Objective and Background: The decision regarding elective cholecystectomy in older patients with symptomatic cholelithiasis is complicated. We developed and validated a prognostic nomogram to guide shared decision making for these patients.

Methods: We used Medicare claims (1996–2005) to identify the first episode of symptomatic cholelithiasis in patients older than 65 years who did not undergo hospitalization or elective cholecystectomy within 2.5 months of the episode. We described current patterns of care and modeled their risk of emergent gallstone-related hospitalization or cholecystectomy at 2 years. Model discrimination and calibration were assessed using a random split sample of patients.

Results: We identified 92,436 patients who presented to the emergency department (8.3%) or physician’s office (91.7%) and who were not immediately admitted. The diagnosis for the initial episode was biliary colic/dyskinesia (65.3%), acute cholecystitis (26.6%), cholecodolithiasis (5.7%), or gallstone pancreatitis (2.4%). The 2-year emergent gallstone-related hospitalization rate was 11.1%, with associated in-hospital morbidity and mortality rates of 56.5% and 6.5%. Factors associated with gallstone-related acute hospitalization included male sex, increased age, fewer comorbid conditions, complicated biliary disease on initial presentation, and initial presentation to the emergency department. Our model was well calibrated and identified 51% of patients with a risk less than 10% for 2-year complications and 5.4% with a risk more than 40% (C statistic, 0.69; 95% confidence interval, 0.63–0.75).

Conclusions: Surgeons can use this prognostic nomogram to accurately provide patients with their 2-year risk of developing gallstone-related complications, allowing patients and physicians to make informed decisions in the context of their symptom severity and its impact on their quality of life.

Keywords: aged, gallstones, management, prognostic nomogram, symptomatic cholelithiasis

First claim for gallstones (ICD-9 574*, or 575*) in patients 66 yr or older from 1996–2005 (N = 188,296)

Part A and B enrollment 1 yr before and 2 yr after initial episode (N = 167,103)

Excluded patients admitted to the hospital on the initial episode (N = 117,158)

Excluded patients undergoing elective cholecystectomy (21%) N = 92,436

CT or US 1 mo before or after initial episode (N = 144,042)

FIGURE 1. Cohort Selection. Symptomatic cholelithiasis defined by (1) Primary diagnosis of ICD-9-CM code 574 or 575 (or 2) Primary diagnosis of acute pancreatitis (577.0) and a secondary diagnosis of 574 or 575. Only patients 66 years or older who underwent CT and/or US in the month before or after diagnosis were included. Patients who underwent cholecystectomy at initial presentation were excluded. CT indicates computed tomography; US, ultrasound.

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and physician visits with (1) an International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) primary diagnosis of 574* or 575* or (2) primary diagnosis of acute pancreatitis (ICD-9-CM 577.0) and a secondary diagnosis of ICD-9-CM 574* or 575* as has been done previously. Although Medicare data from 1995 to 2007 were available, we only included incident gallstone cases from 1996 to 2005. This was done to (1) identify patient comorbidities from the claims data the year before the incident diagnosis and (2) to enable us to “follow” all patients via their claims data for at least 2 years after the date of initial diagnosis. The first claim for symptomatic cholelithiasis was identified for each patient and defined as the incident episode. Patients were included if they were 66 years or older and had Medicare Parts A and B fee-for-service and no Health Maintenance Organization for 1 year prior (to identify incident cases) and 2 years after the incident claim, or until death. Patients who were admitted to a hospital or those undergoing cholecystectomy at the time of the incident episode of symptomatic cholelithiasis were excluded. To ensure we were capturing patients with confirmed symptomatic cholelithiasis, patients were excluded if the diagnosis of cholelithiasis was not accompanied by computed tomography or ultrasound in the 1 month before or after the claim. Computed tomography and ultrasound were identified in the carrier and outpatient Standard Analytic File claims files using Current Procedural Terminology codes (Supplemental Digital Content Table 1 available at http://links.lww.com/SLA/A597).

We excluded patients who underwent elective cholecystectomy after the initial episode. To define elective cholecystectomy, we searched for any claim for cholecystectomy (Supplemental Digital Content Table 1 for ICD-9-CM and Clinical Procedural Terminology codes available at http://links.lww.com/SLA/A597) after the incident episode that was coded as “elective” in the Medicare type of admission variable. Then, we calculated a cumulative incidence curve for elective cholecystectomy. Patients were censored for death and emergency cholecystectomy. A piecewise regression model was used to identify the time point when the cumulative incidence plateaued (inflection point). The location of this inflection point (or joint point) was estimated by nonlinear least squares regression. For elective cholecystectomy, the inflection point was 2.44 months (Fig. 2: 95% confidence interval 2.39–2.48). We used this inflection point to define elective cholecystectomy for the cohort, and excluded any patient undergoing a cholecystectomy coded as elective within 2.5 months after the incident episode. The final study cohort included 92,436 patients.

Covariates

We recorded patient demographic characteristics including age, sex, race/ethnicity, Elixhauser comorbidity index, and diagnosis at initial claim for symptomatic cholelithiasis (biliary colic/biliary dyskinesia, acute cholecystitis, common bile duct stones, and gallstone pancreatitis; Table 1). Elixhauser comorbidity index was used as a summary measure for patient comorbidity, as described in the previous text. Type of initial visit (emergency department vs physician office) was also recorded.

Description of Trajectory

Patients were followed up from the date of initial episode to any gallstone-related event. Potential gallstone-related events included emergent hospitalization, emergent cholecystectomy, delayed elective cholecystectomy (>2.5 months after initial episode), or emergency department/outpatient physician visits with a gallstone-related diagnosis. Emergent admission was identified using Medicare Part A inpatient inpatient billing claims and defined as any gallbladder-related claim coded as “emergency” or “urgent” in the type of admission variable. Overall in-hospital morbidity and mortality, perioperative complications, and 30-day operative mortality were calculated for patients who underwent emergent cholecystectomy. Codes used to identify perioperative complications within 30 days of the date of surgery are included in Supplemental Digital Content Table 1 available at http://links.lww.com/SLA/A597. Operative mortality was defined as death from any cause occurring within 30 days from the date of surgery or a discharge status coded as “discharged dead.” Patients who did not experience any of the above outcomes and did not die

FIGURE 2. Cumulative incidence curve for elective cholecystectomy for the study cohort using a piecewise regression model (least squares nonlinear regression). Patients were censored for death or emergency cholecystectomy. Of these patients undergoing elective cholecystectomy, 79.6% underwent cholecystectomy at 3 months and 88.9% underwent cholecystectomy at 12 months. For elective cholecystectomy, the joint point/inflection point (represented by the dotted vertical line) was 2.44 months (95% CI, 2.39–2.48). CI indicates confidence interval.
were presumed not to have any gallstone-related problems during the 2-year period after the initial episode.

**Trajectory of Care**

Descriptive statistics were used to summarize the sample characteristics at initial presentation and to describe patients within each trajectory of care: (1) patients without further problems, (2) patients who presented with multiple emergency department visit or physician visits but who were not admitted, and (3) patients who required emergent hospitalization.

**Risk Prediction Model Creation and Validation**

For the purpose of model identification and validation, we randomly split the overall cohort of patients into a training sample \( (N = 46,218) \) and a validation sample \( (N = 46,218) \). We used the training sample for model selection and then applied the obtained model parameters to check the performance of the selected model in the validation sample. We developed a Cox proportional hazards regression model used in training sample who actually required emergent care in a Kaplan-Meier time-to-event analysis. The predicted mean of each decile in the training model sample was compared with the mean observed proportion of patients in the model validation sample who actually required emergent care in a Kaplan-Meier time-to-event analysis.

C statistics were estimated by using R package “survC1” and all other statistical analyses were performed using SAS version 9.3 (SAS Inc., Cary, NC). Statistical significance was accepted at the \( P < 0.05 \) level.

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**RESULTS**

**Overall Sample Characteristics**

We identified 117,158 patients presenting with an initial episode of symptomatic cholelithiasis; 24,722 (21.1%) underwent elective cholecystectomy within 2.5 months, leaving 92,436 patients who met our inclusion criteria (Table 1). The mean age was 77.0 \( \pm \) 7.2 years. The majority of patients were white (87.5%) and females (61.1%). Outpatient evaluation was initially performed in 91.7% of
patients, whereas the remaining 8.3% first presented to the emergency department. The primary visit diagnosis for the incident episode was biliary colic in 65.3%, acute cholecystitis in 26.7%, common bile duct stones in 5.7%, and gallstone pancreatitis in 2.4%.

**Description of Trajectory**

Figure 2 shows the cumulative incidence of elective cholecystectomy a 1 year. As described in the methods, elective cholecystectomy was defined as cholecystectomy within 2.5 months of diagnosis based on the inflection point. A total of 77.2% of elective cholecystectomies were performed in the first 2.5 months after the incident episode of symptomatic gallstones.

Of the 92,436 patients who did not undergo early elective cholecystectomy, 10,247 (11.1%) eventually required emergency hospitalization for gallstone-related complications, and 8508, or 83.0%, of these admitted patients underwent emergency cholecystectomy (Fig. 3). An additional 12,176 patients (13.1%) re-presented to the emergency department or to an outpatient physician at least once during the 2 years for biliary symptoms but did not require hospitalization or emergent cholecystectomy. A total of 3704 patients underwent delayed elective cholecystectomy more than 2.5 months after the initial episode. Of these patients, 3.4% had postoperative complications, and perioperative mortality was 0%. Finally, 69,309 patients (71.7%) did not require any emergent gallstone-related intervention or additional visits. 49,483 (53.5%) survived to 2 years and the remainder died of unrelated causes during the 2-year follow-up period.

In-hospital morbidity and mortality were high for the 10,247 patients who presented with emergent hospitalization for gallstone-related complications; 56.5% and 6.1%, respectively. Perioperative morbidity (26.8%) and mortality (1.2%) for the 8508 patients who underwent emergent cholecystectomy were also elevated.

**Prognostic Nomogram Creation and Validation**

The overall cohort was randomly split into equal-sized training and validation samples; sample characteristics and 2-year rates of emergent events were similar for the 2 samples (Fig. 4; Table 1). The training sample was used to generate a Cox proportional hazards regression model for the development of emergent gallstone-related events (Table 2). Factors independently associated with need for emergency care were older age, white race, male sex,

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**FIGURE 3.** Trajectory of care for Medicare patients with symptomatic cholelithiasis initially managed nonoperatively (N = 92,436). A total of 10,247 (11.1%) subsequently required emergent care, 12,176 (13.1%) had recurrent symptoms but did not require hospitalization or surgery, and 70,013 did not require any further intervention. Of the patients who did not require intervention, 70.7% survived to 2 years. ED indicates emergency department.

**FIGURE 4.** “Predicting Risk of Complications in Older Patients with Gallstones,” PREOP-Gallstones model nomogram. To use the nomogram, a vertical line is drawn from each factor to the corresponding position on the “Points” line. Once the points are tabulated for each factor, the points are then added. A line is drawn from this position on the “Points” line to the “Emergent visit probability” lines to determine a patient’s 12-month and 24-month risk for developing emergent gallstone-related complications. HMO indicates Health Maintenance Organization; BC, biliary colic; AC, acute cholecystitis; GP, gallstone pancreatitis; CBDS, common bile duct stones.
initial visit to emergency room department, and a diagnosis of complicated gallstone disease (gallstone pancreatitis, common bile duct stones, and acute cholecystitis) at initial presentation. Patients with the least comorbidities were also more likely to require emergency care.

On the basis of this multivariable model, we developed our model, the PREOP-Gallstones model, which can be used to promote shared decision making (Fig. 4). A prognostic nomogram can be used by clinicians to visually calculate probabilities of an outcome using data based on regression modeling. In using this nomogram, a line is drawn vertically from each factor to the corresponding point. Once all factors and points are tabulated, these points can be added, and then another vertical line is used to determine a patient’s 12-month and 24-month risk for developing emergent gallstone-related complications.

When applied to the validation sample, the C statistic for our model was 0.69 (95% confidence interval, 0.63–0.75). Figure 5 shows the calibration plot comparing predicted deciles of risk of emergent complications.

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### DISCUSSION

We used a large population-based cohort to describe the trajectory of care in older patients presenting with an initial episode of symptomatic cholelithiasis who did not undergo elective cholecystectomy. Although cholecystectomy is the standard of care for patients presenting with symptomatic cholelithiasis, we observed that many older patients did not undergo elective cholecystectomy. As in prior studies, the majority of older patients with symptomatic cholelithiasis in our study who did not undergo elective cholecystectomy did not ultimately experience complications that required hospitalization or surgery. However, nearly one third required delayed elective cholecystectomy, had ongoing symptoms, or required emergency gallstone-related hospitalization, and morbidity and inhospital mortality high for these patients who eventually required emergent care. On the basis of these data, we developed the PREOP-Gallstones model, a nomogram that reliably predicted patients with an more than 40% 2-year risk of developing gallstone-related complications (approximately 10% of the cohort) and an additional 50% of patients with less than 10% 2-year risk.

Our study is the first to incorporate easily measurable characteristics into a risk prediction model to identify the likelihood for emergent biliary-related hospitalization for older patients with biliary disease. A prognostic nomogram visually depicts the findings of multivariate modeling, has been previously implemented into decision modeling for patients who underwent surgery, and has been suggested to enhance communication between patients and practitioners. Unlike complex statistical models, nomograms can be easily integrated into the patient-practitioner encounter and thereby improve the shared decision-making process. The PREOP-Gallstones model included variables such as age, race/ethnicity, sex, number of comorbidities, initial diagnosis, and location for initial visit, and was able to identify a group of patients at high-risk (>40%) for subsequent gallstone-related emergent hospitalizations and a group at low risk. Practitioners can use these readily available characteristics to

![Model calibration: Observed/expected need for emergent care at 2 yr](image)

**FIGURE 5.** Model calibration results. The observed-to-expected probabilities for patients requiring emergent care (hospitalization and/or cholecystectomy) at 2 years. The graph illustrates that there was little difference between the expected calculated probability for emergent care and the mean observed probabilities.
counsel each individual patient on their expected risks for requiring emergency care.

The characteristics associated with emergent biliary complications were not anticipated. Initial presentation to the emergency department and complicated biliary disease, factors that are likely proxies for disease severity, were also independent risk factors for subsequent hospitalization. Older age has been previously suggested to be a risk factor for persistent biliary symptoms after an initial attack. Increased comorbidity, which for these older patients is a threat for a competing risk of early death, was a protective factor for subsequent biliary complications. Although this finding seems counterintuitive, the number of comorbidities in this vulnerable cohort of older patients likely limited their life expectancy. Many of these patients with multiple comorbidities may have died from their chronic medical conditions such as heart disease, before they could develop symptoms of gallstone disease. This is further supported by the relatively high mortality rate (22.9%) at 2 years we observed for the overall cohort and the dramatically elevated 2-year mortality rate of 40.4% for those patients with 3 or more Charlson comorbidities. Finally, we observed, as others have, that male sex is an indicator for increased biliary disease severity. The male predominance in emergent biliary surgery has been suggested to be related to social factors (men may be less likely follow medical advice), biochemical factors (female hormones may sensitize women to the inflammation of cholecystitis), anatomic factors, or less frequent use of medical services among men.

The relative contributions for these factors should also be placed in the appropriate context. The 2 factors most strongly associated with an emergent presentation were initial patient presentation to the emergency department and a diagnosis of complicated biliary disease. As the nomogram illustrates, a patient presenting with either of these factors has a dramatically elevated risk for emergent biliary complications at 2 years (15%–25%). In contrast, a patient presenting with the cumulative burden of all the other factors combined but without complicated biliary disease or emergent presentation would have only an approximate 10% risk at 2 years. As a result, the PREOP-Gallstones model could be validated and the practical utility demonstrated by future studies using electronic medical records in clinical practice settings with additional pertinent clinical findings, such as ultrasound characteristics or patient laboratory values.

Our findings also suggest that elective cholecystectomy is underused in a cohort of older patients with symptomatic cholelithiasis who are more likely to experience disease progression than younger patients. The reasons for this disparity are multifactorial, but one contributing factor is the absence of a solid evidence base on which to counsel patients. The PREOP-Gallstones model fills this knowledge gap for both patients and practitioners.

Our study has several limitations. Our goal was to review current practice patterns and identify risk factors for developing complications related to gallstones, to determine if all older patients do in fact need cholecystectomy after an initial episode, and if they do not, who would most benefit. As such, we excluded patients admitted to the hospital on the initial episode because these were patients with severe enough symptoms to require admission. We also excluded patients who underwent an early elective cholecystectomy in the initial 2.5 months after diagnosis (N = 24,722), representing only 21% of the study population. For these patients, the decision to perform early cholecystectomy was likely dictated by patient disease severity, patient or practitioner preference, or any number of reasons that our analysis cannot capture. We suspect that the rates of emergent admission would be higher if these 21% did not undergo cholecystectomy. As a result, our model findings only apply to a marginal population of patients in whom the decision to perform cholecystectomy can be difficult.

In addition, the model C statistic would suggest a marginal discriminatory ability, but our calibration results indicate that these findings are likely due to poor discrimination among patients in the lowest deciles of requiring emergent care. However, within each decile, prediction was very accurate, and our model was able to accurately identify the 10% of patients who have a more than 40% risk of developing emergent biliary complications (high specificity) and more than 50% who have a less than 10% 2-year risk.

In addition, the PREOP-Gallstones model is based on administrative data that cannot capture practitioner or patient intent. Some patients may have elected to forego surgery counter to recommendations, or there may have been indications for delaying surgery such as need for antiplatelet therapy for a recent percutaneous coronary intervention. In other cases, patients may have been scheduled for elective cholecystectomy but their disease progressed in the interim. Given the model limitations, physicians should consider the results in the context of each individual patient's symptom severity, presentation, and preferences. For instance, although one patient may view a 10% risk for emergent care as prohibitive, another may view this as a minute, and as a result, surgeons should work with patients to develop the optimal individualized treatment plan for them. In this manner, our model can be used in uncertain cases to counsel patients that are at high-risk for disease progression and who may benefit most from early elective cholecystectomy. Conversely, our model was able to generally identify certain patients that have low risk (<10%) for subsequent biliary complications, and elective cholecystectomy may not be necessary for this group. Further validation of our model with other samples may be needed to illustrate its utility in this regard.

CONCLUSIONS

The PREOP-Gallstones model will enable internists, hospitalists, primary care physicians, and surgeons to use readily identifiable patient characteristics to quantify an individualized risk score of requiring emergent biliary care. Practitioners can use these data to accurately provide patients with their 2-year risk of developing gallstone-related complications at the point of care, allowing patients to make informed decisions in the context of their symptom severity and its impact on their quality of life. This approach has the potential to mitigate the morbidity and mortality of emergency care and reduce unnecessary cholecystectomy for patients who are unlikely to benefit.

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