Exploring Novel Medicare Readmission Risk Variables in Chronic Obstructive Pulmonary Disease Patients at High Risk of Readmission within 30 Days of Hospital Discharge

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Abstract

Rationale: New risk factors for readmission within 30 days of hospital discharge for patients with chronic obstructive pulmonary disease (COPD) need to be identified in view of the lack of efficacy of current interventions for preventing readmission.

Objectives: To identify novel risk predictors for 30-day readmission among COPD index admissions at high risk of readmission.

Methods: For this analysis, we used the fiscal year 2015 hospital-specific Medicare Hospital Readmissions Reduction Program workbook for Staten Island University Hospital (Staten Island, NY). We analyzed 41 variables, each with a risk-variable score. A predicted probability of readmission was calculated for each case by using the risk-variable regression coefficient and a hospital-specific effect. A predicted probability greater than 0.4 was used to identify patients with COPD with a high risk of readmission in both the readmitted and nonreadmitted groups. A percent ratio of the readmission percentage divided by the nonreadmission percentage was generated for each risk variable for patients with a predicted probability of readmission greater than 0.4. A percent ratio greater than 3 was used to identify high-risk variables predictive of readmission. A risk index was defined as the number of high-risk variables present for each index admission.

Measurements and Main Results: Nine high-risk variables were identified. A risk index greater than 3 for all index admissions identified 54 (22.7%) of 238 readmitted patients versus 41 (6.5%) of 630 nonreadmitted patients ($P < 0.0001$; positive predictive value, 0.56; specificity, 0.93). A risk index greater than 2 for multiple-admission patients identified 56 (65.1%) of 86 readmitted patients versus 135 (40.7%) of 332 nonreadmitted patients ($P < 0.0001$; positive predictive value, 0.65; specificity, 0.86). Over 30% of readmitted patients meeting the risk index criteria were discharged to home without organized home care. Sleep apnea, vertebral fractures, and electrolyte and acid–base disorders were newly identified predictors of readmission.

Conclusions: This study developed a risk index based upon the 2015 Hospital Readmissions Reduction Program worksheet for one hospital to explore risk variables predictive of 30-day readmissions for patients with COPD at high risk of readmission (>0.4). Because most currently used interventions lack efficacy in preventing 30-day readmission, interventions based upon the newly identified variables should be validated with larger validation cohorts.

Keywords: hospital readmission; populations at risk; COPD

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Chronic obstructive pulmonary disease (COPD) is currently one of the five measures monitored by the Centers for Medicare and Medicaid Services Hospital Readmissions Reduction Program (HRRP) (1). This program uses specific risk variables to tabulate a predicted readmission outcome within 30 days of discharge for each participating acute care hospital. There are numerous studies that have found various risk factors that predict 30-day readmission after an admission for COPD (2–7). Only one study used Medicare claims data with the same diagnostic code criteria for COPD used in the HRRP (2).

Only a few types of interventions to prevent these readmissions have been effective (2, 8, 9). Jennings and colleagues (10) randomized patients to either a control group (standard care) or a bundle group in

which patients were treated using several approaches: smoking cessation counseling, screening for gastroesophageal reflux disease and depression or anxiety, standardized inhaler teaching, and a 48-hour postdischarge telephone call. The risk of emergency department visits or hospitalizations within 30 days was not different between the groups. The overall lack of efficacy of these interventions in preventing 30-day COPD readmissions may be due to the majority of the readmissions not being directly related to COPD (3, 11).

We recently suggested that risk predictors for COPD 30-day readmission may depend on the principal discharge diagnosis of the readmission (12). Patients with readmission within 30 days for sepsis were more frequently older than 90 years of age and had higher rates of hypertensive heart and renal disease or encephalopathy at the time of index admission for COPD. This was in contrast to patients with readmission within 30 days for COPD exacerbation, who had higher rates of lung fibrosis but lower rates of hypertensive heart and renal disease or encephalopathy, renal failure, and peptic ulcer disease at the time of index admission for COPD. Age did not predict readmissions for COPD exacerbation. This suggested that effective interventions to prevent COPD readmission within 30 days may vary and be dependent on the clinical pathway leading to the specific type (i.e., diagnosis) of the readmission. Risk predictors, along with appropriate interventions, would have to be found for each of these specific pathways and then validated with large cohorts.

Another approach might be to examine only those patients with the highest number of risk predictors. These patients may have accumulated all of these predictors by a variety of clinical pathways to their COPD admissions, but they may require only a few more risk variables to cause a readmission for COPD exacerbation, sepsis, and so forth. We used our HRRP worksheet to explore the latter approach. The worksheet is a Microsoft Excel worksheet listing all COPD index admissions to our institution. The HRRP sheet uses 41 risk variables, each of which is associated with a regression coefficient. The coefficients can be used to find those patients with the highest predicted probability of readmission (PPR). The goal was to find a new subgroup of risk variables that could be used in a simple risk index to predict a high rate of 30-day readmissions for index admissions. Any novel risk variables used in the risk index could help in searching for newer interventions that may be useful for 30-day readmission prevention.

Methods

Risk Variables

Risk variables are used by the HRRP to predict readmission rates when standardized to other hospitals with similar risk profiles. These variables are based on Medicare claims data from the preceding 3 years. Each variable is associated with a regression coefficient. A high PPR is associated with a high number of risk variables with high positive regression coefficients. The risk variables and their associated regression coefficients (in descending order) are summarized in the online supplement. The worksheet provides no information on race, ethnicity, socioeconomic status, COPD severity, or physical activity.

A binomial system is used on the worksheet for each risk variable within each index admission line listing, except for age over 65 (*see* Table 1). A variable is assigned a 0 if not present and a 1 if present. The 0 or 1 is multiplied by the regression coefficient for that variable. The sum of the products is then added to the hospital-specific effect (HE). The HE represents the underlying risk of a readmission at each specific hospital after accounting for patient risk. This is the same across all discharges for a given hospital. The HE at our institution was −1.87394019738093. The PPR is obtained for each index admission by applying an exponential function to the sum of the risk variable/regression coefficients and the HE. A final score is tabulated after a comparison is made between the hospital's predicted outcome (i.e., the sum of its PPRs) and other risk-matched hospitals' expected outcomes. The latter is based on the hospital average effect, which is the underlying risk of a readmission at the average hospital after accounting for patient risk.

For this analysis, we used the fiscal year 2015 HRRP Hospital-Specific Report workbook for our hospital (Staten Island University Hospital, Staten Island, NY). This workbook contains a line listing that includes all eligible Medicare COPD admissions from July 1, 2010, through June 30, 2013. Diagnosis codes used by the HRRP to identify index COPD admissions were 491.21, 491.22, 491.8, 491.9, 492.8, 493.20, 493.21, 493.22, and 496. Other codes used were for a principal diagnosis of respiratory failure (518.81, 518.82, 518.84, 799.1) and when combined with a secondary diagnosis of acute exacerbation of COPD (491.21, 491.22, 493.21, 493.22). Patient identifiers were blinded for this study.

Analysis

We analyzed the 41 HRRP COPD readmission risk variables to try to identify predictors among those patients determined to be at high risk of readmission by PPR. Thirty-day readmissions were not eligible as index admissions. For the fiscal year 2015 three-year data collection period, our 714-bed teaching hospital had 238 (27.4%) COPD readmissions among 868 eligible discharges for COPD. The mean PPR among the readmitted patients (0.296001921) was higher than among the nonreadmitted group (0.242869521) ($P < 0.0001$ by two-tailed Student's t test). The number of patients with a PPR greater than 0.40 was significantly higher among the readmitted patients (43 [18.1%] of 238) than among the nonreadmitted group (45 [7.1%] of 630) ($P < 0.0001$ by two-tailed Fisher's exact test). A PPR greater than 0.40 was selected to identify the high-risk readmission patients. Risk variables were evaluated for index admissions with a PPR greater than 0.40 by comparing the readmitted and nonreadmitted groups. The age variable was modified to those patients older versus younger than 91 years of age. Risk variables were compared using a two-tailed Fisher's exact test. A percent ratio of the readmission percentage divided by the nonreadmission percentage was calculated for each risk variable. A percent ratio greater than 3 was used to identify high-risk variables. The percent ratio is equal to ([all true negatives] × [>0.4 PRR true positives]) / ([all true positives] × [>0.4 PRR false positives]).

Risk Index

The risk index was defined as the number of high-risk variables present for each index admission. Use of the risk index did not require calculation of the PPR. The risk

Table 1. Sample calculation of predicted probability of readmission based on risk variable regression coefficients for three index COPD admissions (all age 65 yr)

	Met CA	CHF	CRFS	Severe CA	All Other Variables	Sum of Products	Sum of Products + HE*	PPR
Patient 1	1	0	0	0	0	0.2304 + 0 + 0 + 0 + 0 = 0.2304	0.2304 − 1.8739 = −1.6435	0.1620
Patient 2	1	1	0	0	0	0.2304 + 0.2072 + 0 + 0 + 0 = 0.4376	0.4376 − 1.8739 = −1.4363	0.1921
Patient 3	1	1	1	1	0	0.2304 + 0.2072 + 0.2004 + 0.1795 + 0 = 0.8175	0.8175 − 1.8739 = −1.0564	0.2580
Risk variable regression coefficient	0.2304	0.2072	0.2004	0.1795	NA			

Definition of abbreviations: CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; CRFS = cardiorespiratory failure or shock; HE = hospital-specific effect = −1.8739; Met CA = metastatic cancer or acute leukemia; NA = not applicable; PPR = 1/[1 + EXPONENTIAL(−1*(sum of products + HE))]; Severe CA = lung, upper digestive tract, and other severe cancers.
*Risk variable regression coefficient and HE are rounded off for this example.

index cutoff was initially evaluated to predict 30-day readmission with 100% specificity. Because this would have resulted in few identified index admissions with a high risk of readmission, lower risk index cutoffs were evaluated. The risk index was also evaluated for patients with multiple index admissions (i.e., two or more index admissions). In the latter cases, the highest risk index for any two successive index admissions was used. A 30-day readmission after the initial index admission for a patient with multiple index admissions was not counted as a readmission when this subgroup was evaluated. At that time, it would not have been known that the patient was to become a multiple-admission patient. Each risk index cutoff was analyzed by using two-tailed Fisher's exact tests, as well as for its positive predictive value, negative predictive value, sensitivity, and specificity.

Results

Six hundred seventeen patients were responsible for the 868 index admissions. Nine variables were identified that had percent ratios greater than 3 (*see* Table 2). These were defined as the high-risk variables to be used in the risk index. The regression coefficient values for the nine variables varied widely and even included one variable with a negative value.

Thirty-day readmission results were evaluated for all index admissions using various risk index results (*see* Figure 1). Patients with more than one of nine identified readmission risk variables (i.e., a risk index greater than 1) had significantly more readmissions within 30 days than the nonreadmitted patients. Using a risk index greater than 5 resulted in six identified readmissions with 100% specificity. A risk index greater than 4 was associated with a positive predictive value of 0.655 (19 of 238 readmissions vs. 10 of 630 nonreadmissions; $P < 0.0001$). A risk index greater than 3 was associated with a positive predictive value of 0.568 (54 of 238 readmissions vs. 41 of 630 nonreadmissions; $P < 0.0001$).

The risk index was also useful in predicting 30-day readmissions for patients with multiple admissions during the 3-year data collection period. A risk index greater than 2 was associated with a positive predictive value of 0.651 (56 of 56 readmissions vs. 135 of 332 nonreadmissions; $P < 0.0001$). Four

Table 2. Comparison of readmitted and nonreadmitted patients with COPD and high predicted probability of readmission scores

Readmission Risk Variable	Readmitted with PPR >0.4 (*N = 238* Total Readmitted)	Not Readmitted with PPR >0.4 (*N = 630* Total Not Readmitted)	*P* Value*	Percent Ratio
Fibrosis of lung or other chronic lung disorders	22 (9.2%)	17 (2.7%)	0.0001	3.43
Vertebral fracture	7 (2.9%)	6 (1.0%)	0.0553	3.09
Depression	24 (10.1%)	16 (2.5%)	0.0001	3.97
Anxiety	10 (4.2%)	5 (0.8%)	0.0016	5.29
Metastatic cancer	8 (3.4%)	4 (0.6%)	0.0049	5.29
Cardiorespiratory failure or shock	39 (16.4%)	32 (5.1%)	<0.0001	3.23
Disorders of fluid/electrolyte/acid–base	43 (18.1%)	38 (6.0%)	<0.0001	3.00
Respirator dependence/respiratory failure	7 (2.9%)	5 (0.8%)	0.023	3.71
Sleep apnea	18 (7.6%)	14 (2.2%)	0.0005	3.40

Definition of abbreviations: COPD = chronic obstructive pulmonary disease; PPR = predicted probability of readmission.
*By two-tailed Fisher's exact test.

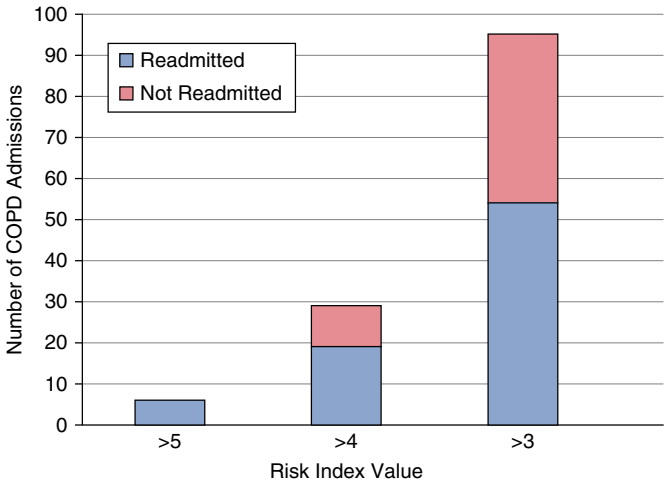

Figure 1. Thirty-day readmissions for 868 COPD index admissions by risk index value. COPD = chronic obstructive pulmonary disease.

hundred fifty (72.9%) of 617 patients had a single index admission, whereas the other 167 (27.1%) patients had a total of 418 multiple index admissions.

There was a higher frequency of COPD 30-day readmissions for each index admission among the patients with multiple admissions (128 [30.6%] of 418) than among those with only one index admission (110 [24.4%] of 450; $P = 0.0477$). For patients with multiple admissions, 30-day COPD readmissions were even more frequent for index admissions with a risk index greater than 2 (56 [29.3%] of 191) than among those with index admissions with a risk index less than 3 (30 [13.2%] of 227) ($P = 0.0001$). A risk index greater than 2 was present among 72 multiple-admission patients. This represented 11.7% of all of the 617 patients within the cohort. There were a total of 78 readmissions among the multiple-admission patients with a risk index greater than 2 when the initial index admission was included. Predicted readmissions occurred 56 times (77.7%) among the 72 patients with multiple admissions and a risk index greater than 2 when compared with the rest of the patients in the cohort (160 readmissions [29.4%] among the other 545 patients) ($P < 0.0001$).

Table 3 reviews various risk factor prevalences for 30-day readmissions for all COPD index admissions and for multiple COPD index admissions by risk index. Thirty-three (61.1%) of 54 index admissions with a risk index greater than 3 and an associated 30-day readmission had a history of sleep apnea. The percentage was almost 90% for readmitted COPD index admissions with sleep apnea and a risk index greater than 4. There were 26 (46.4%) patients with sleep apnea of the 56 readmissions among the patients with multiple admissions. Ten (18.5%) of 54 index admissions with a risk index greater than 3 and an associated 30-day readmission had a history of a vertebral fracture. Forty-eight (88.9%) of 54 index admissions with a risk index greater than 3 and an associated 30-day readmission had a history of a disorder of fluid, electrolyte, or acid–base homeostasis. Forty of these patients also had a history of congestive heart failure. Twelve of the 40 patients were discharged to home without organized home health services.

Table 3 also reviews home discharge disposition for 30-day readmissions for all COPD index admissions and for multiple COPD index admissions by risk index. There was a high rate (31.5%) of discharge to home without organized home care for index admissions and a risk index greater than 3 among those who had a readmission within 30 days. The rate of discharge to home without organized home care (39.3%) for multiple-admission patients and a risk index greater than 2 among those who had a 30-day readmission was also high.

Discussion

The goal of this study was to explore the high-risk COPD group (i.e., PPR >0.4) for novel risk variables so that newer interventions could be formulated. The efficacy of these interventions will have to be validated with a larger cohort before implementation. We identified nine HRRP variables that were predictive of readmission within 30 days after discharge for an index admission for COPD. These variables were identified by studying only patients at high risk for readmission (i.e., PPR >0.40). The most frequently reported risk predictors of 30-day readmission for patients with COPD include heart failure, anemia, COPD severity scores, low socioeconomic status, anxiety, depression, and low physical activity (2–7). Only two (anxiety and depression) of the nine variables we identified by using PPR-based methodology are among the previously reported predictors.

The variables identified in this study may serve as the final "tipping point" for COPD readmission within 30 days among

Table 3. Home discharge disposition and prevalence of various risk factors for 30-day readmissions for all COPD index admissions and for multiple COPD index admissions by risk index

Index Admissions	Risk Index	Readmitted within 30 Days	Discharged to Home without Home Care	Anxiety and/or Depression	Vertebral Fracture	Sleep Apnea	Disorders of Fluid, Electrolyte, and Acid–Base
All	>3	54	17 (31.5%)	39 (72.2%)	10 (18.5%)	33 (61.1%)	50 (92.6%)
Only multiple	>2	56	22 (39.3%)	35 (62.5%)	8 (14.3%)	26 (46.4%)	48 (85.7%)

Definition of abbreviation: COPD = chronic obstructive pulmonary disease.

patients who already have a lot of other risk variables present. The prior risk factors present are a heterogeneous group because a variety of clinical pathways lead to the index COPD admission that is followed by a readmission within 30 days (e.g., lung fibrosis in patients of all ages in patients with readmissions for COPD vs. hypertensive heart and renal disease in patients older than 90 years of age with readmissions for sepsis).

The application of a risk index greater than 3 for patients with single admissions would have identified 95 patients. Fifty-four (56.8%) of these patients were readmitted within 30 days. If the formulated interventions were found to be effective, then they would have to be applied to only 10.9% (95 of 868) of the total cohort.

Risk Variables

Seven of the nine risk variables identified were novel. Sleep apnea and a 30-day readmission were present in more than 60% of index admissions with a risk index greater than 3 and more than 46% of evaluable index admissions for patients with a risk index greater than 2 and multiple admissions. Sleep apnea has not previously been reported as a risk factor for readmission in patients with COPD. Recently, an overlap syndrome of COPD and obstructive sleep apnea has been described (13). This syndrome poses various clinical management challenges. Stanchina and coworkers (14) used diagnostic coding and chart reviews to identify 227 patients with overlap syndrome. Longer time on continuous positive airway pressure (CPAP) was associated with reduced mortality. Use of CPAP has not previously been recommended or evaluated as an intervention that could diminish 30-day readmission in patients with overlap syndrome. Although HRRP attached a negative regression coefficient (−0.011911569) to sleep apnea, it may be an important area to target via CPAP use. Compliance with CPAP therapy may also prevent nonpulmonary reasons for readmission, such as arrhythmias.

Vertebral fractures and a 30-day readmission were present in more than 18% of index admissions with a risk index greater than 3 and more than 14% of evaluable index admissions for patients with a risk index greater than 2 and multiple admissions. Vertebral fracture has not previously been reported as a risk factor for readmission in patients with COPD. Patients with COPD are at risk for osteoporosis-related vertebral fractures, which predispose these patients to more fractures and worsening pulmonary function (15). On the basis of chest radiography, Majumdar and colleagues (15) found a 9% prevalence of vertebral compression fractures among 245 patients with COPD presenting with exacerbations to three Canadian emergency rooms. Almost half of the patients with vertebral fractures were not treated for osteoporosis, and all had received an oral corticosteroid. Vertebral fractures were associated with advanced pulmonary disease and a low body mass index. Nuti and coworkers (16) showed that COPD severity and glucocorticoid treatment, both inhaled and oral, were associated with increased risk of vertebral fractures. COPD severity scores are predictive of 30-day readmission (3). Others have found a higher risk of in-hospital mortality for patients with COPD and malnutrition (17). Patients with vertebral fractures should be targeted for osteoporosis treatment, inhaler use counseling, and nutritional counseling. Further studies should be done to assess whether interventions targeting patients with COPD and vertebral fractures are effective in preventing readmission.

Disorders of fluid, electrolyte, and acid–base homeostasis and a 30-day readmission were present in more than 92% of index admissions with a risk index greater than 3 and more than 85% of evaluable index admissions for patients with a risk index greater than 2 and multiple admissions. Fluid, electrolyte, and acid–base disorders have not previously been reported as risk factors for readmission in patients with COPD. Fluid, electrolyte, and acid–base disorder constituted a risk variable with a relatively high regression coefficient (0.200416442). This variable includes elements that may be related to the functional status of a patient with COPD (acidosis, alkalosis, or mixed acid–base balance disorder with hypercapnia) or congestive heart failure (hyponatremia, hypernatremia, hyperosmolality, hypoosmolality). It was not possible to associate specific abnormalities with specific patients, because patient identifiers were blinded in this study.

Hyponatremia is a predictor of higher 30-day readmission for congestive heart failure (18). Heart failure was present in 40 (83.3%) of 48 index admissions with a risk index greater than 3; a disorder of fluid, electrolyte, or acid–base disorder; and a 30-day readmission. This is in concordance with other studies in which researchers have identified congestive heart failure as a major predictor of readmission for COPD (2, 3). In our PPR-based analysis, heart failure did occur more frequently among readmitted patients (38 [16.0%] of 238 vs. 39 [6.2%] of 630; $P < 0.0001$), but the risk ratio (2.58) was not greater than 3. Other variables were stronger based on the criteria used. Twelve patients were discharged to home without organized home health services out of the 40 patients with a risk index greater than 3; a fluid, electrolyte, or acid–base disorder; and a 30-day readmission. This suggests that patients with COPD, heart failure, and hyponatremia should be referred to home care.

Interventions to Reduce 30-Day Readmissions

Referral to organized home care has been shown to decrease COPD 30-day readmissions. Shah and colleagues (2) found that, compared with index patients who were not readmitted, readmitted patients were more likely to have a lower rate of discharge to home without home care (53.7% vs. 62.1%; $P < 0.001$). Risk index screening was useful in identification of patients suitable for home care referral. Table E1 in the online supplement suggests that 31–50% of patients readmitted within 30 days with increased risk indices were discharged to home without home care.

Numerous factors may hinder the ultimate effectiveness of interventions being evaluated:

1. The HRRP index admission group may not truly represent patients who were primarily admitted for a direct complication of COPD. HRRP index admissions are based upon Medicare Severity Diagnosis-Related Group coding rules. If a patient has two principal diagnoses, the hospital is allowed to bill for the diagnosis-related group with higher reimbursement. This may lead to selection of COPD from among the index admission groups over other diagnoses, such as metastatic carcinoma.

2. Coding data suggest that 60–70% of readmissions are not directly related to an exacerbation of COPD (3, 11). This is further confounded by the dual-diagnosis coding regulations described in item 1 above.
3. Interventions do not work or are less likely to work as the patient's COPD progressively worsens.
4. Certain cost-effective interventions have probably not been identified to date.
5. The cost of the intervention for many hospitals has risen precipitously because of the HRRP penalty system.

The HRRP uses rolling 3-year data. Even if our institution were 100% effective in preventing the 37 admissions that result in a $500,000 yearly penalty, the full financial benefits of the successful interventions would not be seen until fiscal year 2020. Lost readmission revenue and some lost revenue related to the transfer rule raise the cost of intervention. Perhaps penalties should continue to be based on rolling 3-year data collection periods, but with extra weighting of the last year of data collection to help lower the costs of interventions more quickly.

Conclusions

This study developed a risk index based upon the 2015 HRRP worksheet for one teaching hospital in New York City to explore risk variables predictive of readmission within 30 days among patients with COPD at high risk of readmission (i.e., PPR >0.4). The risk index was able to identify patients with a high positive predictive value and good specificity at various cutoff values. The index was also useful in targeting patients with COPD with multiple index admissions at a lower cutoff value. Using our PPR-based methodology, we identified risk variables that have not been described previously, including COPD with sleep apnea overlap syndrome, vertebral fractures, and electrolyte abnormalities. Because most of the currently used interventions lack efficacy in preventing 30-day readmission, evaluation of interventions based upon these newly identified variables may be helpful. ■

Author disclosures are available with the text of this article at www.atsjournals.org.

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