergone PLB. There were a total of 26,941 patients who underwent PLB. Hemorrhage risk was 1.43% among patients undergoing PLB. When stratified by setting, odds of hemorrhage were 4.5 times higher when biopsy was performed in an inpatient setting ($p<0.001$). Risk factors associated with hemorrhage included marital status, liver cancer and comorbidity score. The use of PLB has increased over time. Reassuringly, the hemorrhage risk associated with PLB is low.

INTRODUCTION

Hepatocellular carcinoma (HCC) is the fifth most frequently diagnosed cancer among men and the seventh among women worldwide.[1] Besides primary hepatic malignancy, the liver is also a common site of metastasis for lung, pancreatic, colorectal, breast, and stomach cancers.[2,3] Percutaneous liver biopsy (PLB) plays an important role in definitive diagnosis of focal hepatic lesions.[4] Image guidance was first introduced in the late 1980s, and has become a standard of practice in PLB of focal lesions.[4–7] Ultrasound and computed tomography (CT) are the most commonly used imaging modalities. Occasionally, magnetic resonance imaging and fluoroscopy are also used to guide biopsy. Other important uses of PLB include staging of diffuse liver disease and treatment efficacy monitoring.[4] The use of image guidance is more controversial in these latter clinical settings.[2,4]

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PLB in general is considered a safe procedure.[8] Procedure associated mortality rate is estimated to be less than 0.01%, with hemorrhage being the most common post-procedure complication and the major cause of death.[2,8,9] However, some previous studies suggest biopsy of neoplastic lesions is associated with higher risk of hemorrhage. The incidence of life threatening hemorrhage in patients with diffuse liver disease is estimated to be between 0.04% and 0.1%, whereas that among cancer patients ranges from 0.28% to 3.6%. [2,10–13] There is no study that uses data from large multicenter cohorts to study the rate and risk factors of hemorrhage after PLB among cancer patients in the U.S.

According to estimates from the Surveillance, Epidemiology, and End Results (SEER) Program, liver cancer has been increasing at an average of 4% annually in the last ten years.[14] The practice of liver biopsy has also changed considerably in the past few decades with the introduction of image-guidance and shift towards outpatient biopsy. There remains a lack of literature that characterizes these changes taking place. Better understanding of changes in procedure setting, utilization, and cost of PLB in the U.S. may help identify areas of inefficiencies and inform future allocation of healthcare resources.

Based on these issues, we decided to undertake a study that focuses on image-guided PLB among cancer patients in the U.S. Using a large administrative dataset, we aim to characterize the safety, utilization and cost of PLB in the last decade.

METHODS

Data Source

We used data from the Perspective database (Premier Inc., Charlotte, North Carolina), which is a voluntary, fee-supported database that collects inpatient and outpatient information from over 600 hospitals throughout the United States.[15] Hospitals participating in this database represented all regions of the nation (Northeast: 13%, Midwest: 25%, South: 42%, West: 20%).[16] The majority of hospitals were small to midsize nonteaching facilities located in urban areas. Perspective provided not only demographic, disease and procedure information, but also a date-stamped log of all billed items. In 2006, Perspective collected almost 5.5 million hospital discharges, which represented about 15% of all hospitalizations in the nation.[17] Perspective offers rich information for quality and outcomes research and has been used in several health services studies.[16–23]

Patient Selection

We selected cancer patients (International Classification of Disease, Ninth Revision [ICD-9] codes 140-208) who had undergone one or more image-guided percutaneous liver biopsies between 2006 and 2012. Percutaneous liver biopsy was identified using both ICD-9-CM code (50.11) and procedure codes specific to the Premier dataset. Image-guidance for procedures during the biopsy hospital visit were selected using ICD-9-CM codes (88.76, 88.01), CPT codes (ultrasound guidance for needle placement - 76942, CT guidance for needle placement - 77012, fluoroscopic guidance for needle placement - 77002, MRI guidance for needle placement – 77021, Real time abdominal ultrasound with image -

76700, 76705), and text from field notes. If a patient had multiple biopsies, the most recent record was utilized.

Patient, Procedural, and Hospital Factors

Patient demographic variables examined included age (<60, 60–69, 70–79, 80 and above), sex, race (white, black, other), marital status (married, single, unknown), and insurance status (Medicare, Medicaid, commercial, uninsured). Two patient clinical factors were analyzed: cancer site (primary liver cancer only, liver cancer with another cancer(s), non-liver cancer(s)), and the Elixhauser Comorbidity Index (0–4, 5–8, 9–12, 13 and above).[24] Biopsy-related variables examined included procedure setting (inpatient or outpatient), type of image guidance (ultrasound, CT, or other), and year of biopsy (2006–2012). Hospital level variables analyzed were rural versus urban locality, regional location (Northeast, Midwest, South, or West), teaching status (yes or no), and bed-size (<400, 400–600, >600).

Outcome Measures

The primary outcome of interest was any hemorrhage after image-guided PLB. Hemorrhage was defined as a claim for a bleeding event or blood transfusion during the biopsy hospital visit or the subsequent hospital visit if within one month of the biopsy. The claims were selected using ICD-9 codes for hemorrhage (459.0, 958.2, 998.11, 998.12) or for transfusion after a hemorrhage (99.01, 99.03, 99.04, 99.07) and CPT code (36430).

We also looked at changes in the total utilization and median cost of image-guided PLB by the calendar year. Total number of biopsy claims and cancer patients present in the dataset is tallied for a given calendar year. All biopsies a patient received are counted. For cost estimation, we took an institutional perspective. The premier Perspective dataset provided estimate of the actual cost to treat a patient, which included both variable costs and fixed costs. Approximately three quarters of the hospitals in the dataset submit cost data directly from their internal accounting systems, while the rest provide estimates based on Medicare cost to charge ratios.[18,19,21] Since cost data was bundled per hospital visit, we used only outpatient data for estimation of procedure cost so that cost associated with other aspects of the visit is minimal.

Statistical Analysis

To determine which patient, procedural, and hospital characteristics were associated with biopsy setting (inpatient or outpatient), we first conducted bivariate analysis using the Chi-square test, and then entered into a multivariable generalized estimation equation (GEE) model variables with a significance level of $p<0.05$. GEE model was used to adjust for clustering at the hospital level. Similarly, frequencies of hemorrhage for each categorical risk factor were assessed using the Chi-square test. Multivariable GEE model was then used to determine independent association between each risk factor and post-biopsy hemorrhage. Results were reported in odds ratios (OR) with 95% confidence intervals and p values. All analyses were conducted using SAS version 9.2 (SAS Institute, Inc, Cary, North Carolina).

Sensitivity Analysis

Since we analyzed only the most recent PLB per patient and that a history of previous PLB might be related to risk of hemorrhage, we conducted a sensitivity analysis by adding a dichotomous variable for prior biopsy to our hemorrhage GEE model.

RESULTS

Between 2006 and 2012, 26,941 cancer patients in our cohort received image-guided PLB. The majority of patients were white (67.8%), above 60 years old (70.1%) and insured by Medicare (56.2%). There were slightly more males (53.1%) than females. Three thousand six hundred and thirty-nine (13.5%) patients were diagnosed with only liver cancer, 5,029 (18.7%) had liver cancer diagnosis in additional to other cancer(s), while the rest (67.8%) had cancer(s) at other sites. Cohort characteristics are summarized in Table 1.

We selected the most recent biopsy record for each patient, of which 15,608 (57.9%) were conducted in the outpatient setting. The majority of biopsies (67.2%) were guided by CT imaging, followed by 28.5% by ultrasound, and 4.7% by fluoroscopy, MRI, or other imaging modalities. Bivariate analysis showed that patient characteristics differed between those receiving image guided PLB in the inpatient versus outpatient setting for all variables analyzed (Table 1). Hospital characteristics including urban locality, regional location, teaching status, and bed size were also associated with likelihood of receiving inpatient versus outpatient biopsy. We then constructed a multivariable GEE model to explore patient and hospital characteristics associated with receiving biopsy in inpatient versus outpatient settings (Table 1). Biopsy in the outpatient setting became more common over time. In 2006, patients were half as likely to receive image-guided PLB as an outpatient than in 2012 (OR=0.61, 95% CI: 0.48–0.77). The odds of receiving biopsy as an outpatient versus inpatient were not different between years 2008–2012. Outpatient biopsies were more likely to be CT-guided, while ultrasound guidance was more common in the inpatient setting. Patients with liver cancer diagnosis as well as those with a comorbidity score less than 5 were more likely to have an outpatient biopsy. Those over 80 years old were less likely to receive the biopsy as an outpatient compared to those of other ages (OR=0.76, 95% CI: 0.70–0.82). All minority races were more likely to have an inpatient biopsy than white patients. Compared to Medicare patients, Medicaid and uninsured patients were less likely to receive biopsy as an outpatient (OR=0.65, 95% CI: 0.57–0.74; OR=0.55, 95% CI: 0.45–0.68), whereas patients with private insurance were more likely to receive it as an outpatient (OR=1.24, 95% CI: 1.16–1.33). Outpatient biopsies were more common in hospitals serving a rural population (OR=2.06, 95% CI: 1.41–3.02).

Hemorrhage after image-guided PLB was uncommon, occurring in approximately 1.43% (n=387) of cancer patients undergoing the procedure. However, almost half (44.9%) of those who experienced hemorrhage required blood transfusion. The proportion of patients experiencing hemorrhage was much higher after inpatient biopsy (2.6%) than outpatient biopsy (0.6%, $p<0.001$). Ultrasound guided and CT guided PLB had similar incidence of hemorrhage (1.4% and 1.3% respectively), while hemorrhage risk associated with other image-guidance modalities was almost 3 fold higher (3.3%, $p<0.001$). Hemorrhage was more common among patients with liver cancer diagnosis (1.9%) compared to those without

liver cancer diagnosis (1.3%). Risk of hemorrhage did not change over time (p=0.9). In a multivariable model that included patient, procedural, and hospital characteristics, we found marital status, comorbidity score, cancer site(s), and biopsy setting (inpatient vs. outpatient to be independently associated with hemorrhage risk (Table 2). Single patients were at lower risk of hemorrhage compared to married patients (OR=0.74, 95% CI: 0.58–0.95). Patients with liver cancer diagnosis were more likely to experience hemorrhage than patients with cancer(s) at other sites (liver cancer only OR=1.91, 95% CI: 1.49–2.45; liver and other cancer(s) OR=1.49, 95% CI: 1.13–1.96). Those with an Elixhauser comorbidity score less than 5 were about half as likely to have a hemorrhage event than patients with a comorbidity score between 5 and 8 (OR=0.57, 95% CI: 0.39–0.85). Comorbidity scores higher than 8 were not associated with further increase in hemorrhage risk. While imaging modality was not independently associated with the outcome, patients receiving the biopsy as an inpatient remained at higher risk for hemorrhage after controlling for other variables in the model (OR=4.48, 95% CI: 3.32–6.05). None of the four hospital level variables were associated with hemorrhage risk.

In our sensitivity analysis, we found that 663 (2.46%) of our study cohort had prior PLBs (image-guided or non-image guided). However, adding prior PLB as a dichotomous variable to our GEE model for hemorrhage did not change parameter estimates or significance determination of other variables in the model (Supplemental Table1).

There were a total of 27,617 image-guided PLB claims over the seven-year study period. The number of claims more than doubled from 2,228 in 2006 to 5,410 in 2012 (Table 3). The growth was mainly seen among outpatient image-guided PLB. Outpatient claims increased 3.6-fold (from 925 in 2006 to 3,372 in 2012) while inpatient claims increased 1.6-fold (from 1,303 in 2006 to 2,038 in 2012). The median cost of outpatient image-guided PLB increased by 25.1% from $940 in 2006 to $1,176 in 2012. When stratifying by imaging modality, the median cost was $1,456 for ultrasound-guided PLB, $1,445 for CT-guided PLB, and $2,607 for PLB guided by other imaging modalities.

DISCUSSION

Image-guided percutaneous liver biopsy is used with increasing frequency as a diagnostic tool, with overall procedure utilization increasing by 2.4 fold, and outpatient procedure volume increasing by 3.6 fold between 2006 and 2012. The majority of PLBs were performed in the outpatient setting, and guided by CT scan. Hemorrhage is the most common post-biopsy complication and major cause of death. Our study shows that with image guidance, the overall risk of a hemorrhage or transfusion after image-guided PLB is 1.43%, and only 0.6% among patients selected to undergo outpatient biopsy.

Previously reported hemorrhage risk among patients with malignancies ranged from 0.28% to 3.6%.[10–13] The variation in observed hemorrhage rates may be due to differences in sample size, center experience, or method for case/complication identification. Most of these studies were conducted in the late 80s or early 90s, and included subjects from single institutions.[10–12] Our hemorrhage risk estimate was closest to that reported in a more recent study in the UK (1.6%), which also used a nation-wide hospital administrative dataset.[13] In

our cohort, patients with liver cancer diagnosis had a higher risk of hemorrhage compared to patients without liver cancer diagnosis. The higher hemorrhage risk among liver cancer patients may be a function of the small vessels associated with tumors being more fragile and prone to rupture.[11]

Differences in hemorrhage rates between biopsy settings may be due to selection bias, since patients need to meet certain criteria to be referred for outpatient biopsy. Furthermore, the difference is likely due to variables not included in our regression model such as medication, since adjusting for variables in the GEE model did not have much effect on the inpatient versus outpatient odds ratio estimate. There might also be detection bias since patients admitted to the hospital will be monitored by healthcare professionals, which may lead to better detection and recording of less severe hemorrhage events compared to patients discharged home.

We observed a significant shift from inpatient to outpatient liver biopsy between 2006 and 2008. The recommendations for more outpatient liver biopsy started as early as the late 1980s.[8,25] Outpatient liver biopsy was recommended based on the observation that approximately 60% of complications associated biopsy occurred within the initial 2 hours and 96% within the first 24 hours.[10] In 1989, the American Gastroenterological Association advised that biopsy be undertaken as an inpatient if patient was of advanced age, had serious coagulopathies, ascites, severe liver disease (e.g. hepatic failure, severe jaundice, significant extrahepatic obstructure), encephalopathy or severe diseases in other organ systems (e.g. congestive heart failure).[8]

Although the above guidelines were not specific for biopsy of suspected malignancies, we found characteristics of cancer patients receiving inpatient versus outpatient biopsy to be largely inline with the general practice guidelines. Our data showed that patients over eighty years of age were less likely to receive biopsy as an outpatient. The Elixhauser comorbidity score, which accounts for underlying liver disease, coagulopathy, and major disease in organ systems, was negatively associated with likelihood of outpatient biopsy.[24] However, we also found sex, race, marital status, and insurance status to be independently associated with likelihood of receiving biopsy as an outpatient. Of the two most commonly used image-guidance modalities, CT was more frequently used in the outpatient setting, while ultrasound more so in the inpatient setting. The type of imaging modality used did not independently associate with differences in hemorrhage risk.

Total volume of image-guided PLB increased 2.43 fold from 2006 to 2012. When adjusting for changes in the number of cancer patients in the dataset, there remained a 1.45 fold increase in procedure volume per 100,000 cancer patients. This suggests that the increase in utilization of image-guided PLB is not only due to increase in cancer incidence, but also an increase in the percentage of patients biopsied. In our dataset, cost of ultrasound-guided PLB was approximately the same as those performed under CT-guidance. This was different from a previous cost benefit study by Kliewer et al, who found PLB under ultrasound-guidance to cost less than that under CT-guided.[26] CT-guided PLB was estimated to be 1.89 times as expensive as ultrasound-guided PLB. This discrepancy may be due to the use of different cost estimates (median versus average costs). Furthermore, Kliewer et al accounted for

opportunity costs of CT and ultrasound machine usage, as well as complication and retesting costs. However, their study was based on a small sample (n=437) from a single institution, whereas our dataset provide a large sample of hospitals across the nation. It should be noted that aside from cost considerations, ultrasound-guided PLB offers the extra benefits of allowing for real-time needle placement guidance, avoiding ionizing radiation, and shorter procedure time compared to CT-guided PLB.[4]

There are several limitations with our study. First of all, we did not know the indication for the liver biopsy. While all patients had a diagnostic code for cancer, we did not know if the biopsy was for diagnosis, staging or for underlying liver diseases. Secondly, we don't have information on the number of passes, type of needle used, or drugs administered (e.g. anticoagulants) prior to biopsy, which could all be related to hemorrhage risk after biopsy.[4,27,28] Thirdly, we have no data on household income, education attainment, cancer stage, and distance between hospital and residential location, which may affect the likelihood of receiving image-guided PLB. Fourthly, the Perspective database only records time of events detailed to the month level. Hence we were unable to ascertain timing of post-procedural hemorrhage, and may have included hemorrhage due to other causes. Finally, although the Perspective dataset sample hospitals across the nation, patients treated in small to mid-size, non-teaching hospitals in urban areas in the Southern region were disproportionally higher in the dataset. Therefore, our results may not be generalizable to the entire U.S. population.

In conclusion, using a large national hospital dataset we found the use of image-guided percutaneous liver biopsy in cancer patients has increased over time, especially in the outpatient setting. During this time the rate of post-procedure hemorrhage has remained constant. It is not known if this increase in procedures is resulting in improved outcomes, or if it has resulted in a decrease in open biopsies. Reassuringly, the complication risk is low, particularly among women undergoing outpatient procedures.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Demographic, clinical and hospital characteristics of patients who received percutaneous liver biopsy (PLB) from 2006–2012.

	Image Guided PLB (N=26,941)	Outpatient Image Guided PLB (N=15,608)	Inpatient Image Guided PLB (N=11,333)	OR[a] (95% CI)	p value
Age					**<0.001**
<60	8,057 (29.91)	4,744 (30.39)	3,313 (29.23)	0.99 (0.92, 1.07)	0.9
60–69	7,498 (27.83)	4,553 (29.17)	2,945 (25.99)	Reference	
70–79	7,190 (26.69)	4,173 (26.74)	3,017 (26.62)	0.94 (0.87, 1.02)	0.2
≥80	4,196 (15.57)	2,138 (13.70)	2,058 (18.16)	0.75 (0.69, 0.82)	<0.001
Sex					
Male	14,301 (53.08)	8,137 (52.13)	6,164 (54.39)	Reference	
Female	12,640 (46.92)	7,471 (47.87)	5,169 (45.61)	1.21 (1.14, 1.27)	<0.001
Race					**<0.001**
White	18,267 (67.80)	11,382 (72.92)	6,885 (60.75)	Reference	
Black	2,871 (10.66)	1,288 (8.25)	1,584 (13.98)	0.74 (0.67, 0.81)	<0.001
Hispanic	1,013 (3.76)	384 (2.46)	629 (5.55)	0.66 (0.55, 0.81)	<0.001
Other	4,789 (17.78)	2,554 (16.36)	2,235 (19.72)	0.87 (0.75, 0.99)	<0.05
Marital Status					**<0.001**
Married	13,224 (49.09)	8,433 (54.03)	4,791 (42.27)	Reference	
Single	10,609 (39.38)	5,438 (34.84)	5,171 (45.63)	0.76 (0.71, 0.81)	<0.001
Unknown	3,108 (11.54)	1,737 (11.13)	1,371 (12.10)	1.01 (0.64, 1.58)	0.9
Insurance Status					**<0.001**
Medicare	15,148 (56.23)	8,590 (55.04)	6,558 (57.87)	Reference	
Medicaid	1,925 (7.15)	797 (5.11)	1,128 (9.95)	0.64 (0.57, 0.74)	<0.001
Commercial	7,963 (29.56)	5,322 (34.10)	2,641 (23.30)	1.24 (1.16, 1.33)	<0.001
Uninsured	1,229 (4.56)	509 (3.26)	720 (6.35)	0.55 (0.45, 0.67)	<0.001
Other/ Unknown	676 (2.51)	390 (2.50)	286 (2.52)	0.88 (0.74, 1.04)	0.1
Cancer Site					**<0.001**
Liver Only	3,639 (13.51)	2,265 (14.51)	1,374 (12.12)	1.279 (1.17, 1.40)	<0.001

	Image Guided PLB (N=26,941)	Outpatient Image Guided PLB (N=15,608)	Inpatient Image Guided PLB (N=11,333)	OR[d] (95% CI)	p value
Combination	5,029 (18.67)	3,620 (23.19)	1,409 (12.43)	2.245 (2.02, 2.49)	<0.001
Non-liver	18,273 (67.83)	9,723 (62.29)	8,550 (75.44)	Reference	
Elixhauser Comorbidity Score					**<0.001**
0–4	5,851 (21.72)	4,490 (28.77)	1,361 (12.01)	2.58 (2.33, 2.86)	<0.001
5–8	8,770 (32.55)	4,548 (29.14)	4,222 (37.25)	Reference	
9–12	6,401 (23.76)	3,361 (21.53)	3,040 (26.82)	0.96 (0.90, 1.02)	0.2
≥13	5,919 (21.97)	3,209 (20.56)	2,710 (23.91)	0.99 (0.92, 1.07)	0.9
Year of Biopsy					**<0.001**
2006	2,209 (8.20)	891 (5.71)	1,318 (11.63)	0.61 (0.48, 0.77)	<0.001
2007	2,486 (9.23)	1,226 (7.85)	1,260 (11.12)	0.81 (0.66, 0.99)	<0.05
2008	3,178 (11.80)	1,792 (11.48)	1,386 (12.23)	0.97 (0.82, 1.16)	0.8
2009	3,884 (14.42)	2,375 (15.22)	1,509 (13.32)	1.17 (0.99, 1.36)	0.05
2010	4,768 (17.70)	2,859 (18.32)	1,909 (16.84)	1.07 (0.95, 1.21)	0.3
2011	5,123 (19.02)	3,178 (20.36)	1,945 (17.16)	1.02 (0.93, 1.12)	0.6
2012	5,293 (19.65)	3,287 (21.06)	2,006 (17.70)	Reference	
Image Type					**<0.001**
Ultrasound	7557 (28.05)	4,369 (27.99)	3,188 (28.13)	0.79 (0.64, 0.98)	<0.05
CT	18,115 (67.24)	11,200 (71.76)	6915 (61.02)	Reference	
Other	1,269 (4.71)	39 (0.25)	1,230 (10.85)	0.01 (0.01, 0.12)	<0.001
Hospital Location					
Urban	23,810 (88.38)	13,388 (85.78)	10,422 (91.96)	Reference	
Rural	3,131 (11.62)	2,220 (14.22)	911 (8.04)	2.06 (1.41, 3.02)	<0.001
Region					**<0.05**
Northeast	3,023 (11.22)	1,217 (7.80)	1,806 (15.94)	0.38 (0.20, 0.72)	<0.01
Midwest	5,168 (19.18)	3,288 (21.07)	1,880 (16.59)	0.96 (0.67, 1.38)	0.8
South	12,967 (48.13)	7,486 (47.96)	5,481 (48.36)	Reference	
West	5,783 (21.47)	3,617 (23.17)	2,166 (19.11)	0.64 (0.27, 1.48)	0.3

	Image Guided PLB (N=26,941)	Outpatient Image Guided PLB (N=15,608)	Inpatient Image Guided PLB (N=11,333)	OR[a] (95% CI)	p value
Teaching Hospital					
Yes	9,351 (34.71)	4,885 (31.30)	4,466 (39.41)	1.36 (0.86, 2.17)	0.2
No	17,590 (65.29)	10,723 (68.70)	6,867 (60.59)	Reference	
Bed size					**0.98**
<400	13,170 (48.88)	7,967 (51.04)	5,203 (45.91)	Reference	
400–600	8,284 (30.75)	4,550 (29.15)	3,734 (32.95)	1.06 (0.61, 1.84)	0.8
>600	5,487 (20.37)	3,091 (19.80)	2,396 (21.14)	1.01 (0.47, 2.16)	0.9

[a]Odds ratios were derived from multivariable GEE model for receiving image guided PLB in outpatient versus inpatient setting. All variables listed in the table were included in the model.

Table 2

Predictors of hemorrhage after image-guided percutaneous liver biopsy (PLB) among cancer patients (N=26,941).

	Hemorrhage N (%)	OR (95% CI)	p
Age			**0.4**
≤60	111 (1.38)	0.94 (0.72, 1.24)	0.7
60–69	103 (1.37)	Reference	
70–79	96 (1.34)	0.99 (0.73, 1.33)	0.9
≥80	75 (1.79)	1.27 (0.88, 1.81)	0.2
Sex			
Male	220 (1.54)	Reference	
Female	165 (1.31)	0.96 (0.78, 1.19)	0.7
Race			**0.09**
White	224 (1.23)	Reference	
Black	51 (1.78)	1.27 (0.88, 1.83)	0.2
Hispanic	23 (2.27)	1.29 (0.76, 2.28)	0.4
Other	87 (1.82)	1.45 (1.07, 1.97)	<0.05
Marital Status			**0.04**
Married	199 (1.50)	Reference	
Single	143 (1.35)	0.74 (0.57, 0.95)	<0.05
Unknown	43 (1.38)	0.73 (0.48, 1.11)	0.1
Insurance Status			**0.5**
Medicare	215 (1.42)	Reference	
Medicaid	34 (1.77)	1.08 (0.70, 1.66)	0.7
Commercial	107 (1.34)	1.19 (0.88, 1.61)	0.2
Uninsured	16 (1.30)	0.83 (0.50, 1.38)	0.5
Other/ Unknown	13 (1.92)	1.33 (0.73, 2.41)	0.4
Cancer Site			**<0.001**
Liver Only	72 (1.98)	1.91 (1.49, 2.45)	<0.001
Combination	77 (1.53)	1.49 (1.13, 1.96)	<0.01
Non-liver	236 (1.29)	Reference	
Elixhauser Comorbidity Score			**<0.01**
0–4	38 (0.65)	0.571(0.38, 0.85)	<0.01
5–8	136 (1.55)	Reference	
9–12	118 (1.84)	1.21 (0.95, 1.54)	0.1
≥13	93 (1.57)	1.04 (0.80, 1.34)	0.8
Biopsy Setting			
In-patient	294 (2.59)	4.483 (3.321, 6.05)	<0.001
Out-patient	91 (0.58)	Reference	

	Hemorrhage N (%)	OR (95% CI)	p
Imaging Type			**0.2**
Ultrasound	106 (1.40)	0.95 (0.72, 1.25)	0.7
CT	237 (1.31)	Reference	
Other	42 (3.31)	1.47 (0.96, 2.24)	0.08
Year of Biopsy			**0.9**
2006	38 (1.72)	1.08 (0.70, 1.68)	0.7
2007	46 (1.85)	1.30 (0.84, 1.98)	0.2
2008	47 (1.48)	1.14 (0.75, 1.72)	0.5
2009	57 (1.47)	1.25 (0.85, 1.82)	0.2
2010	70 (1.47)	1.21 (0.88, 1.65)	0.2
2011	67 (1.31)	1.14 (0.81, 1.61)	0.5
2012	60 (1.13)	Reference	
Hospital Location			
Urban	342 (1.44)	Reference	
Rural	43 (1.37)	1.47 (0.98, 2.21)	0.06
Region			**0.3**
Northeast	53 (1.75)	1.06 (0.71, 1.58)	0.8
Midwest	75 (1.45)	1.31 (0.83, 2.03)	0.3
South	173 (1.33)	Reference	
West	84 (1.45)	1.37 (0.97, 1.94)	0.07
Teaching Hospital			
Yes	142 (1.52)	0.93 (0.67, 1.30)	0.7
No	243 (1.38)	Reference	
Bed size			**0.1**
<400	164 (1.25)	Reference	
400–600	127 (1.53)	1.23 (0.91, 1.66)	0.2
>600	94 (1.71)	1.56 (0.98, 2.48)	0.06

Table 3

Changes in utilization and cost of image-guide percutaneous liver biopsy from 2006 to 2012.

Year	No. of image-guided PLB claims	No. cancer patients in the dataset	No. of image-guided PLB per 10,000 cancer patients	Median cost (IQR) of image-guided PLB
2006	2,228	476,161	47	$940 (862)
2007	2,554	517,386	49	$989 (962)
2008	3,263	583,181	56	$1,051 (1016)
2009	4,007	623,830	64	$1,087 (999)
2010	4,897	708,736	69	$1,103 (1114)
2011	5,258	796,057	66	$1,134 (1136)
2012	5,410	790,295	68	$1,176 (1094)
Total	27,617	4,495,646	N/A	N/A