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Factors That Predict High Health Care Utilization and Costs for Patients With Inflammatory Bowel Diseases

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Abstract

BACKGROUND & AIMS—A subset of patients with inflammatory bowel diseases (IBD) have continuously active inflammation, leading to a high number of complications and high direct health care costs (diagnostic tests, medications, and surgeries) and indirect costs (reduced employment and productivity and fewer opportunities for activities). Identifying these high-risk patients and providing effective interventions could produce better outcomes and reduce costs. We used prior year data to create IBD risk models to predict IBD-related hospitalizations, emergency department visits, and high treatment charges (>$30,000/year) in the subsequent year.

METHODS—We performed a retrospective study of medical records from all patients with IBD treated at the University of Michigan Hospital from fiscal years 2013–2015. We selected clinical variables from the prior year and tested their abilities to predict 3 adverse outcomes (IBD-related hospitalizations, emergency department visits, and treatment charges >$30,000/year) in the subsequent year. Individual patients were only included once in the data set. We created a multivariate model that was based on a 70% randomly selected cohort (1005 patients) and validated the model on the other 30% (425 patients). Logistic regression was used for bivariate and multivariate analyses.

RESULTS—Factors that predicted high-cost outcomes included the presence of psychiatric illness, use of corticosteroids, use of narcotics, low levels of hemoglobin, and high numbers of IBD-related hospitalizations. In the validation cohort, the model predicted IBD-related hospitalizations, emergency department visits, and high charges in the following year with receiver operating characteristic curve values of 0.751, 0.738, and 0.744, respectively.

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Supplementary Material

Note: To access the supplementary material accompanying this article, visit the online version of *Clinical Gastroenterology and Hepatology* at www.cghjournal.org, and at http://dx.doi.org/10.1016/j.cgh.2016.09.012.

Conflicts of interest

The authors disclose no conflicts.

CONCLUSIONS—We identified 5 factors that can effectively identify patients with IBD at high risk for hospitalization, emergency department visits, and high treatment charges in the next year. These patients should be closely monitored and aggressively managed.

Keywords

Crohn's Disease; Ulcerative Colitis; AUROC Analysis; Management

Inflammatory bowel disease (IBD) is a chronic illness with an unpredictable course. Roughly half of patients have well-controlled disease with intermittent flare-ups. The other half of IBD patients have more aggressive disease, some with intermittent severe flare-ups and some with continuously active inflammation.[1,2] The latter group of patients more commonly develop complications and have high health care costs including both direct costs including diagnostic testing, medications, and surgeries and indirect costs including reduced employment, reduced productivity of paid work, and reduced opportunities for unpaid activities.[3–5] It has been reported that the top 10% of patients with highest charges account for 50% of the total cost of IBD care.[6] Therefore, it is important to identify these high-risk patients and intervene to best prevent complications and improve quality of life.

There have been many studies investigating individual predictors of aggressive IBD course. These include disease factors such as extensive disease, fistulizing disease, high inflammatory activity, early need for corticosteroids, need for biologic therapy, and patient factors such as young age, prior smoking, anemia, and high numbers of telephone encounters, which have been reported as predictors of hospitalizations or surgeries.[7–12] These factors may be used by physicians to identify patients who could benefit from earlier and more aggressive treatment. The increasing use of electronic medical records (EMRs) allows for new opportunities to flag these patients in an automated fashion. However, a model integrating these risk factors has not been developed. Furthermore, data on factors predicting high costs of care are limited.[6] Therefore, this study aimed to identify predictive factors readily available in a standard EMR (EPIC Systems, Verona, WI) to develop a multivariate model to predict the probability of IBD-related hospitalization, emergency department (ED) visit, and high total charges in the subsequent year.

Methods

We retrospectively reviewed the EMRs of all patients with the International Classification of Diseases, 9th Revision diagnostic codes of 555 and 556 who came to University of Michigan Health System from fiscal years (FY) 2013 to 2015 (July 1, 2012 to June 30, 2015). To prevent patients from being represented more than once in the data set, if patients presented in all 3 FYs, 2 consecutive years of their clinical data were randomly selected (either FY2013–14 or FY2014–15) for inclusion. We aimed to create a model that was based on the training data set that we generated by randomly selecting 70% of patients in our cohort and validate the model with the other 30% of patients. We excluded patients with single visits in a given year or no visits in a subsequent year (eg, second opinions, patients presenting for chromoendoscopy and endoscopic mucosal resection procedures). Only the patients who had

data for both predictive and outcome variables in consecutive years were included in this study.

We extracted the following variables from the medical record: patient demographic data, type of IBD, presence of psychiatric illness including depressive disorders, anxiety disorders, and bipolar disorder; laboratory values indicating disease activity including the maximum values of C-reactive protein (CRP) and erythrocyte sedimentation rate (ESR) during each year and the minimum values of hemoglobin (Hgb) and serum albumin during each year were recorded. Medication usage was recorded as “use” or “not use” including corticosteroids (both systemic and topical), immunomodulators (azathioprine, 6-mercaptopurine, and methotrexate), anti-tumor necrosis factor (TNF)-alpha agents, and narcotics. The numbers of hospital encounters were recorded including telephone encounters (including patient electronic communication), outpatient visits, ED visits, IBD-related hospitalizations, number of cross-sectional imaging tests, and number of endoscopies and surgeries in the prior year. The outcomes we considered included IBD-related hospitalization, ED visit, and high total charges of the subsequent year. Charges for outpatient oral or subcutaneous medications were unable to be captured. Charges from outside the health system were also unable to be included.

IBD-related hospitalization was defined when the patients were hospitalized because of IBD flare-ups, complications of IBD such as intra-abdominal abscess and fistula, or complications of surgical treatment for IBD, as determined by manual chart review. Hospitalizations because of IBD-associated disorders such as primary sclerosing cholangitis, venous thromboembolism, and cholelithiasis and its complications were not considered directly IBD-related.

For total charges, we manually reviewed the medical records of the upper half of total charges in our cohort and found that a significant number of patients with high costs had other comorbidities that contributed to most of their medical charges, such as treatment of cancer (including colon cancer), atherosclerotic diseases requiring interventions, severe chronic liver disease with complications, end-stage renal disease requiring dialysis, and severe osteoarthritis requiring arthroplasty. All patients in whom we determined that their charges in the outcome year were mostly due to non-IBD causes were excluded from analyses. Furthermore, we arbitrarily considered annual medical charges ≥$30,000 (the 75th percentile) as high charges for the purposes our study. This cut point was selected because we intended the charges model to identify the top quartile of charges in our cohort.

Statistical Analysis

For our descriptive patient data, continuous data were presented as mean and standard deviation for parametric distributions and median, range, and interquartile range for non-parametric distributions. Categorical and ordinal data were presented as percentages. Logistic regression was used for bivariate and multivariate analysis. All 3 outcomes were categorized into dichotomous outcomes: “yes” and “no” for ED visits and hospitalizations and “<$30,000” and “≥$30,000” for total annual charges. All subjects with missing values with respect to the outcome variables were excluded from the analysis.

Analyses were performed in R version 3.2.2. Before logistic regression, the R package *corrgram* was used to determine the correlation coefficients between all pairs of predictor variables. The predictor variables that had high correlation coefficients ($r \geq 0.5$) with other variables and would likely produce collinearity in modeling were selectively excluded from analyses. Predictor variables potentially correlating with the outcomes ($P < .1$) on bivariate analysis were selected for multivariate analysis. The backward selection method was applied to these bivariate significant predictors to build the best model. The R package *ROCR* was used to draw a receiver operating characteristic (ROC) curve and calculate the area under ROC curve (AuROC) for each outcome. A user-friendly version of this model was made publicly available at https://www.pathology.med.umich.edu/shiny/ by using the Rstudio shiny application (shiny.rstudio.com).

This study was approved by the University of Michigan Institutional Review Board (HUM00111986).

Results

The data of 2746 IBD patients were initially retrieved. Of these, 1316 patients were excluded; 1030 patients had no visit in the subsequent year, and 286 patients had other comorbidities contributing to most of their medical charges. In total, there were 1430 IBD patients included in analyses, 1005 in the training cohort and 425 in the validation cohort. Clinical demographic data, IBD characteristics, and encounter details are described separately for the training and validation cohorts in Table 1. Patient characteristics do not significantly differ between training and validation data sets.

Bivariate Analyses of Predictors of Inflammatory Bowel Disease–related Hospitalization, Emergency Department Visits, and High Total Charges in the Subsequent Year

As shown in Supplementary Table 1, young age, presence of psychiatric illness, diagnosis of Crohn's disease (CD), use of corticosteroids, use of narcotics, high CRP levels, high ESR levels, low Hgb levels, low albumin levels, and high number of telephone encounters, ED visits, IBD-related hospitalizations, imaging tests, and endoscopies in the prior year were significantly associated with all poor outcomes in the subsequent year. Use of immunomodulators and high number of surgeries were significantly associated with IBD-related hospitalizations and high total charges but not ED visits in the subsequent year. Use of anti-TNF therapy was a significant predictor of ED visits and high charges but not for IBD-related hospitalizations in the subsequent year. High numbers of outpatient visits was a significant protective factor for IBD-related hospitalization in the next year. Gender and distance from the hospital were not significant predictors for all outcomes.

Multivariate Analyses of Predictors of Inflammatory Bowel Disease–related Hospitalization, Emergency Department Visits, and High Total Charges, and Unified Inflammatory Bowel Disease Risk Model Development

Supplementary Figure 1 is a correlogram representing the correlation coefficients (r) between the predictive parameters. There is a strong correlation ($r > 0.5$) between CRP and ESR, albumin and Hgb level, and IBD-related hospitalization and both ED visits and the

number of imaging tests. Because of the likelihood of collinearity, these should not be analyzed together in multivariate analysis. After head-to-head comparisons in multivariate models, CRP was selected over ESR, IBD-related hospitalization was selected over ED visits and imaging tests, and Hgb was selected over albumin, because each were more powerful predictors than their correlates as determined by AuROC curve of the multivariate logistic models predicting outcomes.

Table 2 shows the independent multivariate predictors for all adverse outcomes in the subsequent year. Use of corticosteroids, use of narcotics, low Hgb levels, and high number of IBD-related hospitalizations were retained as independent predictors for all poor outcomes in multivariate models. The presence of psychiatric illness was a significant predictor for IBD-related hospitalization and ED visits in the subsequent year, and its association with high total charges was nearly statistically significant. A high number of outpatient visits was a significant protective factor for IBD-related hospitalization in the next year. Diagnosis of CD when compared with diagnosis of ulcerative colitis (UC) and young age were significant predictors for ED visits, whereas high CRP levels were significantly associated with high total charges in the subsequent year.

Because these 3 multivariate models contained similar significant predictors, we sought to develop a unified IBD Risk model with a consistent set of predictors to simplify their use in practice. The significant predictors presented in all multivariate models were included in the unified IBD Risk model. The presence of psychiatric illness was also included because its association with high total charges was nearly significant, and it was an independent predictor in the other 2 multivariate models. The final unified set of 5 predictors was composed of the presence of psychiatric illness, use of corticosteroids, use of narcotics, low Hgb levels, and high numbers of IBD-related hospitalizations. The AuROC curves to predict the subsequent year IBD-related hospitalization, ED visit, and high total charges were 0.751, 0.738, and 0.744, respectively, in the validation cohort (Figure 1). The β-coefficient values and P values of the variables in the model for each outcome are shown in Supplementary Table 2.

Sensitivity analyses performed to ascertain the performance of the model to predict high total charges at the 50th, 60th, 90th, and 95th percentiles are shown in Table 3. The AuROC curve became higher when the cutoff value was higher. By using the cutoff value for the 95th percentile of charges (>$127,000), the AuROC was 0.749 for the validation data set.

Discussion

In this study we built a unified predictive model to predict the risk of subsequent year IBD-related hospitalization, ED visits, and high total charges in IBD patients on the basis of logistic regression modeling. The unified model included 5 predictors from the previous year: the presence of psychiatric illness, use of corticosteroids, use of narcotics, low Hgb levels, and high numbers of IBD-related hospitalizations. We have provided a user-friendly Web application of this model at https://www.pathology.med.umich.edu/shiny/ to allow readers to assess which of their IBD patients are at high risk of undesirable clinical events in the next year.

Chronic diseases can be crushingly expensive and account for most of the costs of modern health care.[13] Interventions to improve outcomes in chronic disease management can improve outcomes and quality of life but often increase costs.[14] It is important that any chronic disease management program is targeted to the patients at highest risk of poor clinical and financial outcomes to limit these costs and produce the most health care value.[15]

In this study, we found that IBD Risk models with 5 predictors available from an EMR from the previous year had the best performance to predict the 3 outcomes of subsequent year IBD-related hospitalization, ED visit, and high total charges. Psychiatric illnesses, particularly major depression and anxiety disorders, are common in IBD patients, with the reported prevalence of 26%–30% and 23%–31%, respectively.[16,17] These are more common in those with active disease.[17] Psychiatric illnesses including anxiety and depression could be the result of more severe IBD. A recent study by Click et al[18] reported that presence of psychiatric illness was significantly associated with future high health care usage. Corticosteroid use is an indicator of poor disease control and perhaps reluctance to step up to steroid-sparing therapy. Early corticosteroid use is associated with disabling disease and hospitalizations in both CD and ulcerative colitis (UC).[7,9,19,20] Furthermore, steroid use has also been reported to be significantly associated with future high health care use.[18]

Narcotic use indicates uncontrolled symptoms in IBD patients, which may be from active inflammation or visceral hypersensitivity. Furthermore, narcotic use could also contribute to narcotic bowel syndrome in IBD patients. Moreover, narcotics may mask symptoms of underlying inflammation in IBD and lead to delay in detecting complications and treatment. Narcotic use has been reported to be associated with decreased quality of life,[21] increased health care use,[18] and even increased mortality among IBD patients.[22]

A combination of iron deficiency anemia and anemia of chronic disease is common in IBD patients.[23] Two recent studies found that anemia was associated with a more severe disease course and could be used as an objective marker of disabling disease in IBD.[12,24] Among chronic diseases with variable courses between individuals including IBD, hospitalization related to the disease appears to be a clear marker for increased disease activity and marked aggressiveness of disease course in the future. In UC, medical hospitalization has been reported to predict future colectomy.[25] Our results showed that IBD-related hospitalization was an independent predictor for all of the undesirable clinical outcomes we studied.

Younger age has been found to be a predictor of more aggressive disease in both CD and UC in many previous studies.[1,2,19,26,27] Also, young patients have been reported to have higher health care costs in IBD.[28] In this study, younger age was associated with all negative outcomes in bivariate analysis but not in multivariate analysis of IBD-related hospitalizations and high total charges. The rate of telephone calls has recently been identified as associated with increased rates of ED visits and hospitalizations.[10] It was shown to be associated with all negative outcomes in bivariate analysis but failed to retain its significance in multivariate analysis after we added psychiatric illness as a predictor. It is interesting to note that more outpatient visits was a significant protective factor for IBD-related hospitalization in the subsequent year in this study. This supports the potential

benefits of the use of a chronic disease management model in high-risk patients with closer monitoring and tighter control of inflammation.

The limitations of this study include its retrospective nature and the limitations of EMR data. First, because this is a retrospective study using EMR data, we did not have all possible disease characteristics that have been reported to be associated with more aggressive disease, including upper gastrointestinal tract location, perianal involvement, and stricturing/penetrating behavior in CD[19,20,26,29] and pancolonic involvement in UC,[1,7] which do not have International Classification of Diseases, 9th version codes. Second, we analyzed CD and UC together rather than create 2 distinct models for each diagnosis. We considered the importance of CD vs UC diagnosis in a sensitivity analysis and did not find significant differences when diagnosis was included in the model as an independent predictor. Therefore, we chose to use a unified IBD Risk model. Third, we could not account for the health care utilization outside of our system. External validation from other populations is needed in future studies, although multiple studies from Binion and colleagues at the University of Pittsburgh have already found several of these bivariate predictors to be valid in their tertiary care patient population.[12,18]

The findings of this study could lead to future risk stratification and intervention at IBD centers by using a chronic disease management model or IBD medical home. Alternatively, individual IBD patients could use this model via the Web app to estimate their risk and to help them make informed decisions about health care insurance and deductible choices for the coming year.

In conclusion, IBD patients can be risk-stratified with readily available EMR data to predict which patients are most likely to have high health care usage and costs in the next year.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations in this paper

AuROC	area under the receiver operating characteristic curve
CD	Crohn’s disease
CRP	C-reactive protein
ED	emergency department
EMR	electronic medical record

ESR	erythrocyte sedimentation rate
FY	fiscal years
Hgb	hemoglobin
IBD	inflammatory bowel disease
ROC	receiver operating characteristic curve
TNF	tumor necrosis factor
UC	ulcerative colitis

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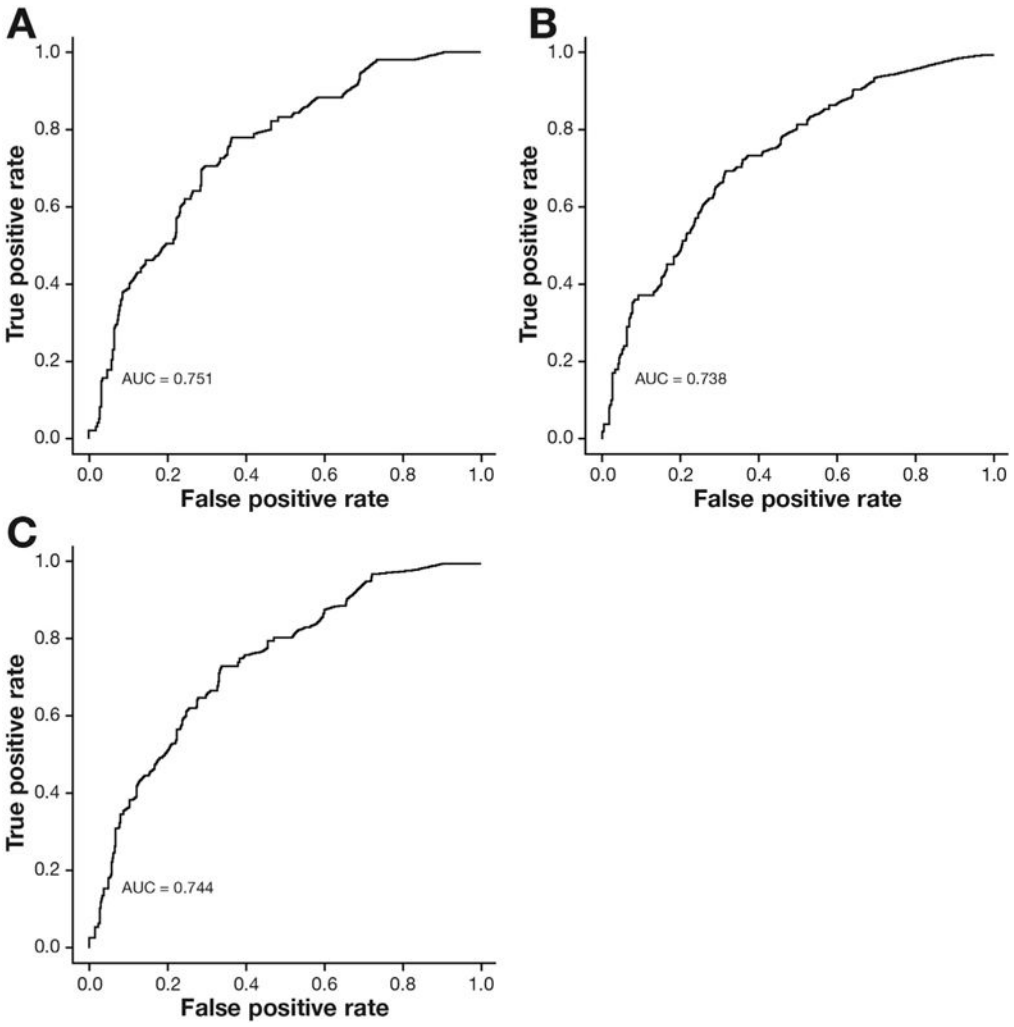

Figure 1.

ROC curves for prediction of IBD-related hospitalization (*A*), ED visits (*B*), and high charges (>$30,000) (*C*) in the subsequent year from the validation data set results.

Table 1

Patient Characteristics in Training and Validation Cohort

	Training set (n = 1005)		Validation set (n = 425)	
Characteristics	**Predictors**	**Outcomes**	**Predictors**	**Outcomes**
Male gender (%)	474 (47.2)		190 (44.7)	
Age (mean ± SD) (*y*)	40.0 ± 17.9		40.0 ± 17.6	
IBD type				
CD	611 (60.8)		251 (59.1%)	
UC	394 (39.2)		174 (40.9%)	
On corticosteroids	431 (42.9)		169 (39.8%)	
On immunomodulators	483 (48.1)		207 (48.7%)	
On anti-TNF therapy	469 (46.7)		187 (44.0%)	
On narcotics	419 (41.7)		163 (38.4%)	
Psychiatric illness	226 (22.5)		82 (19.3%)	
Maximum CRP (median, range, IQR) (*mg/L*)	1.0 (0–61, 3)		1.0 (0–35.0, 3)	
Maximum ESR (median, range, IQR) (*mm/h*)	18 (1–121, 28)		19 (1–109, 30)	
Minimum albumin (mean ± SD) (*mg/dL*)	3.82 ± 0.67		3.78 ± 0.70	
Minimum Hgb (mean ± SD) (*g/dL*)	11.7 ± 2.4		11.6 ± 2.5	
No. of cross-sectional imaging tests, median (range)	1 (0–11)		0 (0–9)	
No. of cross-sectional imaging tests				
None	482 (48.0%)		223 (52.5%)	
1	351 (34.9%)		126 (29.6%)	
≥2	172 (17.1%)		76 (17.9%)	
No. of endoscopies, median (range)	1 (0–8)		1 (0–6)	
No. of endoscopies				
None	496 (46.7%)		198 (46.6%)	
1	349 (41.3%)		149 (35.1%)	
≥2	160 (12.0%)		78 (18.3%)	
No. of surgeries, median (range)	0 (0–4)		0 (0–2)	
No. of surgeries				
None	936 (93.1%)		385 (90.6%)	
1	49 (4.9%)		37 (8.7%)	
≥2	20 (2.0%)		3 (0.7%)	
No. of telephone encounters, median (range)	8 (0–87)		8 (0–74)	
No. of telephone encounters				
None	65 (6.5%)		36 (8.5%)	
1–5	318 (31.6%)		123 (28.9%)	
6–10	243 (24.2%)		99 (23.3%)	
>10	379 (37.7%)		167 (39.3%)	

	Training set (n = 1005)		Validation set (n = 425)	
Characteristics	**Predictors**	**Outcomes**	**Predictors**	**Outcomes**
No. of OP visits, median (range, IQR)	1 (0–15)		1 (0–11)	
No. of OP visits				
None	140 (13.9%)		47 (11.1%)	
1	486 (48.4%)		202 (47.5%)	
≥2	379 (37.7%)		176 (41.4%)	
No. of ED visits, median (range, IQR)	0 (0–11)	0 (0–10)	0 (0–12)	0 (0–8)
No. of ED visits				
None	697 (69.4%)	765 (76.2%)	297 (69.9%)	320 (75.3%)
1	202 (20.1%)	148 (14.7%)	82 (19.3%)	63 (14.8%)
≥2	106 (10.5%)	92 (9.1%)	46 (10.8%)	42 (9.9%)
No. of IBD-related hospitalizations, median (range, IQR)	0 (0–8)	0 (0–7)	0 (0–10)	0 (0–7)
No. of IBD-related hospitalizations				
None	750 (74.7%)	723 (72.9%)	313 (73.6%)	312 (73.4%)
1	141 (14.0%)	179 (17.8%)	67 (15.8%)	81 (19.1%)
≥2	114 (11.3%)	103 (10.2%)	45 (10.6%)	32 (7.5%)
Total charges, median (range, IQR) (US $)	15,240 (13–927,800; IQR = 35,754)	16,970 (0–106,2000; IQR = 21,578)	14,710 (72–594,000; IQR = 35,971)	11,560 (0–592,900; IQR = 27,879)

IQR, interquartile range; OP, outpatient; SD, standard deviation.

Table 2

Multivariate Analyses of Predictors of IBD-related Hospitalization, ED Visit, and High Total Charges

	IBD-related hospitalizations		ED visits		High charges (>$30,000)	
Predictor variables	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
On corticosteroids	1.80	1.25–2.61	1.54	1.09–2.17	1.89	1.29–2.79
On narcotics	1.72	1.16–2.56	1.89	1.30–2.75	1.90	1.27–2.86
Minimum Hgb (per g/dL)	0.88	0.01–0.95	0.90	0.83–0.97	0.89	0.81–0.97
Total IBD-related hospitalizations	1.65	1.36–2.02	1.31	1.10–1.57	1.31	1.09–1.59
Psychiatric illness	1.60	1.08–2.36	1.61	1.11–2.32	1.49	0.97–2.24
Total OP encounters	0.80	0.70–0.91				
Age (per year)			0.987	0.978–0.997		
Diagnosis of CD			1.48	1.04–2.11		
Maximum CRP (per mg/L)					1.03	1.00–1.06

CI, confidence interval; OR, odds ratio.

Table 3

Sensitivity Analysis of the Unified Model Predicting High Charges at Different Cutoffs

	***β*-coefficient value, *P* value**									
Variable	**50%tile (>$12,000)**		**60%tile (>$15,000)**		**75%tile (>$30,000)**		**90%tile (>$78,000)**		**95%tile (>$127,000)**	
Psychiatric illness	0.31	.07	0.28	.11	**0.37**	**.04**	0.46	.06	0.64	.06
Minimal Hgb level (per g/dL)	**−0.13**	**<.01**	**−0.15**	**<.01**	**−0.17**	**<.01**	**−0.18**	**<.01**	**−0.16**	**.03**
On corticosteroids	**0.36**	**.02**	**0.37**	**.01**	**0.58**	**<.01**	**0.66**	**<.01**	**0.90**	**.02**
On narcotics	**0.54**	**<.01**	**0.70**	**<.01**	**0.58**	**<.01**	0.42	.13	−0.26	.51
IBD-related hospitalization	0.15	.10	0.12	.19	**0.289**	**<.01**	**0.26**	**.01**	**0.47**	**<.01**
AuROC (validation data set)	**0.705**		**0.709**		**0.744**		**0.788**		**0.749**	

NOTE. Boldface indicates statistically significant values ($P < .05$). %tile, percentile.