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Implementation of a Critical Pathway for Complicated Gallstone Disease: Translation of Population-based Data into Clinical Practice

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Abstract

BACKGROUND—Evidence-based guidelines recommend cholecystectomy during initial hospitalization for complicated gallstone disease. Previous studies as well as quality initiative data from our institution demonstrated that only 40–75% of patients underwent cholecystectomy on index admission.

STUDY DESIGN—In January 2009, we implemented a critical pathway to improve cholecystectomy rates for all patients emergently admitted for acute cholecystitis, mild gallstone pancreatitis, or common bile duct stones. We compared cholecystectomy rates during initial hospitalization, time to cholecystectomy, length of initial stay (LOS), and readmission rates in pre-pathway (1/05–2/08) and post-pathway patients (1/09–5/10).

RESULTS—Demographic and clinical characteristics were similar between pre-pathway (n=455) and post-pathway patients (n=112). Cholecystectomy rates during initial hospitalization increased from 48% to 78% after pathway implementation ($P<0.0001$). There were no differences in operative mortality or operative complications between the two groups. For patients undergoing cholecystectomy on initial hospitalization, the mean LOS decreased after pathway implementation (7.1 days to 4.5 days; $P<0.0001$), primarily due to a decrease in the time from admission to cholecystectomy (4.1 days to 2.1 days; $P<0.0001$). 33% of pre-pathway and 10% of post-pathway patients required readmission for gallstone-related problems or operative complications ($P<0.0001$), and each readmission generated an average of \$19,000 in additional charges.

CONCLUSIONS—Implementation of a multidisciplinary critical pathway improved cholecystectomy rates on initial hospitalization and lowered costs by shortening length of stay and markedly decreasing readmission rates for gallstone-related problems. Broader implementation of similar pathways offers the potential to translate evidence-based guidelines into clinical practice and minimize the cost of medical care.

Keywords

acute cholecystitis; gallstone pancreatitis; common bile duct stones; cholecystectomy; critical pathway; clinical pathway

INTRODUCTION

Approximately 20 million people in the United States have gallstones¹. Annually, 1–4% of people with gallstones will develop gallstone-related complications requiring acute hospitalization^{2,3}. Gallstone disease is the cause of over one million hospitalizations, 700,000 operative procedures, and \$5 billion in cost annually¹, making it the most costly digestive disease in the United States⁴. The most common gallstone-related complications requiring hospital admission and prompt intervention are cholecystitis, choledocholithiasis (common bile duct stones), and gallstone pancreatitis.

In the 1800s gallstone disease was treated with cholecystostomy, stone removal, and development of a permanent biliary fistula^{5,6}. Late in the century, Carl Johann August Langenbuch recognized that the gallbladder gave rise to gallstones and that it was not essential to life. Using cadaveric dissection, he developed the technique of cholecystectomy and performed the first live human cholecystectomy in 1882 on a 43-year man suffering with gallstone disease for 16 years^{7,8}. His open cholecystectomy became the gold standard for symptomatic cholelithiasis, and remained so for over a century, until the introduction of laparoscopic cholecystectomy in the 1980s.

Despite initial debate in the early 1900s regarding the safety of cholecystectomy in the setting of acute gallstone-related complications, open cholecystectomy was performed routinely on initial hospitalization for complicated gallstone disease and was shown to be safe and to prevent recurrent hospitalizations. This is primarily because recurrence of gallstone complications after an initial hospitalization is high: 20–50% for acute cholecystitis^{9–18}, 40–50% for common bile duct stones^{19,20}, and 25–63% for gallstone pancreatitis^{21–24}. With the introduction of laparoscopic cholecystectomy, the benefits of the laparoscopic approach and its increased difficulty in the acute setting reintroduced questions about the timing of cholecystectomy for acute gallstone-related complications.

Subsequently, both laparoscopic and open cholecystectomy have been shown to be safe in the setting of gallstone-related complications. A Cochrane group has performed a comprehensive review of randomized controlled trials (1998–2003) evaluating cholecystectomy on initial hospitalization versus delayed laparoscopic cholecystectomy for acute cholecystitis²⁵. They concluded that laparoscopic cholecystectomy on initial hospitalization was associated with reduced hospital stays and no difference in conversion rates, morbidity, or mortality²⁵. Recent studies advocate early cholecystectomy and recommend laparoscopic cholecystectomy within one week of presentation and clearance of stones from the common bile duct^{26,27}. Evidence-based guidelines released by the International Association of Pancreatology in 2002 (based on studies from 1970s through 2000) recommend that cholecystectomy be performed for mild gallstone pancreatitis as soon as the patient has recovered from the acute pancreatitis, ideally during the same hospitalization²⁸.

Despite clear practice guidelines, many patients with complicated gallstone disease are not receiving definitive therapy. Single-institution and population-based studies demonstrate that only 40–75% of patients with acute cholecystitis, gallstone pancreatitis, and common bile duct stones undergo cholecystectomy on initial hospitalization^{19,29–31}, despite the proven efficacy and safety of cholecystectomy in the acute setting.

Based on these data, we reviewed our own experience at the University of Texas Medical Branch (UTMB) and found that less than 50% of patients underwent cholecystectomy during initial emergency admission for complicated gallstone disease, leading to multiple readmissions for gallstone-related problems. In addition, we found long preoperative lengths of stay for patients undergoing cholecystectomy. In response to this information we

undertook a quality initiative and implemented a cholecystectomy “critical pathway” in January of 2009 with the aim of improving cholecystectomy rates at our institution, and increasing compliance with evidence-based guidelines regarding treatment of complicated gallstone disease. We examined cholecystectomy rates before and after implementation of the critical pathway and compared surgical complications, conversion to open cholecystectomy, number of readmissions, hospital charges, and length of stay between pre- and post-pathway groups.

METHODS

This study was approved by the Institutional Review Board at the University of Texas Medical Branch at Galveston.

The University of Texas Medical Branch is a tertiary referral center located in Galveston, Texas. The main hospital, John Sealy Hospital, had 550 beds during the pre-pathway period. In September of 2008, Hurricane Ike caused damage to the hospitals and clinics of the University of Texas Medical Branch and forced the medical center to close temporarily. John Sealy Hospital reopened in January 2009 with a current inpatient capacity of approximately 350 beds.

Cholecystectomy Critical Pathway

The cholecystectomy critical pathway was implemented in January 2009 when the hospital reopened after Hurricane Ike. Implementation of the critical pathway was a multidisciplinary effort involving the general surgery faculty and residents, anesthesia faculty and residents, medicine faculty and residents, clinical pathway nurse, and the operating room staff. The cholecystectomy critical pathway contains the following provisions:

1. Patients with acute cholecystitis, gallstone pancreatitis, or choledocholithiasis are required to undergo cholecystectomy on initial hospitalization, unless clearly contraindicated. This was true regardless of the time from onset of symptoms to presentation.
2. For patients with acute cholecystitis, cholecystectomy should occur within 48 hours of admission.
3. For patients with gallstone pancreatitis or choledocholithiasis, cholecystectomy should occur within 48 hours of resolution of symptoms and bile duct clearance, respectively. For patients with common bile duct stones and gallstone pancreatitis, the need for cholangiography and/or bile duct clearance and the methods used are left to the discretion of the surgeon caring for the patient.

Accepted contraindications included myocardial infarction or stent placement within the prior three months, active use of clopidogrel (Plavix; Bristol-Myers Squibb, Sanofi-Aventis), and being in the first or third trimester of pregnancy. Other comorbidities and aspirin use may have been relative contraindications, according to the discretion of the involved surgeon and anesthesiologist. The reasons for failure to perform cholecystectomy were reviewed for each patient discharged without cholecystectomy.

Data Source and Patient Information

As part of the ongoing quality initiative in the Department of Surgery at UTMB, data are collected on patients admitted emergently to the hospital with complicated gallstone disease (acute cholecystitis, gallstone pancreatitis, and choledocholithiasis). Patients with symptomatic cholelithiasis were excluded. Prospective data collection is ongoing. Patients with an initial hospitalization for complicated gallstone disease from January 2005 to

February 2008 comprised the pre-pathway group (n = 455), and patients admitted to the hospital from January 2009 to May 2010 comprised the post-pathway group (n = 112).

Data were obtained from chart review of electronic (December 2007-present) and paper medical records (January 2005-November 2007). Data collected for analysis include patient age, race/ethnicity, insurance status, primary diagnosis, comorbidities, and health behaviors (smoking status and alcohol abuse). Data were also collected on radiologic studies performed as part of diagnostic evaluation, including right upper quadrant ultrasound, CT scan, magnetic resonance cholangiopancreatography (MRCP), endoscopic retrograde cholangiopancreatography (ERCP), and nuclear medicine biliary imaging (HIDA) scans. Results for laboratory tests on admission, such as white blood cell count (WBC), basic metabolic profile (BMP), liver function tests (LFTs), International Normalized Ratio (INR), amylase, and lipase levels on admission were also recorded. Other variables of interest include admitting service for the initial hospitalization, length of hospital stay, open vs. laparoscopic cholecystectomy, the use of intraoperative cholangiogram (IOC) during surgery, and perioperative complications (bile leak, bile duct injury, retained stones, biloma abscess, wound infection, pneumonia). A number of patients were missing laboratory values; the N for each laboratory test is included in Table 1.

Patients were followed for six months following discharge from initial hospitalization, or until June 2010 for post-pathway patients. We recorded readmissions related to surgical complications or gallstone complications, subsequent cholecystectomy in patients discharged without cholecystectomy during initial hospitalization, and charges for initial hospitalization and readmissions and emergency room (ER) visits following discharge. Financial data on hospital and ER charges were provided by the Department of Clinical Data Management at UTMB. Total hospital charges were calculated by summing the charges for initial hospitalization, readmissions, and ER visits. Ten patients were missing charge data for the 1st readmission to the hospital, and 3 patients were missing charge data for the 2nd readmission. Missing values were imputed using the median readmission charge for the respective readmission: \$9,842 for 1st readmission and \$10,279 for 2nd readmission.

Statistical Analysis

Patient demographics, comorbidities, health behaviors, diagnoses, and laboratory values and radiologic studies were compared between the pre- and post-pathway groups using chi-square tests for categorical variables and independent sample t-tests for continuous variables. We compared the percentage of patients undergoing cholecystectomy on initial hospitalization before and after implementation of the critical pathway using chi-square test. Among patients who underwent cholecystectomy, the percentages undergoing open cholecystectomy and intraoperative cholangiogram were compared between the pre- and post-pathway groups using chi-square test. Due to small expected cell counts, Fisher's exact test was used to examine differences in surgical complication rates between pre- and post-pathway groups. Other variables evaluated before and after implementation of the critical pathway were total length of stay in the hospital, pre-operative and post-operative length of stay, readmission rates, subsequent cholecystectomy, and total hospital charges. The statistical significance of differences between groups was analyzed with chi-square tests and t-tests, as appropriate. A P-value of 0.05 or less was considered statistically significant. All statistical analyses were performed with SAS software, version 9.2 (Cary, NC).

RESULTS

Characteristics of Patients by Critical Pathway Group

From January 2005 to May 2008, 455 patients were admitted to the hospital with complicated gallstone disease and included in the pre-pathway group. Following implementation of the cholecystectomy critical pathway in January 2009, 112 patients were admitted to the hospital with complicated gallstone disease and included in the post-pathway group. Table 1 shows patient demographics, health status and behaviors, and healthcare factors by critical pathway group. There were no differences with respect to mean age, gender, race/ethnicity, insurance status, diagnosis, or diagnostic tests/procedures between the two groups. Comorbidities, health behaviors, and lab values were also similar between the two groups, though total bilirubin and alkaline phosphatase levels were higher among pre-pathway patients. Forty-three percent of patients in the overall cohort were uninsured and there was no difference in insurance status before and after pathway implementation.

Rate of Cholecystectomy Pre- and Post-Pathway Implementation

Prior to pathway implementation, 48% of patients underwent cholecystectomy on initial hospitalization, compared to 78% of patients in the post-pathway group ($P < 0.0001$) (Table 2). When comparing the no cholecystectomy patients before and after pathway implementation, the post-pathway patients who didn't undergo cholecystectomy were similar with regard to age, gender, race, comorbidities, admitting diagnosis and diagnostic evaluation. However, after pathway implementation, patients not undergoing cholecystectomy were more likely to have a clear contraindication. Clear contraindications were identified in 17 of 237 patients (7%) before pathway implementation and 8 of 25 patients after pathway implementation (32%, $P < 0.0001$). Of the 8 post-pathway patients, one was on aspirin and clopidogrel (Plavix); the patient discontinued these medications and returned for elective cholecystectomy. One patient with common bile duct stones had had a myocardial infarction within the last month, with coronary stent placement and aspirin and clopidogrel (Plavix). He underwent high-risk sphincterotomy and cholecystectomy was indefinitely delayed. Another patient had a hypertensive crisis and cholecystectomy was delayed. Another had unstable new-onset tachyarrhythmias. One woman was admitted with and died of H1N1 pneumonia and her cholecystitis was of questionable significance. The last three patients were late in the third trimester of pregnancy, and cholecystectomy was delayed until after delivery.

Cholecystectomy rates improved regardless of admitting diagnosis, from 45% to 77% for acute cholecystitis ($P < 0.0001$), 47 to 77% for common bile duct stones ($P = 0.05$), and 57 to 79% for gallstone pancreatitis ($P = 0.03$). For uninsured patients cholecystectomy rates increased from 49% before implementation to 82% after implementation ($P < 0.0001$), while rates for insured patients increased from 47% to 74% ($P < 0.0001$). Overall, patients admitted to a medical service were less likely to undergo cholecystectomy both before and after pathway implementation. After pathway implementation, cholecystectomy rates improved from 55% to 84% ($P < 0.0001$) for patients admitted to the surgical service and from 29% to 58% ($P = 0.0005$) for patients admitted to a medical service. Rates of cholecystectomy increased among patients with coronary artery disease, diabetes, and hypertension.

Table 3 shows length of hospital stay, readmission rate, subsequent cholecystectomy rate, and hospital charges before and after pathway implementation. The total length of stay was shorter after pathway implementation (5.39 vs. 4.44 days, $P = 0.01$). Thirty-three percent of pre-pathway patients and 10% of post-pathway patients required readmission to the hospital for gallstone-related problems or operative complications ($P < 0.0001$). Twenty-eight percent of patients in the pre-pathway group underwent subsequent cholecystectomy, compared to

only 5% in the post-pathway group. Readmissions for gallstone-related problems and operative complications were associated with an average charge of \$19,310 per readmission, so a reduction in readmission rates represents a significant cost savings for patients and payers. Because more patients underwent surgery, the mean charge for initial hospitalization was slightly higher (\$25,500 vs. \$21,000, $P=0.01$), but as shown in the following section, the charges in patients undergoing cholecystectomy decreased after pathway implementation. In addition, the charges associated with readmission were lower after pathway implementation (\$19,800 vs. \$13,250, $P=0.04$).

Outcome of Patients with Cholecystectomy on Initial Hospitalization by Pathway

In patients who underwent cholecystectomy on initial hospitalization, approximately 23% in the pre-pathway group had open cholecystectomy, compared with 10% of patients in the post-pathway group ($P=0.01$) (Table 4). Conversion to open cholecystectomy was required in 33 (16%) patients from the pre-pathway group and 5 (6%) from the post-pathway group ($P=0.02$). There were no differences in operative mortality, common bile duct injuries, and other complications in the two groups. For patients undergoing cholecystectomy on initial hospitalization, the mean length of stay decreased from 7.1 days to 4.5 days after implementation of the pathway ($P<0.0001$). This was largely the result of a decrease in the time from admission to cholecystectomy from 4.1 days to 2.1 days after pathway implementation ($P<0.0001$). The mean total charges among patients undergoing cholecystectomy during initial hospitalization decreased by \$2,825 after pathway implementation.

DISCUSSION

Following review of quality initiative data at our institution, we implemented a critical pathway to improve clinical management of patients with complicated gallstone disease. Prior to implementation of the critical pathway, only 48% of patients emergently admitted to our hospital for complicated gallstone disease were receiving definitive treatment, despite evidence-based practice guidelines recommending cholecystectomy on initial hospitalization. Pathway implementation increased cholecystectomy rates to 78%, decreased preoperative and total lengths of stay, and reduced readmission rates, thereby improving patient care and decreasing costs. There were no differences in operative mortality or other complications between the two groups and conversion rates to open cholecystectomy were lower after pathway implementation.

Despite clear recommendations, cholecystectomy is still not routinely performed on initial hospitalization for complicated gallstone disease. Our pre-pathway data are consistent with previously reported studies. Casillas and colleagues³⁰ reported that 56% of patients with acute cholecystitis admitted to the surgical service of a large urban teaching hospital underwent cholecystectomy during initial hospitalization. The same study showed that early laparoscopic cholecystectomy was associated with significantly reduced length of stay in the hospital, no major complications, and no difference in conversion rate compared to non-surgical treatment or delayed cholecystectomy³⁰. Data from the Nationwide Inpatient Sample showed that only 51% of patients admitted for acute gallstone pancreatitis between 1998 and 2003 underwent cholecystectomy prior to discharge²⁹. Another study evaluating Medicare patients with acute cholecystitis demonstrated a 75% cholecystectomy rate with a 38% 2-year gallstone-related readmission rate in patients not undergoing cholecystectomy³¹. Our pre-pathway cholecystectomy rates were slightly lower than previously reported population-based studies. The lower rate can be attributed, in part, to our payer mix. Forty-three percent of patients in our study were uninsured, which is higher than the national average and certainly not comparable to the Medicare study in which 100% were insured.

Because of our payer mix, the implementation of this pathway was especially important. As the hospital is not reimbursed for the care of uninsured patients, multiple readmissions without definitive care were not only detrimental to patients, but costly for the institution. Single-stage definitive treatment on initial hospitalization was more efficient and decreased overall costs as well as the total duration of morbidity. We suspect that there are significant variations in cholecystectomy rates depending on U.S. region, payer mix, and hospital setting. Implementation of similar pathways in hospitals experiencing the same problems can be beneficial.

We performed cholecystectomy regardless of the duration of symptoms prior to presentation based on a previous single institution study demonstrating the safety of this approach (PUT IN REFERENCE Tzovaras *World J Gastroenterol.* Sep 14 2006;12(34):5528–5531). Many patients have acute on chronic symptoms and it is often difficult to determine the exact duration of onset of symptoms. However, in the post-pathway group there was no difference in the duration of symptoms prior to presentation between the cholecystectomy and no cholecystectomy groups. These procedures were done without higher rates of complications or conversion to open cholecystectomy. In addition, because many of our patients are uninsured, bringing them back for elective cholecystectomy is difficult. Moreover, our data show that patients in the pre-pathway group, many of whom had admissions for acute gallstone disease prior to presentation, had higher rates of open cholecystectomy (23% vs. 10%) as did patients who underwent delayed cholecystectomy in the pre-pathway group (14%). Based on these data, we proceed to cholecystectomy regardless of the duration of symptoms.

Implementation of this pathway required a multidisciplinary approach. We encountered several problems. The first was the volume of patients presenting with acute cholecystitis. Our hospital has a trauma/emergency surgery service which could be overburdened with the number of patients requiring urgent operation. This service is covered in-house by general surgeons (not on the emergency service) during evening and weekend hours. Before pathway implementation, the OR staff and anesthesiologists were reluctant to perform these cases on evenings and weekends, as they were not “emergencies”. However, since there is always a surgeon in the hospital, many could be done during these hours, decreasing the daytime burden on the trauma service. Surgeons worked together to get the cases done. For example, if a patient came in at 4 am and was posted for a cholecystectomy, the on-call surgeon passed this on to the daytime trauma team. Likewise, if the OR was not able to accommodate the case before 5 pm, the evening on-call faculty would do the operation. Despite the cooperation and significant improvement in cholecystectomy rates, 17 of 25 patients (68%) after pathway implementation had no clear contraindication to cholecystectomy. Targeting this population will allow us to further increase our cholecystectomy rates in excess of 90%.

It is important to document that complication rates did not increase with increased cholecystectomy rates in the acute setting. In fact, conversion rates were lower and there was no difference in postoperative complications. We hypothesize that conversion rates and overall open cholecystectomy rates were lower after pathway implementation because many patients in the pre-pathway group had previous admissions for complicated gallstone disease that were not taken into account since they occurred prior to the start of data collection for our study. Patients discharged without cholecystectomy in the post-pathway group were more likely to have a clear contraindication compared to patients discharged without cholecystectomy in the pre-pathway group. This may be partly attributed to increased documentation of contraindications as a result of pathway implementation but most likely is due to awareness and monitoring of the pathway.

In addition, not all post-pathway patients had clear contraindications, indicating further room for improvement. In addition to improving quality of care, the implementation of critical pathways is a means of providing cost-effective care and decreasing the use of hospital resources^{32, 33}. Studies have demonstrated cost savings with implementation of critical pathways for laparoscopic cholecystectomy in inpatient settings^{34, 35} as well as outpatient settings^{32, 33}. Our study evaluates hospital charges—not cost—and does not attempt a formal cost-effectiveness analysis. Patients who underwent cholecystectomy on initial hospitalization had lower total hospital charges after pathway implementation as a result of shorter times from admission to cholecystectomy and decreased overall length of stay. Readmissions, which generated an average charge of approximately \$19,000, decreased from 33% to 10%. In addition, the charges for readmissions after cholecystectomy, largely from operative complications, were lower.

There were several limitations to this study. At the time of data analysis, complete 6-month follow-up was not available in some post-pathway patients. To the extent that these patients will have additional operative- or gallstone-related readmissions or ER visits, the readmission rates and cost totals in our analysis may be underestimated in post-pathway patients. However, readmissions in this group were largely due to operative complications and not gallstones, and we would expect most readmissions to occur in the first 30 days. Another potential limitation is that data were collected over a several year period, and secular trends could be contributing to changes in length of hospital stay and hospital charges, in the absence of the critical pathway. Finally, the sample size in the post-pathway group is small, potentially increasing the risk of type II error. Further efforts at improving cholecystectomy are focused in two areas: the medical service and the Emergency Department. Education and awareness of the pathway in these areas will help continue to improve cholecystectomy rates.

Despite evidence-based guidelines recommending cholecystectomy on initial hospitalization for complicated gallstone disease, cholecystectomy was not routinely performed on initial admission for complicated gallstone disease at our institution. Despite the fact that surgeons have known how to definitively treat this problem since 1882, we suspect that this is a common problem at many institutions across the United States and encourage hospitals to evaluate their own experience. The implementation of a critical pathway allowed us to increase cholecystectomy rates from 48% to 78% on initial hospitalization, while simultaneously decreasing preoperative and total lengths of stay and reducing readmission rates. Targeting the patients who did not have a clear contraindication and did not undergo cholecystectomy will allow further improvement in our cholecystectomy rates. Single-stage definitive treatment on initial hospitalization was more efficient and decreased overall costs as well as the total duration of morbidity. Dissemination of this pathway to other hospitals experiencing similar problems, and broader implementation of similar pathways, offers the potential to translate evidence-based guidelines into clinical practice and minimize the cost of medical care.

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ABBREVIATIONS

UTMB	University of Texas Medical Branch
MRCP	magnetic resonance cholangiopancreatography

ERCP	endoscopic retrograde cholangiopancreatography
HIDA	nuclear medicine biliary imaging
WBC	white blood cell count
BMP	basic metabolic profile
LFT	liver function test
INR	International Normalized Ratio
IOC	intraoperative cholangiogram
ER	emergency room

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Table 1

Demographics, Health Status, and Healthcare Factors by Pathway Group

Variable	Pre-Pathway (n = 455) n (%) or Mean $\pm$ SD	Post-Pathway (n = 112) n (%) or Mean $\pm$ SD	P Value
Age	44.7 $\pm$ 20.5	46.9 $\pm$ 17.9	0.26
Female	317 (69.8)	78 (69.6)	0.97
Race/ethnicity			
White	211 (46.4)	49 (43.8)	0.57
Black	53 (11.7)	12 (10.7)	
Hispanic	179 (39.3)	50 (44.6)	
Other	12 (2.6)	1 (0.9)	
Insured	260 (57.1)	62 (55.4)	0.73
Comorbidities			
Coronary artery disease	45 (9.9)	7 (6.4)	0.26
Myocardial infarction	14 (3.1)	3 (2.9)	0.92
Diabetes	62 (13.6)	17 (16.4)	0.47
Hypertension	150 (33.0)	38 (36.2)	0.53
Chronic obstructive pulmonary disease	13 (2.9)	1 (1.0)	0.26
Health behaviors			
Current smoker	92 (20.2)	20 (19.4)	0.85
Alcohol abuse	31 (6.8)	9 (8.7)	0.51
Admitting service			
Surgery	333 (73.4)	83 (74.1)	0.16
Medicine	99 (21.8)	19 (17.0)	
Other -Pediatrics, Geriatrics, OB/GYN	22 (4.9)	10 (8.9)	
Lab values			
Temperature (degrees Celsius); N = 423/105	36.7 $\pm$ 2.5	36.8 $\pm$ 0.5	0.62
White blood cell count; N = 449/106	11.8 $\pm$ 5.2	11.3 $\pm$ 4.3	0.27
Total bilirubin; N = 455/105	1.7 $\pm$ 2.5	1.4 $\pm$ 1.6	0.04
Direct bilirubin; N = 444/105	0.5 $\pm$ 1.3	0.4 $\pm$ 1.0	0.51
Aspartate aminotransferase; N = 455/106	166.2 $\pm$ 245.8	166.5 $\pm$ 217.2	0.99
Alkaline phosphatase; N = 372/106	172.8 $\pm$ 130.8	148.4 $\pm$ 99.5	0.04
Amylase; N = 449/104	157.5 $\pm$ 432.1	210.7 $\pm$ 693.4	0.45
Lipids; N = 455/106	715.0 $\pm$ 1653.7	895.3 $\pm$ 1748.1	0.34
Diagnosis			
Acute cholecystitis	300 (65.9)	71 (63.4)	0.88
Common bile duct stones	49 (10.8)	13 (11.6)	
Gallstone pancreatitis	106 (23.3)	28 (25.0)	
Tests/Procedures			
Ultrasound	327 (71.9)	88 (78.6)	0.15
MRCP	92 (20.2)	21 (19.8)	0.92
ERCP	104 (22.9)	22 (20.8)	0.64

Variable	Pre-Pathway (n = 455)	Post-Pathway (n = 112)	P Value
	n (%) or Mean $\pm$ SD	n (%) or Mean $\pm$ SD	
CT Scan	210 (46.2)	44 (41.5)	0.39
HIDA	20 (4.4)	7 (6.6)	0.34

MRCP, magnetic resonance cholangiopancreatography; ERCP, endoscopic retrograde cholangiopancreatography; HIDA, nuclear medicine biliary imaging

Table 2

Rates of Cholecystectomy Pre-and Post-Pathway Implementation Overall and by Insurance Status, Diagnosis, Admitting Service, and Comorbidities

	Pre-Pathway (n = 455) n (%)	Post-Pathway (n = 112) n (%)	P Value
Cholecystectomy on initial hospitalization	218 (47.9)	87 (77.7)	<0.0001
Diagnosis			
Acute cholecystitis	135 (45.00)	55 (77.46)	<0.0001
Common bile duct stones	23 (46.94)	10 (76.92)	0.05
Gallstone pancreatitis	60 (56.60)	22 (78.57)	0.03
Uninsured	95 (48.7)	41 (82.0)	<0.0001
Insured	123 (47.3)	46 (74.2)	<0.0001
Admitting service			
Surgery	183 (54.95)	70 (84.34)	<0.0001
Medicine	23 (23.23)	12 (63.16)	0.0005
Other -Pediatrics, OB/GYN, Geriatrics	11 (50.00)	5 (50.00)	1.000
Comorbidities			
Coronary artery disease	12 (26.67)	5 (71.43)	0.03
Diabetes mellitus	23 (37.10)	14 (82.35)	0.001
Hypertension	65 (43.33)	26 (68.42)	0.006
Current smoker	32 (34.78)	15 (75.00)	0.001

Table 3

Cholecystectomy, Conversion to Open, Length of Hospital Stay, Readmissions, Subsequent Cholecystectomy, and Hospital Charges by Pathway

Outcomes	Pre-Pathway (n = 455) n (%) or Mean $\pm$ SD	Post-Pathway (n = 112) n (%) or Mean $\pm$ SD	P Value
Cholecystectomy on initial hospitalization	218 (47.9)	87 (77.7)	<0.0001
Contraindications/patients discharged without cholecystectomy on initial hospitalization	17/237 (7.17)	8/25 (32.00)	<0.0001
Cholecystectomy post initial hospitalization	129 (28.4)	6 (5.4)	<0.0001
Cholecystectomy post initial hospitalization/patients discharged without cholecystectomy	129/237 (54.4)	6/25 (24.0)	0.004
Open cholecystectomy	18 (14.2)	0 (0.0)	
Convert to open	12 (9.5)	0 (0.0)	
Total length of stay, initial hospitalization	5.4 $\pm$ 4.3	4.4 $\pm$ 3.0	0.01
Any readmission	150 (33.0)	11 (9.8)	<0.0001
Mean readmissions among those readmitted	1.2 $\pm$ 0.5	1.0 $\pm$ 0.0	<0.0001
Readmission charges	19,790 $\pm$ 20,205	13,256 $\pm$ 8,571	0.04
Charges for initial hospitalization	21,137 $\pm$ 16,399	25,468 $\pm$ 14,189	0.01
Total hospital charges (Initial + Readmission)	27,705 $\pm$ 21,793	26,888 $\pm$ 15,044	0.64
Total charges (Hospital + ER post-discharge)	27,981 $\pm$ 21,736	26,888 $\pm$ 15,044	0.53

Table 4

Outcomes in Patients with Cholecystectomy on Initial Hospitalization by Pathway

	Pre-Pathway (n = 218)	Post-Pathway (n = 87)	P Value
	n (%) or Mean $\pm$ SD	n (%) or Mean $\pm$ SD	
Open cholecystectomy	50 (23.3)	9 (10.3)	0.01
Convert to open	33 (15.5)	5 (5.8)	0.02
Intraoperative cholangiogram	74 (34.6)	9 (10.3)	<0.0001
Post-operative complications	41 (18.8)	13 (14.9)	0.42
Bile leak	7 (3.2)	2 (2.3)	0.67
Retained stone	17 (7.8)	5 (5.8)	0.53
Biloma abscess	4 (1.8)	0 (0.0)	0.58
Wound infection	5 (2.3)	3 (3.5)	0.69
Pneumonia	5 (2.3)	0 (0.0)	0.33
Bile duct injury	2 (0.9)	1 (1.2)	0.85
Post-operative length of stay	3.0 $\pm$ 3.4	2.4 $\pm$ 2.3	0.09
Total length of stay	7.1 $\pm$ 4.5	4.5 $\pm$ 3.1	<0.0001
Time to cholecystectomy	4.1 $\pm$ 2.7	2.1 $\pm$ 1.9	<0.0001
Any readmission	15 (6.9)	6 (6.9)	1.00
Mean readmissions*	1.3 $\pm$ 0.5	1.0 $\pm$ 0.0	
Charges for initial hospitalization	28,812 $\pm$ 17,620	26,692 $\pm$ 12,203	0.23
Total hospital charges (Initial + Readmission)	30,772 $\pm$ 21,180	27,948 $\pm$ 13,513	0.17
Total charges (Hospital + ER post discharge)	30,849 $\pm$ 21,114	27,948 $\pm$ 13,513	0.16

* Among patients with at least 1 readmission