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# Index versus Non-index Readmission After Hepato-Pancreato-Biliary Surgery: Where Do Patients Go to Be Readmitted?

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## Abstract

**Introduction** The Center for Medicare and Medicaid Services (CMS) has identified readmission as an important quality metric. With an increased emphasis on regionalization of complex hepato-pancreato-biliary (HPB) surgery to high-volume centers, care of readmitted HPB patients may be fragmented if readmission occurs at a non-index hospital. We sought to define the proportion of HPB readmissions, as well as evaluate outcomes, that occur at an index versus non-index hospitals and to identify factors associated with non-index hospital readmission.

**Methods** The National Readmissions Database (NRD) was used to identify patients who underwent major HPB surgery between 2010 and 2015. Factors associated with readmission at 30 and 90 days at index versus non-index hospitals were analyzed. Differences in mortality and complications were analyzed among patients readmitted to index versus non-index hospitals.

**Results** A total of 49,080 patients underwent HPB surgery (liver $n = 27{,}081$, 55%; pancreas $n = 14{,}787$, 30%; biliary $n = 7212$, 15%). Overall, 6643 (14%) and 11,709 (24%) patients were readmitted within 30 and 90 days, respectively. Among all first readmissions, 18 and 21% were to a non-index hospital within the first 30 and 90 days, respectively. On multivariable analysis, factors associated with readmission to a non-index hospital included age (OR 1.19, 95% CI 1.05, 1.34), pancreatic cancer (OR 1.40, 95% CI 1.14, 1.34) and ≥ 3 comorbidities (OR 1.34, 95% CI 1.10, 1.63), while procedures on the pancreas (OR 0.69, 95% CI 0.61, 0.80), private insurance (OR 0.77, 95% CI 0.68, 0.87), initial admission at a large hospital (OR 0.77, 95% CI 0.65, 0.91), and initial admission length of stay > 7 days (OR 0.77, 95% CI 0.69, 0.86) were associated with decreased odds of a non-index hospital readmission (all $p < 0.05$). Patients readmitted to a non-index hospital had higher inpatient mortality (3.7 vs. 2.7%, $p = 0.010$).

**Conclusions** Roughly 1 in 5 patients were readmitted to a non-index hospital where the initial HPB operation had not taken place. Readmission to a non-index hospital was associated with higher overall in-hospital mortality. The impact of regionalization of HPB care relative to site of subsequent readmission may have important implications for patients.

**Keywords** Index readmission · Non-index readmission · Care fragmentation

## Introduction

Readmission reduction is central to improving health-care quality and reducing cost.[1–4] The Hospital Readmissions Reduction Program (HRRP) was introduced as a component of the Patient Protection and Affordable Care Act and was enacted in October of 2012.[5] The HRRP includes penalties for hospitals with higher than expected readmission rates for three medical conditions (acute myocardial infarction, congestive heart failure, and pneumonia) and three surgical procedures (coronary artery bypass graft, hip and knee arthroplasty).[5] These programs are expected to be expanded to cover a broader range of diagnoses and conditions in the near future.

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Hepato-pancreato-biliary (HPB) surgery can be associated with high—and highly variable—rates of readmission (10–29%), morbidity (39–44%), and mortality (5–11%).[6–9] In addition, with the centralization of HPB surgical procedures to tertiary centers, post-surgical patients may be readmitted at a hospital other than the location where the original surgery took place. In turn, care fragmentation, defined as a lack of care continuity, can be associated with higher cost and lower quality; in contrast, continuity of care has been associated with better outcomes.[10–13] The impact of care fragmentation among surgical patients has just begun to be quantified. Using the State Inpatient Database of California, Zheng et al. reported that 20% of patients who underwent a major surgery for cancer were admitted to a non-index hospital.[14] Interestingly, readmission to a non-index hospital was associated with a more urgent need for readmission, as well as rural residence and a more extensive initial surgical procedure. In turn, non-index readmissions resulted in higher mortality independent of patient factors. Of note, the effect of non-index hospital readmission on mortality was mitigated by adjusting for conditions present at readmission. To this point, data from our group had previously suggested that non-index readmissions were more common among patients with malignant diagnoses.[15]

While the impact of non-index readmissions has been explored in several other surgical specialties,[16, 17] patterns of readmission after HPB surgery remain poorly characterized. As such, the objective of the current study was to define patterns of readmission, including the proportion of patients readmitted to index versus non-index hospitals, after HPB surgery. In particular, using the Healthcare Cost and Utilization Project (HCUP) Nationwide Readmissions Database (NRD), we sought to determine factors associated with readmission to index versus non-index hospitals, as well as characterize potential differences in short-term outcomes among patients based on readmission location.

## Methods

### Study Population and Data Collection

Patients ≥ 18 years old who underwent a hepatic, pancreatic, or biliary (HPB) resection for benign and malignant diagnoses between 2010 and 2015 were identified using the National Readmissions Database (NRD) (Supplemental Table 1). The NRD is sponsored by the Agency for Healthcare Research and Quality (AHRQ) and is part of the Healthcare Cost and Utilization Project.[1] This data source contains over 100 variables, including clinical and non-clinical data elements gathered from hospital discharge abstracts drawn from 22 HCUP State Inpatient Databases (SID), which contain patient linkage numbers that allow tracking of persons across hospitals within a state. The NRD accounts for 51.2% of the US population and 49.3% of hospitalizations. Approximately 85% of SID discharges are included in the NRD.[1] The unweighted NRD contains data on 15 million discharges. The NRD contains three discharge-level files: Core File, Severity File and Diagnosis and Procedure Groups File. Additionally, it contains one hospital-level file: Hospital-level File. For the purposes of this study, the three discharge-level files were combined using the NRD unique record identifier (KEY_NRD).[1] The index event was defined as the starting point for analysis of repeat hospital visits and a readmission was defined as the subsequent inpatient admission within a specified time period; readmission may have been for a specific cause or any cause.[1]

Index events were defined based on ICD-9-CM procedure codes representing hepato-pancreato-biliary surgery (Supplementary Table 1). Index events during which the patient died (DIED = 1) in the hospital were excluded as there was no risk of readmission. Transfers and same day events (SAMEDAYEVENT! =0) were excluded as these represent a more complex type of care. For each year (YEAR), index events with discharge month (DMONTH) of October–December were excluded as 30-day and 90-day readmission data for these patients would not necessarily be available. Patients who had missing length of stay (LOS = missing) were excluded, as it was not possible to determine the time between discharge and readmission. Patients who left the hospital against medical advice were excluded. Discharges representing all-cause readmission were included.

The primary outcomes were 30- and 90-day readmission. The number of days to readmission was calculated as suggested by HCUP NRD using the patient linkage number (NRD_visitLink) and length of stay.[1] Cause of readmission and procedures performed during readmission were determined using ICD-9-CM procedure and diagnosis codes. The HCUP NRD includes all 30 variables required to calculate the Elixhauser comorbidity score.[1, 18] A comorbidity index was calculated for each patient using these variables and patients were categorized as follows: no comorbidities, one comorbidity, two comorbidities, or three or more comorbidities. The HCUP NRD also includes two measures of severity. The severity of illness subclass is categorized as follows: minor loss of function (includes cases with no comorbidity or complication), moderate loss of function, major loss of function, and extreme loss of function. The risk of mortality subclass is divided into four categories: minor likelihood of dying, moderate likelihood of dying, major likelihood of dying, and extreme likelihood of dying.[1]

### Data Analysis

Median and interquartile range was used to summarize non-normally distributed continuous variables. Mean and standard deviations were used to summarize normally distributed

continuous variables. Categorical variables were reported as frequencies and percentages. Chi-squared or Fisher's exact tests were used to perform univariate comparisons, as appropriate. Variables with $p$ values < 0.05 in the univariate analysis were included in multivariable logistic regression models. Data analysis was performed with STATA 14.0 MP or R software for statistical computing, v. 3.0.2 34.

## Results

There were 49,080 patients who met inclusion criteria. Patients had a median age of 61 (interquartile range, IQR, 50–69) years and 53% ($N$ = 26,222) were female. The majority of patients underwent liver surgery ($N$ = 27.081, 55%), while a small subset underwent pancreatic ($N$ = 14,787, 30%) or biliary ($N$ = 7212, 15%) surgery. A larger proportion of patients underwent surgery for a malignant ($N$ = 32,830, 67%) versus a benign ($N$ = 15,902, 33%) indication. Most patients had 1 ($N$ = 10,810, 22%), 2 ($N$ = 11,265, 23%), or 3 or more ($N$ = 20,316, 42%) comorbidities. The majority of patients had a minor ($N$ = 19,592, 40%) or moderate ($N$ = 16,668, 34%) likelihood of dying. In terms of illness severity, 45% ($N$ = 22,094) of patients had moderate loss of function and 30% ($N$ = 14,495) had major loss of function. The most common payers were Medicare ($N$ = 19,307, 39%) and private ($N$ = 21,741, 44%) insurers. Patients were evenly distributed across income quartiles (quartile 1 $N$ = 10,666, 22%; 2 $N$ = 10,997, 23%; 3 $N$ = 12,033, 25%; 4 $N$ = 14,436, 30%). Most patients were treated in large hospitals ($N$ = 38,129, 78%) and in metropolitan, teaching hospitals ($N$ = 41,645, 85%). Length of stay was most often less than 7 days ($N$ = 29,240, 60%). The majority of patients had a routine discharge ($N$ = 34,695, 70%), while a minority was discharged with home health ($N$ = 10,721, 22%).

There were 6643 (13%) patients readmitted within 30 days and 11,709 (24%) patients readmitted with 90 days of hospital discharge (Fig. 1a**)**.

### 30-Day Readmission

Among patients readmitted within 30 days (Table 1, Fig. 1b), there were 5472 (82%) patients readmitted to the index hospital (IH) and 1171 (18%) admitted to non-index hospitals (NIH). Patients readmitted within 30 days had a median age of 60 (IQR 50–69) years and 50% were female. Most readmissions within 30 days were following liver ($N$ = 3122, 47%) or pancreatic ($N$ = 2460, 37%) surgery; the majority of readmissions were among patients who had a malignant indication ($N$ = 4576, 69%) for surgery. In terms of illness severity, 41% ($N$ = 2716) of patients readmitted within 30 days had moderate loss of function and 37% ($N$ = 2452) had major loss of function. Patients were evenly distributed across income quartiles (quartile 1 $N$ = 1448, 22%; 2 $N$ = 1553, 23%; 3 $N$ = 1614, 25%; 4 $N$ = 1880, 29%). Among patients readmitted within 30 days, most patients had been initially treated in large hospitals ($N$ = 5195, 78%) and in metropolitan, teaching hospitals ($N$ = 5680, 86%). The majority of patients had a routine discharge ($N$ = 4329, 65%), yet a minority was discharged with home health ($N$ = 1851, 28%).

Among patients who were readmitted within 30 days (Table 1), patients who were readmitted to non-index hospitals were more likely to be older (NI median 63, IQR 53–72 vs. I median 60, IQR 50–69, $p < 0.001$), have had liver surgery (NI 52% vs. I 47%, $p < 0.001$), and have undergone surgery for a malignant indication (NI 73% vs. I 68%, $p < 0.001$). Patients readmitted to a non-index hospital were also more likely to have more medical comorbidities (three or more comorbidities, NI 52% vs. I 46%, $p < 0.001$). In addition, patients readmitted to non-index hospitals were less likely to be in the lowest median household income quartile (quartile 4, NI 26% vs. I 30%, $p = 0.04$). There were no differences among patients readmitted with 30 days to index versus non-index hospitals with regard to the size or teaching status of hospital where the surgical procedure was performed. Of note, patients readmitted to non-index hospitals within 30 days were more likely to have had a length of stay ≤ 7 days (NI 56% vs. I 51%, $p = 0.002$) and were less likely to have been discharged with home health care (NI 24% vs. I 29%, $p < 0.001$).

On multivariable analysis (Table 2), several factors were associated with readmission to a non-index hospital. Specifically, 2 (OR 1.36, 95% CI 1.03, 1.79, $p = 0.030$) or ≥ 3 comorbidities (OR 1.49, 95% CI 1.14, 1.96, $p = 0.004$), as well as an illness severity of minor (OR 1.60, 95% CI 1.07, 2.39, $p = 0.018$) or moderate (OR 1.42, 95% CI 1.03, 1.97, $p = 0.033$) loss of function, were associated with an increased risk of non-index hospital readmission within 30 days. In contrast, pancreatic procedure (OR 0.69, 95% CI 0.56, 0.83, $p < 0.001$), private (OR 0.77, 95% CI 0.64, 0.92, $p = 0.003$) or Medicaid (OR 0.73, 95% CI 0.56, 0.95, $p = 0.018$) insurance, highest income quartile (OR 0.80, 95% CI 0.66, 0.97, $p = 0.023$), length of stay > 7 days (OR 0.81, 95% CI 0.70, 0.95, $p = 0.003$), and discharge with home health care (OR 0.81, 95% CI 0.69, 0.95, $p = 0.011$) were each associated with a lower risk of non-index hospital readmission.

### 90-Day Readmission

Among patients readmitted within 90 days (Table 3, Fig. 1b), 9275 (79%) were readmitted to the index hospital and 2434 (21%) were readmitted to a non-index hospital. Similar to 30-day readmission, patients readmitted within 90 days (Table 3) to a non-index hospital were older (NI median 64, IQR 53–72 vs. I median 60, IQR 50–69, $p < 0.001$), more likely to have had liver surgery (NI 52% vs. I 46%, $p < 0.001$), and more likely to have undergone surgery for a malignant indication

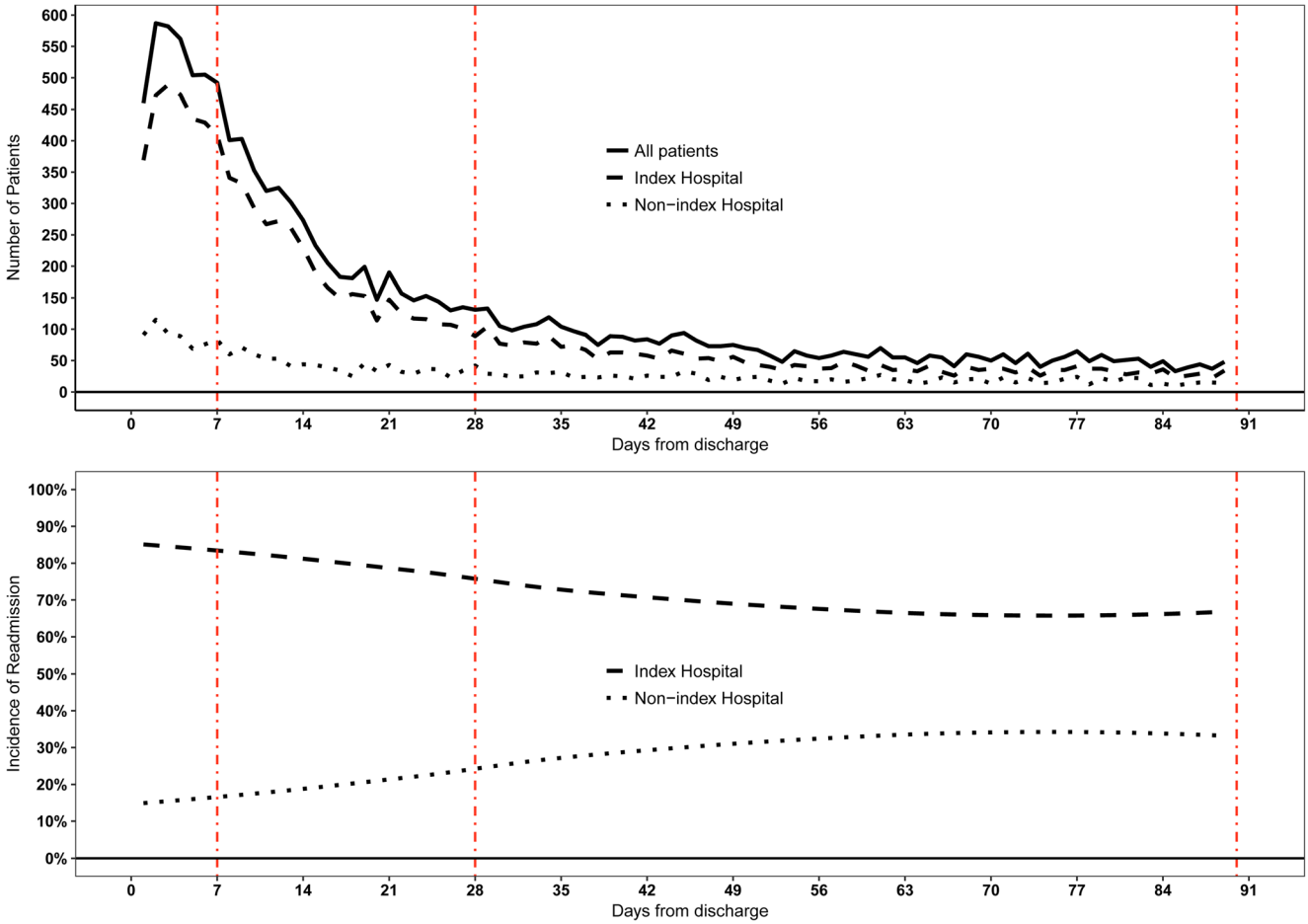


**Fig. 1** **a** Patients readmitted in the first 90 days after hepato-pancreato-biliary procedures: all patients, index readmissions, and non-index readmissions. **b** Cumulative incidence of readmission in the first 90 days after hepato-pancreato-biliary procedures: index readmissions versus non-index readmissions

(NI 76% vs. I 69%, $p < 0.001$). Patients readmitted to a non-index hospital within 90 days were also more likely to have comorbidities (three or more comorbidities, NI 53% vs. I 49%, $p < 0.001$). Of note, patients readmitted to a non-index hospital within 90 days were more likely to have had their index procedure at a small or medium rather than a large hospital (small, NI 9% vs. I 7%; medium, NI 16% vs. I 14%; large, NI 75% vs. I 79%; $p < 0.001$). Ninety-day readmission to a non-index hospital was also associated with length of stay (less than or equal to 7 days, NI 52% vs. I 44%, $p < 0.001$). Patients readmitted to non-index hospitals were more likely to have been discharged routinely (NI 63% vs. I 60%) and less likely to be discharged with home health care (NI 25% vs. I 30%) ($p < 0.001$). There were no differences among patients readmitted within 90 days to index and non-index hospitals with regard to median household income or teaching status of the hospital.

On multivariable analysis (Table 4), older age (OR 1.18, 95% CI 1.05, 1.34, $p = 0.005$), pancreatic cancer (OR 1.40, 95% CI 1.14, 1.70, $p < 0.001$), pancreatic disorders (OR 1.32, 95% CI 1.01, 1.73, $p = 0.040$), and having three or more comorbidities (OR 1.34, 95% CI 1.10, 1.63, $p = 0.003$) were each associated with 90-day non-index hospital readmission. In contrast, private insurance (OR 0.77, 95% CI 0.68, 0.87, $p < 0.001$), performance of the index procedure at a large hospital (OR 0.77, 95% CI 0.65, 0.91, $p = 0.002$), length of stay > 7 days (OR 0.77, 95% CI 0.69, 0.86, $p < 0.001$), and discharge with home health (OR 0.82, 95% CI 0.73–0.92, $p < 0.001$) were each associated with a lower risk of 90-day non-index hospital readmission.

Of note, among patients readmitted within 90 days, the length of stay among patients later readmitted to index hospitals was longer than at non-index hospitals (Table 5, median 8 days, IQR 6–14 vs. median 7 days, IQR 5–12, $p < 0.001$). Admission charges were also higher among patients who were later readmitted to index hospitals (median $98,389, IQR $60,176–173,752 vs. median $90,342, IQR $56,337–160,085, $p < 0.001$). Patients readmitted to index hospitals were more likely to be readmitted for infections and other gastrointestinal complications, while patients readmitted to an index hospital were less likely to be readmitted for cardiac, renal, endocrine, pancreatic, bleeding, and other issues ($p < 0.001$). Patients readmitted to index hospitals were often underwent an operative procedure during the readmission

**Table 1** Characteristics of HPB patients readmitted within 30 days of HPB surgery, by index versus non-index hospital readmission and hospitals to which they were readmitted

| Variable | Total readmissions ($N = 6643$) | Index readmissions ($N = 5472$) | Non-index readmissions ($N = 1171$) | $p$ value |
|---|---|---|---|---|
| Age (median, IQR) | 60 [50–69] | 60 [50–69] | 63 [53–72] | *< 0.001* |
| Female (*N*, %) | 3341 (50%) | 2755 (50%) | 586 (50%) | 0.850 |
| Indication (*N*, %) | | | | *0.018* |
| Liver/bile duct cancer | 761 (11%) | 608 (11%) | 153 (13%) | |
| Pancreatic cancer | 1053 (16%) | 859 (16%) | 194 (17%) | |
| Cancer of the colon | 683 (10%) | 552 (10%) | 131 (11%) | |
| Cancer of the rectum or anus | 289 (4%) | 227 (4%) | 62 (5%) | |
| Other GI cancer | 550 (8%) | 443 (8%) | 107 (9%) | |
| Biliary tract disease | 926 (14%) | 786 (14%) | 140 (12%) | |
| Other liver disease | 467 (7%) | 382 (7%) | 85 (7%) | |
| Pancreatic disorders | 581 (9%) | 492 (9%) | 89 (8%) | |
| Others | 1333 (20%) | 1123 (21%) | 210 (18%) | |
| Type of HPB procedure | | | | *< 0.001* |
| Liver | 3122 (47%) | 2508 (46%) | 614 (52%) | |
| Pancreas | 2460 (37%) | 2091 (38%) | 369 (32%) | |
| Biliary | 1061 (16%) | 873 (16%) | 188 (16%) | |
| Malignant versus benign | | | | *0.001* |
| Benign | 2037 (31%) | 1725 (32%) | 312 (27%) | |
| Malignant | 4576 (69%) | 3720 (68%) | 856 (73%) | |
| Comorbidity category | | | | *< 0.001* |
| 0 | 711 (11%) | 616 (11%) | 95 (8%) | |
| 1 | 1298 (20%) | 1096 (20%) | 202 (17%) | |
| 2 | 1510 (23%) | 1243 (23%) | 267 (23%) | |
| ≥ 3 | 3124 (47%) | 2517 (46%) | 607 (52%) | |
| Mortality category | | | | 0.466 |
| Minor likelihood of dying | 2319 (35%) | 1936 (35%) | 383 (33%) | |
| Moderate likelihood of dying | 2317 (35%) | 1897 (35%) | 420 (36%) | |
| Major likelihood of dying | 1461 (22%) | 1197 (22%) | 264 (23%) | |
| Extreme likelihood of dying | 55 (8%) | 441 (8%) | 104 (9%) | |
| Illness severity category | | | | 0.324 |
| Minor loss of function | 684 (10%) | 565 (10%) | 119 (10%) | |
| Moderate loss of function | 2716 (41%) | 2206 (40%) | 510 (44%) | |
| Major loss of function | 2452 (37%) | 2045 (38%) | 407 (35%) | |
| Extreme loss of function | 790 (12%) | 655 (12%) | 135 (12%) | |
| Primary payer | | | | *< 0.001* |
| Medicare | 2709 (41%) | 2137 (39%) | 572 (49%) | |
| Medicaid | 727 (11%) | 622 (11%) | 105 (9%) | |
| Private insurance | 2797 (42%) | 2377 (44%) | 420 (36%) | |
| Self-pay | 178 (3%) | 143 (3%) | 35 (3%) | |
| No charge | 22 (0.3%) | 21 (0.4%) | 1 (0.1%) | |
| Other | 205 (3%) | 169 (3%) | 36 (3%) | |
| Median household income | | | | *0.047* |
| Quartile 1 (lowest) | 1448 (22%) | 1182 (22%) | 266 (23%) | |
| Quartile 2 | 1553 (24%) | 1270 (24%) | 283 (25%) | |
| Quartile 3 | 1614 (25%) | 1316 (25%) | 298 (26%) | |
| Quartile 4 (highest) | 1880 (29%) | 1590 (30%) | 290 (26%) | |
| Size of hospital | | | | 0.081 |
| Small | 494 (8%) | 397 (7%) | 97 (8%) | |
| Medium | 954 (14%) | 767 (14%) | 187 (16%) | |
| Large | 5195 (78%) | 4308 (79%) | 887 (76%) | |
| Teaching status of hospital | | | | 0.802 |
| Metropolitan, non-teaching | 904 (14%) | 738 (14%) | 166 (14%) | |
| Metropolitan, teaching | 5680 (86%) | 4686 (86%) | 994 (85%) | |
| Non-metropolitan | 59 (0.9%) | 48 (0.9% | 11 (0.9%) | |
| Length of stay (mean, SD) | | | | *0.002* |
| ≤ 7 days | 3471 (52%) | 2810 (51%) | 661 (56%) | |
| > 7 days | 3172 (48%) | 2662 (49%) | 510 (44%) | |
| Discharge destination | | | | *< 0.001* |
| Routine | 4329 (65%) | 3557 (65%) | 772 (66%) | |
| Transfer to short-term hospital | 21 (0.32%) | 14 (0.26%) | 7 (0.60%) | |
| Other transfers* | 439 (7%) | 333 (6%) | 106 (9%) | |
| Home health care | 1851 (28%) | 1565 (29%) | 286 (24%) | |

Statitically significant ($P<0.05$) values are italicized

*Other transfers include skill nursing facilities, intermediate care, and another type of facility

**Table 2** Logistic regression model for predicting non-index 30-day readmission

| Variable | Odds ratio | 95% CI | *p* value |
|---|---|---|---|
| Age (median, IQR) | 1.16 | (0.97, 1.37) | 0.099 |
| Female (*N*, %) | 1.00 | (0.88, 1.14) | 0.969 |
| Indication (*N*, %) | | | |
| Liver/bile duct cancer | Ref. | | |
| Pancreatic cancer | 1.09 | (0.82, 1.45) | 0.536 |
| Cancer of the colon | 0.96 | (0.73, 1.25) | 0.739 |
| Cancer of the rectum or anus | 1.21 | (0.86, 1.71) | 0.282 |
| Other GI cancer | 1.01 | (0.76, 1.35) | 0.936 |
| Biliary tract disease | 0.84 | (0.61, 1.16) | 0.936 |
| Other liver disease | 0.84 | (0.61, 1.16) | 0.289 |
| Pancreatic disorders | 1.07 | (0.77, 1.49) | 0.696 |
| Others | 1.00 | (0.76, 1.31) | 0.545 |
| Type of HPB procedure | | | |
| Liver | Ref. | | |
| Pancreas | 0.69 | (0.56, 0.84) | *< 0.001* |
| Biliary | 0.95 | (0.76, 1.19) | 0.670 |
| Malignant versus benign | | | |
| Benign | Ref. | | |
| Malignant | 1.05 | (0.84, 1.30) | 0.691 |
| Comorbidity category | | | |
| 0 | Ref. | | |
| 1 | 1.15 | (0.87, 1.52) | 0.314 |
| 2 | 1.36 | (1.03, 1.79) | *0.030* |
| ≥ 3 | 1.49 | (1.14, 1.96) | *0.004* |
| Mortality category | | | |
| Minor likelihood of dying | 0.73 | (0.51, 1.05) | 0.089 |
| Moderate likelihood of dying | 0.75 | (0.54, 1.04) | 0.080 |
| Major likelihood of dying | 0.88 | (0.65, 1.17) | 0.375 |
| Extreme likelihood of dying | Ref. | | |
| Illness severity category | | | |
| Minor loss of function | 1.60 | (1.07, 2.39) | *0.021* |
| Moderate loss of function | 1.42 | (1.03, 1.97) | *0.033* |
| Major loss of function | 1.11 | (0.85, 1.46) | 0.447 |
| Extreme loss of function | Ref. | | |
| Primary payer | | | |
| Medicare | Ref. | | |
| Medicaid | 0.73 | (0.566, 0.95) | *0.018* |
| Private insurance | 0.77 | (0.64, 0.92) | *0.003* |
| Self-pay | 1.16 | (0.77, 1.76) | 0.465 |
| No charge | 0.22 | (0.03, 1.66) | 0.142 |
| Other | 0.86 | (0.57, 1.28) | 0.447 |
| Median household income | | | |
| Quartile 1 (lowest) | Ref. | | |
| Quartile 2 | 0.99 | (0.82, 1.20) | 0.920 |
| Quartile 3 | 1.02 | (0.84, 1.23) | 0.866 |
| Quartile 4 (highest) | 0.80 | (0.66, 0.97) | *0.023* |
| Size of hospital | | | |
| Small | Ref. | | |
| Medium | 0.99 | (0.75, 1.32) | 0.967 |
| Large | 0.88 | (0.69, 1.12) | 0.284 |
| Teaching status of hospital | | | |
| Metropolitan, non-teaching | Ref. | | |
| Metropolitan, teaching | 1.02 | (0.84, 1.23) | 0.874 |
| Non-metropolitan | 0.96 | (0.48, 1.91) | 0.896 |
| Length of stay (mean, SD) | | | |
| ≤ 7 days | Ref. | | |
| > 7 days | 0.81 | (0.70, 0.95) | *0.008* |
| Discharge destination | | | |
| Routine | Ref. | | |
| Transfer to short-term hospital | 2.24 | (0.87, 5.76) | 0.094 |
| Other transfers* | 1.22 | (0.94, 1.58) | 0.138 |
| Home health care | 0.81 | (0.69, 0.95) | *0.011* |

Statitically significant ($P<0.05$) values are italicized

*Other transfers include skill nursing facilities, intermediate care, and another type of facility

and were less likely to undergo medical or other treatments (operative I 40% vs. NI 33%; medical I 28% vs. NI 25%; other I 32% vs. NI 42%; $p < 0.001$). Patients readmitted at index hospitals also had lower in-hospital mortality (I 2.7% vs. NI 3.7%, $p = 0.010$).

## Discussion

Readmission to the hospital after a surgical procedure is an important health-care quality metric and its use in reimbursement payment plans has already been incorporated into Medicare.[5] HPB surgery can be associated with high rates of readmission. In fact, among the 49,080 patients who underwent HPB surgery and met inclusion criteria, there were 6643 (13%) patients readmitted within 30 days and 11,709 (24%) patients readmitted with 90 days of hospital discharge. With roughly 1 in 5 patients being readmitted after HPB surgery, significant resources are needed to coordinate the care of these patients in the post-operative setting. As many patients who undergo complex HPB surgery may travel to centralized centers for high-volume care, readmission may occur in a number of different settings. Data on patterns of readmission following HPB surgery have, however, been scarce. The current study was important because we noted readmission at non-index hospitals was common after HPB surgery. In fact, 18% of overall 30-day readmissions occurred at non-index hospitals and the proportion of non-index readmissions increased to 21% among 90-day readmissions. In addition, a variety of patient- (e.g., preoperative comorbidity, income level, etc.), hospital- (e.g., size, length of stay, discharge destination etc.), and procedure- (e.g., surgical operation) level

**Table 3** Characteristics of HPB patients readmitted within 90 days of HPB surgery, by index versus non-index hospital readmission and hospitals to which they were readmitted

| Variable | Total readmissions ($N = 11,709$) | Index readmissions ($N = 9275$) | Non-index readmissions ($N = 2434$) | $p$ value |
|---|---|---|---|---|
| Age (median, IQR) | 61 [51–70] | 60 [50–69] | 64 [53–72] | *< 0.001* |
| Female (*N*, %) | 5851 (50%) | 4628 (50%) | 1223 (50%) | 0.094 |
| Indication (*N*, %) | | | | *< 0.001* |
| Liver/bile duct cancer | 1304 (11%) | 1012 (11%) | 292 (12%) | |
| Pancreatic cancer | 1892 (16%) | 1424 (15%) | 468 (19%) | |
| Cancer of the colon | 1285 (11%) | 1000 (11%) | 285 (12%) | |
| Cancer of the rectum or anus | 562 (5%) | 436 (5%) | 126 (5%) | |
| Other GI cancer | 966 (8%) | 729 (8%) | 237 (10%) | |
| Biliary tract disease | 1609 (14%) | 1356 (15%) | 253 (10%) | |
| Other liver disease | 873 (8%) | 714 (8%) | 159 (7%) | |
| Pancreatic disorders | 951 (8%) | 770 (8%) | 181 (7%) | |
| Others | 2267 (19%) | 1834 (20%) | 433 (17%) | |
| Type of HPB procedure | | | | *< 0.001* |
| Liver | 5565 (47%) | 4309 (46%) | 1256 (52%) | |
| Pancreas | 4151 (35%) | 3372 (36%) | 779 (32%) | |
| Biliary | 1993 (17%) | 1594 (17%) | 399 (16%) | |
| Malignant versus benign | | | | *< 0.001* |
| Benign | 3419 (29%) | 2848 (31%) | 571 (24%) | |
| Malignant | 8247 (71%) | 6390 (69%) | 1857 (76%) | |
| Comorbidity category | | | | *< 0.001* |
| 0 | 1098 (9%) | 907 (10%) | 191 (8%) | |
| 1 | 2175 (19%) | 1762 (19%) | 413 (17%) | |
| 2 | 2615 (22%) | 2075 (22%) | 540 (22%) | |
| ≥3 | 5821 (50%) | 4531 (49%) | 1290 (53%) | |
| Mortality category | | | | 0.110 |
| Minor likelihood of dying | 3496 (30%) | 2786 (30%) | 710 (30%) | |
| Moderate likelihood of dying | 4014 (34%) | 3126 (34%) | 888 (37%) | |
| Major likelihood of dying | 2786 (24%) | 2233 (24%) | 553 (23%) | |
| Extreme likelihood of dying | 1410 (12%) | 1127 (12%) | 283 (12%) | |
| Illness severity category | | | | *0.002* |
| Minor loss of function | 1010 (9%) | 793 (9%) | 217 (9%) | |
| Moderate loss of function | 4378 (37%) | 3394 (37%) | 984 (40%) | |
| Major loss of function | 4282 (37%) | 3424 (37%) | 858 (35%) | |
| Extreme loss of function | 2036 (18%) | 1661 (18%) | 375 (15%) | |
| Primary payer | | | | *< 0.001* |
| Medicare | 4990 (43%) | 3768 (41%) | 1222 (50%) | |
| Medicaid | 1298 (11%) | 1061 (12%) | 237 (10%) | |
| Private insurance | 4724 (40%) | 3885 (42%) | 839 (35%) | |
| Self-pay | 295 (3%) | 239 (3%) | 56 (2%) | |
| No charge | 32 (0.3%) | 30 (0.3%) | 2 (0.1%) | |
| Other | 356 (3%) | 281 (3%) | 75 (3%) | |
| Median household income | | | | 0.105 |
| Quartile 1 (lowest) | 2627 (23%) | 2058 (23%) | 569 (24%) | |
| Quartile 2 | 2724 (24%) | 2159 (24%) | 565 (24%) | |
| Quartile 3 | 2880 (25%) | 2266 (25%) | 614 (26%) | |
| Quartile 4 (highest) | 3237 (28%) | 2613 (29%) | 624 (26%) | |
| Size of hospital | | | | *< 0.001* |
| Small | 869 (7%) | 646 (7%) | 223 (9%) | |
| Medium | 1720 (15%) | 1339 (14%) | 381 (16%) | |
| Large | 9120 (78%) | 7290 (79%) | 1830 (75%) | |
| Teaching status of hospital | | | | 0.227 |
| Metropolitan, non-teaching | 1687 (14%) | 1333 (14%) | 354 (15%) | |
| Metropolitan, teaching | 9901 (85%) | 7848 (85%) | 2053 (84%) | |
| Non-metropolitan | 121 (1%) | 94 (1%) | 27 (1%) | |
| Length of stay (mean, SD) | | | | *< 0.001* |
| ≤ 7 days | 5354 (46%) | 4100 (44%) | 1254 (52%) | |
| > 7 days | 6355 (54%) | 5175 (56%) | 1180 (48%) | |
| Discharge destination | | | | *< 0.001* |
| Routine | 7123 (61%) | 5594 (60%) | 1529 (63%) | |
| Transfer to short-term hospital | 65 (0.56%) | 47 (0.51%) | 18 (0.74%) | |
| Other transfers* | 1135 (10%) | 860 (9%) | 275 (11%) | |
| Home health care | 3379 (29%) | 2769 (30%) | 610 (25%) | |

Statitically significant ($P<0.05$) values are italicized

*Other transfers include skill nursing facilities, intermediate care, and another type of facility

**Table 4** Logistic regression model for predicting non-index 90-day readmission

| Variable | Odds ratio | 95% CI | *p* value |
|---|---|---|---|
| Age (median, IQR) | 1.18 | (1.05, 1.34) | *0.005* |
| Female (*N*, %) | 1.01 | (0.92, 1.10) | 0.903 |
| Indication (*N*, %) | | | |
| Liver/bile duct cancer | Ref. | | |
| Pancreatic cancer | 1.40 | (1.14, 1.70) | *0.001* |
| Cancer of the colon | 1.00 | (0.83, 1.21) | 0.975 |
| Cancer of the rectum or anus | 1.10 | (0.86, 1.41) | 0.435 |
| Other GI cancer | 1.20 | (0.98, 1.48) | 0.079 |
| Biliary tract disease | 0.82 | (0.65, 1.04) | 0.103 |
| Other liver disease | 1.00 | (0.78, 1.28) | 0.980 |
| Pancreatic disorders | 1.32 | (1.01, 1.73) | *0.040* |
| Others | 1.08 | (0.89, 1.31) | 0.430 |
| Type of HPB procedure | | | |
| Liver | Ref. | | |
| Pancreas | 0.69 | (0.61, 0.80) | *< 0.001* |
| Biliary | 0.92 | (0.79, 1.07) | 0.285 |
| Malignant versus benign | | | |
| Benign | Ref. | | |
| Malignant | 1.14 | (0.97, 1.33) | 0.113 |
| Comorbidity category | | | |
| 0 | Ref. | | |
| 1 | 1.08 | (0.88, 1.31) | 0.473 |
| 2 | 1.18 | (0.96, 1.44) | 0.108 |
| ≥ 3 | 1.34 | (1.10, 1.63) | *0.003* |
| Mortality category | | | |
| Minor likelihood of dying | 0.95 | (0.75, 1.22) | 0.708 |
| Moderate likelihood of dying | 0.92 | (0.74, 1.15) | 0.453 |
| Major likelihood of dying | 0.92 | (0.76, 1.12) | 0.404 |
| Extreme likelihood of dying | Ref. | | |
| Illness severity category | | | |
| Minor loss of function | 1.29 | (0.97, 1.71) | 0.708 |
| Moderate loss of function | 1.21 | (0.97, 1.51) | 00.79 |
| Major loss of function | 1.08 | (0.90, 1.30) | 0.386 |
| Extreme loss of function | Ref. | | |
| Primary payer | | | |
| Medicare | Ref. | | |
| Medicaid | 0.80 | (0.67, 0.96) | 0.018 |
| Private insurance | 0.77 | (0.68, 0.87) | *< 0.001* |
| Self-pay | 0.92 | (0.67, 1.27) | 0.629 |
| No charge | 0.27 | (0.06, 1.13) | 0.074 |
| Other | 0.93 | (0.70, 1.34) | 0.615 |
| Median household income | | | |
| Quartile 1 (lowest) | Ref. | | |
| Quartile 2 | 0.93 | (0.81, 1.06) | 0.282 |
| Quartile 3 | 0.95 | (0.83, 1.09) | 0.475 |
| Quartile 4 (highest) | 0.83 | (0.73, 0.95) | *0.007* |
| Size of hospital | | | |
| Small | Ref. | | |
| Medium | 0.86 | (0.71, 1.05) | 0.134 |
| Large | 0.77 | (0.65, 0.91) | *0.002* |
| Teaching status of hospital | | | |
| Metropolitan, non-teaching | Ref. | | |
| Metropolitan, teaching | 1.03 | (0.91, 1.18) | 0.586 |
| Non-metropolitan | 1.11 | (0.70, 1.74) | 0.659 |
| Length of stay (mean, SD) | | | |
| ≤ 7 days | Ref. | | |
| > 7 days | 0.77 | (0.69, 0.86) | *< 0.001* |
| Discharge destination | | | |
| Routine | Ref. | | |
| Transfer to short-term Hospital | 1.69 | (0.96, 2.96) | 0.068 |
| Other transfers* | 1.11 | (0.94, 1.32) | 0.215 |
| Home health care | 0.82 | (0.73, 0.92) | < 0.001 |

Statitically significant ($P<0.05$) values are italicized

*Other transfers include skill nursing facilities, intermediate care, and another type of facility

factors were associated with risk of non-index readmission. The data collectively served to highlight that many post-surgical HPB patients were readmitted to a hospital other than the location where the original surgery took place, and therefore may be at risk for care fragmentation.

Overall, among the 11,709 patients who underwent HPB surgery and were readmitted with 90 days of hospital discharge, 9275 (79%) were readmitted to the index hospital and 2434 (21%) were readmitted to a non-index hospital. Similarly, in a study of 93,062 patients who underwent complex surgical procedures including coronary artery bypass grafting, pulmonary lobectomy, endovascular abdominal aortic aneurysm repair, open abdominal aortic aneurysm repair, colectomy, and hip replacement, Tsai et al. reported that 25% of patients were readmitted to a non-index hospital.[2] In a separate study, among patients who underwent major surgery for cancer, 20% of patients readmitted within 30 days were readmitted to a non-index hospital.[14] Collectively, the data demonstrate that up to 1 in 5 patients who are readmitted following HPB surgery are likely to be re-hospitalized at an institution other than the place where the original surgery took place. As such, readmission estimates based solely on single-center intuitional data almost undoubtedly underestimate the burden of readmission for HPB patients. In addition, with a growing emphasis on surgical volume, procedural expertise, and team-based care, patients are increasingly seeking care at centers distant from their home. In turn, the incidence of non-index readmission following highly specialized surgical procedures such as HPB operation will likely increase over time.

Several factors have been associated with the risk of non-index readmission. Specifically, Zheng et al. reported that non-index hospital readmissions occurred more often among

**Table 5** Comparison of short-term outcomes and patterns of re-admission between patients undergoing to hepato-pancreato-biliary surgery readmitted to index versus non-index hospitals within 90 days ($N = 11,709$)

| | Index readmission ($N = 9275$) | Non-index readmission ($N = 2434$) | $p$ value |
|---|---|---|---|
| Admission length of stay, median (IQR) | 8 (6–14) | 7 (5–12) | < 0.001 |
| Admission total charge, median (IQR) | 98,389 (60,176-173,752) | 90,342 (56,337-160,085) | < 0.001 |
| Reason for 90-day readmission | | | < 0.001 |
| Infections | 3155 (34%) | 663 (27%) | |
| Other GI complications | 2387 (26%) | 395 (16%) | |
| Cardiac and renal | 850 (9%) | 400 (17%) | |
| Endocrine and pancreatic | 789 (9%) | 221 (9%) | |
| Bleeding | 339 (3%) | 104 (4%) | |
| Other | 1755 (19%) | 651 (27%) | |
| Procedures during readmission | | | < 0.001 |
| Other treatments | 2954 (32%) | 1032 (42%) | |
| Medical treatments | 2630 (28%) | 595 (25%) | |
| Operative procedure | 3691 (40%) | 807 (33%) | |
| Readmission—in-hospital mortality | 242 (2.7%) | 87 (3.7%) | 0.010 |
| Readmission—length of stay, median (IQR) | 4 (3–8) | 4 (2–7) | < 0.001 |
| Readmission—total charge, median (IQR) | 30,498 (16,924-59,387) | 29,220 (15,497-56,650) | 0.006 |

patients who required an emergency readmission, as well as patients who resided in a rural setting.[14] In a separate study, Tsai et al. noted that patients who lived further from the index versus non-index hospital were at higher risk of being readmitted to a non-index hospital.[2]

In the current study, several procedural, demographic, and socioeconomic factors were associated with non-index hospital readmission among patients undergoing HPB surgery. Perhaps not surprisingly, patients who had more medical comorbidities were more likely to be readmitted to non-index hospitals. In contrast, other factors such as higher income, private insurance, and initial surgery at a larger hospital were each associated with a lower risk of non-index readmission. Identification of these factors among HPB patients may facilitate identifying patients at higher risk of non-index readmission to allow for earlier intervention.

Another interesting finding in the current study was that index and non-index hospitalizations were notable for differences in the causes for readmission and procedures performed during readmission. For example, patients readmitted to index hospitals were more likely to be readmitted for infections and other GI complications and more often underwent a surgical procedure during their readmission versus patients readmitted to a non-index hospital. In addition, patients readmitted at index hospitals also had lower in-hospital mortality. In a study examining outcomes of Medicare patients who underwent major operations, Brooke et al. had similarly reported that readmission to the index hospital was associated with a lower risk of 90-day mortality compared with readmission to a non-index hospital. Similar to findings in the current study, the authors noted that the mortality difference among index versus non-index hospitals was largest for patients who had undergone pancreatectomy.[19] As such, readmission to the initial index—rather than a non-index—hospital following HPB surgery may be important to mitigate subsequent morbidity and mortality.

The current study had several limitations. While the use of the HCUP NRD allowed for a large sample size that covered over half of the US population, the use of any administrative data is inherently limited due to its retrospective design and the limitations of the data fields included in the database. The NRD database did contain, however, over 100 unique variables including clinical and demographic factors. Due to the yearly nature of the HCUP NRD files, it was also necessary to exclude patients who underwent index procedures in the last 3 months of the year in order to capture 90-day readmissions. Patients readmitted in a different state than the index admission could also not track as each state had different coding for the patient linkage numbers. Furthermore, multiple admissions for the same patient may or may not have been related. NRD does not contain information on patient or hospital zip code; therefore, it was not possible to calculate distance from a patient's home to the initial hospital or to the location of readmission. Finally, some variables included in the HCUP NRD were not available for all years.[1]

In conclusion, roughly 1 in 5 patients discharged after HPB surgery were readmitted to a non-index hospital at which the initial HPB operation had not taken place. Several patient-, hospital-, and procedure-specific factors were associated with the risk on non-index readmission. Readmission to a non-

index hospital was associated with higher overall in-hospital mortality. As centralization of complex surgical care increases, non-index readmission and fragmentation of care following surgery will remain a growing concern. Data from the current study highlights the importance of managing non-index readmission, as well as increasing efforts to readmit patients following complex HPB surgery to the hospital where their initial surgical procedure took place.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare that they have no conflict of interest.

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