ORIGINAL ARTICLE

Analyzing fecal loading and retention patterns by abdominal X-rays of hospitalized older adults: A retrospective study

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Abstract

Background: Aging may affect ascending colon (AC) differently from descending colon (DC) and increase the risk of fecal loading (FL) in AC.

Methods: Patients aged ≥65 years admitted to a community hospital were analyzed by abdominal X-ray for fecal loads and stool retention patterns. FL was scored between 0 and 5 (severe) on each segment of colon with a possible total score 20. Mean segment scores ≥3.5 were designated as high scores for both AC and DC. Logistic regression was performed between groups to identify factors associated with FL patterns.

Results: Groups identified were high FL in both AC and DC (N = 21, 17.2%), FL predominantly in AC (N = 38, 31.1%), low FL in both AC and DC (N=60, 49.2%), and FL low in AC and high in DC (N = 3, 2.5%). Among 71 patients with total FL scores ≥13 (indicating significant stool retention), 37 (52.1%) had the FL predominantly in AC. Patients prescribed antibiotic(s) prior to hospitalization had lower odds of FL predominantly in AC (adjusted odds ratio = 0.18, 95% confidence interval = 0.04–0.84) compared to the group of low FL in both AC and DC with the adjustment of confounders.

Conclusion: This study found that 52.1% of those with significant stool retention on X-ray had the FL predominantly in AC. Antibiotic use was associated with lower odds of having FL predominately in AC. This study provided insights of FL distribution in colon and AC could be an area for significant stool burden in older adults with stool retention.

KEYWORDS
colon, Constipation, fecal loading, radiography

1 | INTRODUCTION

Constipation is one of the most common gastrointestinal diagnoses in outpatient clinics, and the prevalence of chronic constipation has reached a worldwide incidence of 15%.[1] Untreated constipation is associated with increased emergency department visits and hospitalization,[2,3] and it could lead to fecal impaction and incontinence.[3] People with chronic constipation had higher mortality and demonstrated poor quality of life.[4]

The colon is traditionally divided into four segments, from ascending colon (AC), through transverse and descending colon (DC), and ending in rectosigmoid (RS) segment. Along the course, hepatic

flexure could be a barrier for fecal materials passed through toward the transverse colon as the liver situates in the right upper quadrant of the abdomen. There is a difference between AC and DC in the embryological origin, neurological development, and regional functions.[5,6] The aging process may affect AC differently from DC, as evidence suggests that aging impairs cholinergic function of AC but not DC.[7] As the result, AC may be more susceptible to increased fecal loading (FL) than DC in older adults.

There are limited data regarding what constitutes "normal distribution" of feces in the colon of adults.[8] The purpose of this study is to analyze the FL distribution patterns observed by abdominal X-ray, based on the FL scores in the segment of AC and DC. In addition, this study also purports to identify factors associated with a particular stool retention pattern (for example, high FL in AC and low in DC) among a cohort of patients who underwent abdominal X-ray in the hospital setting.

2 | METHODS

2.1 | Data collection

Archived data collected between January 1, 2005, and June 30, 2008, were retrieved from a local community hospital. This dataset was previously described elsewhere.[9] Briefly, approximately 500 patients aged 65 or older were identified by diagnosis codes of International Classification of Diseases, ninth revision, Clinical Modification [ICD-9-CM] for constipation as a primary or secondary diagnosis (constipation = 564.00–564.09; and fecal impaction = 560.30–560.39). Abdominal radiography was performed in the emergency department or within 2 days of admission. Patients were excluded if radiologists reporting complete or partial bowel obstruction, no radiography obtained, or radiographs of poor quality on preliminary review. One hundred twenty-two patients were included in the final analysis. This study was approved by the Institutional Review Board (IRB# 07E127 and # 15E141). No informed consent was required for this study.

Data collected from medical records included demographics, smoking status, medical diagnoses, medication use prior to admission, and discharge diagnoses. Blood test results, including serum albumin, calcium levels, and electrolytes, were obtained from those patients when they were first admitted. All blood tests were performed with standardized procedures for routine laboratory assays at the hospital.

The use of common medications prior to admission (yes vs no) was obtained from the medication reconciliation forms and physician's notes. Because antibiotic use could affect bowel frequency and cause diarrhea, this study collected information on oral antibiotic use prior to admission; recorded as "yes" if it was taken in the outpatient setting and documented by the physicians. Comorbidities and medical history, such as diabetes, chronic obstructive pulmonary disease (COPD), congestive heart failure, and atrial fibrillation, were recorded if they were documented events or reported as existing conditions prior to the study period.

2.2 | Grading of FL on abdominal radiographs

A grading system was adopted based on a modified system developed by Harari[10] and Starreveld et al.[11] In short, an abdominal X-ray film was first divided into four quadrants by two imaginary cross lines: one from left splenic flexure toward the great trochater of the right hip and the other from right hepatic flexure toward the great trochater of the left hip. Each quadrant representing a segment of colon was graded with a score from 0 to 5, with 5 being the most severe. The possible total scores ranged from 0 to 20. The scoring was based on the following criteria: 0 was assigned if no stool or minimal stool was present in a quadrant, 1 was assigned if ¼ of the quadrant was occupied by stool, 2 for 1/4 to 1/2 of the quadrant occupied by stool, 3 for 1/2 to 3/4 of the quadrant occupied by stool, 4 for the entire quadrant occupied by stool, and 5 for the entire quadrant filled with stool and the bowel dilated. Dilation was operationally defined as the maximal transverse dimension of colon ≥6 cm or ≥5 cm in the rectum.[9]

Each of the 122 abdominal radiographs was read and graded independently by three trained medical students and one physician on two separate occasions. During the grading, only the code number of each case's radiograph(s) was available. No other medical information or previous scores were available along with the radiographs. Our previous study has shown the overall inter-rater agreement on abdominal radiograph readings was 0.91, with 95% confidence interval (CI) = 0.88–0.93.[9]

2.3 | Definition of significant stool retention

We use the score of 13 (out of total 20) as the cutoff value to define a significant stool retention.[9] In comparison to another scoring system described by Leech et al.,[12] our current study using the score 13 is comparable to the Leech system in defining a significant stool retention (i.e., 13/20 ≈ 9/15). (Of a note, the Leech system scores three segments – right, left, and rectum/sigmoid colon – and assigns fecal burden score on a 0–5 scale in each segment with the highest total score of 15 and a score ≥9 indicating significant constipation.)

2.4 | Defining FL patterns based on AC and DC grading scores

Our study focused on the AC and DC in recognizing FL patterns. A segment mean score ≥3.5 was designated as a high score, and <3.5 as a low score. We used the cutoff value of 3.5 for significant fecal load in AC and DC as it would suggest at least 1/2 to 3/4 of that segment loaded with fecal material ("stool shadowing") on abdominal X-ray films. Therefore, four possible groups could be identified: high AC and high DC, high AC and low DC (or FL predominantly in AC), low AC and low DC, and low AC and high DC. In the current study, the RS segment was not included in the pattern analysis because: (1) this area serves as a storage site for stool readily for defecation; and

(2) RS segment is not an ideal area in distinguishing between those with and those without significant stool retention (see the Result section). In addition, our study did not include the transverse colon FL data in the pattern analysis because FL in the transverse colon is often not so prominent to be displayed.

2.5 | Statistical analysis

Averaged FL score was used for statistical analysis. Chi-square test and two-sample t tests (2-sided) were used to determine whether there was a significant association between two groups. Multiple logistic regression with adjusted odds ratio (AOR) with a 95% CI was used to determine the association between a risk factor and FL pattern after adjusting for covariates (including age, sex, iron supplement, use of anti-muscarinic receptor blocker, prescribed antibiotic prior to hospitalization, and oral laxatives) in the model.

Hosmer and Lemeshow goodness-of-fit test was used to assess the fit of the model to the data. Regression diagnostics were performed to assess if a model is reasonable. Statistical significance was set at a level of 0.05. Statistical analyses were conducted with the PC SAS version 9.3 (SAS Institute, Inc., Cary, NC, USA).

3 | RESULTS

3.1 | FL distribution among hospitalized older adults

Among 122 patients, 71 cases (58.2%) had a mean total score ≥13, 12 subjects (9.8%) had a score between 12 and 13, and 39 individuals (32%) having a score ≤12 (Table 1). The mean total FL score of all studied patients was 13.38 ± 2.53.

To reveal which segment has the largest difference in the stool load between those with and those without significant stool retention, we calculated the difference of FL scores in each segment between these two groups. The greatest difference was seen in the AC (3.91 [0.94] vs 2.20 [0.99]), with an absolute difference of 1.71 (0.99). In contrast, the RS segment showed the smallest difference (0.91) between the two groups (4.41 [0.80] vs 3.50 [1.18]; Figure 1A,B).

TABLE 1 Mean total fecal loading (FL) scores based on abdominal radiographic grading of study participants (N = 122)

Mean total scores (range = 0–20)		
≥13[*]	N = 71	58.2%
Between 13 and 12	N = 12	9.8%
≤12	N = 39	32%
Mean = 13.38 ± 2.53	N = 122	100%

*Mean total FL score ≥13 Indicating a significant stool retention or stool burden in our study.

3.2 | FL patterns based on AC and DC grading

Based on the definition as described in the Method section for high FL for AC and DC segments, three main groups were observed: high AC and high DC FL (N = 21), FL predominantly in AC (i.e., high AC and low DC; N = 38), and the group with low AC and low DC FL (N = 60; Table 2). The group with low AC and high DC FL had only three cases in the current study (N = 3).

All 21 cases of high AC and high DC FL pattern and 97% (37 out of 38) of those with FL predominantly in AC had significant stool retention (i.e., mean total scores ≥13). Whereas 52.1% (37/71) of cases with significant stool retention had the FL predominantly in AC pattern, those with high AC and high DC constituted another 29.6% (21/71). The remaining 13 patients (13/71 = 18.3%) had either low AC and high DC or low AC and low DC patterns.

3.3 | Characteristics of and factors associated with the FL predominantly in AC pattern

As shown in Table 3, individuals with FL predominantly in AC pattern were of younger age (mean = 82.1 [9.2] vs 85.3 [7.9], $P = 0.043$), and were less likely to take antibiotic(s) prior to hospitalization (crude OR = 0.17, 95% CI = 0.03–0.77) than were the group with low AC and low DC (as a reference group). No significant differences between groups were found in comorbidities, medical history, medication use, length of hospital stay, and laboratory assays, including serum potassium, calcium, and albumin levels.

The use of antibiotic(s) prior to hospitalization remained significantly negatively associated with the FL predominantly in AC pattern (AOR = 0.18, 95% CI, 0.04–0.84) after adjusting for age, sex, and use of iron supplements, anti-muscarinic receptor blocker, and oral laxative (Table 4). The comparisons between the high AC and high DC group and FL predominantly in the AC group yielded no significant differences in the clinical characteristics.

4 | DISCUSSION

This retrospective study reported that three FL patterns were observed based on abdominal X-ray grading scores in the segments of AC and DC. Among those with significant stool retention (i.e., mean total score ≥13 out of 20), 52.1% had the FL predominantly in AC pattern and 29.6% showed the high AC and high DC pattern. Our study further demonstrated that patients who were prescribed antibiotics prior to hospitalization had lower odds of association with FL predominantly in AC pattern, independent of other confounding factors.

Our study identified that the AC segment had the largest difference in average FL scores among the four segments of the colon between the group of significant stool retention and the reference group (total score ≤12). Because RS is the segment that is also overlapped with a full bladder shadow on abdominal radiographs, FL
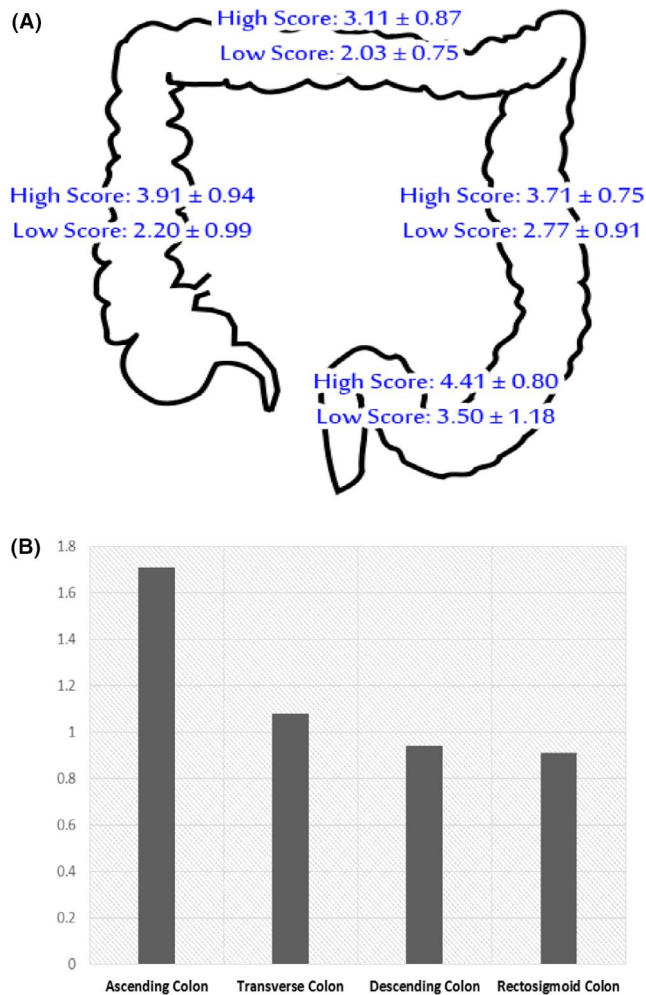
(A)

High Score: 3.11 ± 0.87
Low Score: 2.03 ± 0.75

High Score: 3.91 ± 0.94
Low Score: 2.20 ± 0.99

High Score: 3.71 ± 0.75
Low Score: 2.77 ± 0.91

High Score: 4.41 ± 0.80
Low Score: 3.50 ± 1.18

(B)

FIGURE 1 (A) Mean fecal loading (FL) scores by segments of colon between those with significant stool retention (i.e., total score ≥13, or high scores) and those with total score ≤12 (or low scores) as assessed by abdominal radiography. All scores shown were mean ± standard deviation (SD). All P values between two groups in each segment were <0.001. (B) The difference between mean FL scores between the two groups by each segment of the colon

TABLE 2 Groups based on mean FL scores ≥3.5 as a high score vs. <3.5 as a low score on the AC and DC segments (N = 122)

Low AC and low DC (reference)	N = 60	49.2%
High AC and low DC (i.e., FL predominantly in AC pattern)	N = 38	31.1%
High AC and high DC	N = 21	17.2%
Low AC and high DC	N = 3	2.5%

Abbreviations: AC, ascending colon; DC, descending colon; FL, fecal loading.

grading in this area may vary with a greater degree (as shown by the higher SD for the reference group) among readers compared with other segments (e.g., AC). Although this study is limited in estimating which segment of colon will be a better predictor of overall stool

retention, the AC segment could be a candidate which will be an area for future study in evaluating people with constipation.

Our study revealed two types of stool retention patterns: FL predominantly in AC, and high AC and high DC (while using low AC and low DC as a reference group). Almost all these cases, except one in the former group, had significant stool retention status as defined in our study. The latter type – high AC and high DC – is understandable as feces build up from RS segment progressively up to AC. Nevertheless, the former type – FL predominantly in AC – is an interesting pattern for clinicians to consider while evaluating patients with constipation.

A few studies had shown that patterns of colonic transit differed in patients with chronic idiopathic constipation.[13–15] One study specifically revealed that transit is delayed in the cecum and AC, hepatic flexure, and transverse colon in patients with colonic inertia when compared with controls.[13] Although no patients in the current study had a bowel obstruction per radiographic reports, it was possible that the hepatic flexure could be an anatomic barrier in some patients for feces being moved distally toward the rectum via peristalsis. We have observed in our clinical practice that some older adult patients retained a substantial amount of feces in the cecum and AC segment as shown by their radiographs or computed tomographic scans of the abdomen and pelvis.

It has been shown that enteric nervous system is altered in patients with slow-transit constipation and megacolon,[16] and cholinergic function is involved in the complex regulation of motility.[17,18] One study using ex vivo preparation of the human colon demonstrated that aging impaired cholinergic function of AC but not in DC.[7] Our study findings could indicate that cholinergic dysfunction observed in the AC may result from the consequence of an excessive stool retention in the AC. Excessive pressure on the colonic wall may damage the enteric neuron system or facilitating the neurodegeneration process in the AC segment. Our finding also suggests that AC could be another area for significant stool burden in older adults with constipation.

One interesting finding from our study is that antibiotic use prior to hospitalization was associated with lower odds of having the FL predominantly in AC pattern even after adjusting for confounders. Antibiotic use, particularly penicillin and macrolide, has been a known factor associated with increased bowel motility and/or diarrhea,[19] and macrolide has a gastrointestinal prokinetic effect expediting the bowel transit and therefore may decrease stool burden in the AC. Because of the study's design, it is imperative to recognize that it precludes causal inferences in interpreting our study's findings. Furthermore, our study could not exclude other factors (e.g., COPD/acute bronchitis, virus-related diarrhea, or gastric acid suppression therapy) that could confound the use of antibiotic(s). Considering the limitations of this study, including being retrospective and a small sample size from one site, further research is needed to confirm whether the findings could be replicated.

Constipation is a diagnosis based on patients' subjective symptoms. Because of the low accuracy of self-reported symptoms in certain clinical circumstances, abdominal radiography has been

TABLE 3 Characteristics of patients with FL predominantly in the AC vs the reference group among hospitalized older adults

Variables	FL predominantly in AC (N = 38)	Reference (low AC and low DC) (N = 60)	P value	Crude OR (95% CI)
Mean age, y (SD)	82.2 (9.2)	85.3 (7.9)	0.043[*]	
Female	27 (71%)	45 (75%)	0.815	0.82 (0.32–2.03)
Race: White	37 (97%)	59 (98%)	1.000	--
Nursing home residency	14 (37%)	30 (50%)	0.219	1.71 (0.75–3.93)
Associated acute comorbidity during hospital stay				
Pneumonia	4 (11%)	11 (18%)	0.393	0.52 (0.15–1.78)
COPD exacerbation	3 (8%)	6 (10%)	1.000	0.77 (0.18–3.28)
UTI/Bacteriuria	12 (32%)	15 (25%)	0.495	1.38 (0.56–3.40)
Medical history				
Diabetes	15 (39%)	16 (27%)	0.265	1.79 (0.75–4.26)
Coronary artery disease	11 (29%)	19 (32%)	0.825	0.87 (0.36–2.13)
COPD	10 (26%)	20 (33%)	0.507	0.71 (0.29–1.75)
Stroke	7 (18%)	7 (12%)	0.386	1.70 (0.54–5.33)
Memory impairment	7 (18%)	15 (25%)	0.620	0.67 (0.25–1.85)
Medication uses				
Atypical antipsychotics	5 (13%)	12 (20%)	0.4268	0.60 (0.19–1.88)
Calcium-channel blocker	7 (18%)	10 (17%)	1.000	1.13 (0.39–3.27)
Calcium supplement	17 (45%)	20 (33%)	0.290	1.60 (0.70–3.73)
Iron supplement	8 (21%)	20 (33%)	0.252	0.53 (0.21–1.37)
Anti-muscarinic drug	1 (3%)	3 (5%)	1.000[a]	0.51 (0.05–5.12)
Antihypertensive drug	23 (61%)	38 (63%)	0.832	0.88 (0.38–2.04)
Antihistamine drug	5 (13%)	13 (22%)	0.423	0.54 (0.17–1.68)
Diuretics	18 (47%)	26 (43%)	0.835	1.17 (0.52–2.66)
Narcotics	19 (50%)	27 (45%)	0.681	1.22 (0.54–2.75)
Statins	7 (18%)	10 (17%)	1.000	1.12 (0.38–3.27)
Antibiotic use prior to Admission	2 (5%)	15 (25%)	0.013[a]	0.17 (0.03–0.77)[*]
Antidepressants	18 (47%)	27 (45%)	0.838	1.1 (0.48–2.48)
Oral laxative use	17 (45%)	32 (53%)	0.534	0.71 (0.31–1.6)
Blood test results on admission				
Potassium (mmol/L)	4.10 ± 0.57 (N = 37)	4.17 ± 0.60 (N = 60)	0.563	--
Calcium (mg/dL)	9.09 ± 0.43 (N = 37)	8.95 ± 0.56 (N = 60)	0.189	--
Serum albumin (gm/L)	32.5 ± 6.1 (N = 37)	32.4 ± 5.1 (N = 55)	0.955	--
Length of hospital stay (days)	5.71 ± 3.03	6.05 ± 2.50	0.566	--

Note: A mean segment score ≥3.5 was designated as a high-score and <3.5 as a low-score.

Abbreviations: AC, ascending colon; CI, confidence interval; COPD, chronic obstructive pulmonary disease; DC, descending colon; FL, fecal loading; OR, odds ratio; UTI, urinary tract infection.

aCalculated by Fisher's exact test.

*Indicated significant ($p < 0.05$).

used by clinicians in assessing the severity of FL or stool burden in certain populations and clinical settings.[9,20–23] Despite the controversies on its usefulness in clinical practices,[24–26] using abdominal X-ray in assessing stool burden is reliable among X-ray readers and clinicians,[9,23,25] and is considered one of the tools in evaluating patients with a chief complaint of constipation.[8] Additionally, an abdominal X-ray can be useful in clarifying uncertain situations, such as excessive bowel frequency resulting from excessive fecal burden.[27]

TABLE 4 Factors associated with the fecal loading predominantly in the AC pattern in a multiple logistic regression model (N = 98)

Variables[†]	Adjusted OR	95% CI	P value
Age, y	0.97	0.92–1.02	0.254
Sex (female = 1; male = 0)	0.90	0.33–2.46	0.839
Iron supplements	0.60	0.22–1.65	0.323
Anti-muscarinic receptor blocker	0.55	0.05–6.09	0.624
Antibiotic use	0.18	0.04–0.84	0.029[*]
Oral laxative use	0.82	0.34–1.99	0.658

Abbreviations: AC, ascending colon; CI, confidence interval; OR, odds ratio.

[†]Variables were dichotomized as 1 = yes, 0 = no (baseline), unless stated otherwise. Hosmer and Lemeshow goodness-of-fit test: chi square = 10.06, df = 8, $P = 0.2606$.

[*]Significant ($P < 0.05$).

There are several limitations in this study that should be acknowledged. First, the sample consisted of hospitalized patients with abdominal X-ray who were selected simply based on the billing codes at discharge that included primary or secondary diagnosis of constipation. Furthermore, this study only recruited those aged 65 years or older. It would be more informative in providing a comparison between younger and older patients in their fecal loading patterns in a future study to include younger patients. Second, given that certain medications, including over-the-counter laxatives, were available to patients without prescription, it is possible that the current study did not capture all relevant information on medication use and could not assess their potential effects. Third, the sample size of this study was relatively small, which did not allow the inclusion of other groups (like low AC and high DC) for further comparisons. Fourth, this study was not able to examine the history of surgical procedures involving the abdomen or pelvis, such as bowel resection or hysterectomy, which could alter the anatomic location of the colon and intestinal motility. Last, considering that the sample of patients was from a single study site and was predominantly White patients with advanced age (mean age >80 years), the conclusions of this study may not be generalized to the general population. Despite these limitations, this study provided detailed information on the distribution of FL in each segment of the colon from a sample with documented medical history, comorbidities, and laboratory findings, all of which contributed to the strengths of this study for an under-studied topic.

5 | CONCLUSION

This pilot study described two types of stool retention patterns based on abdominal X-ray grading, including high FL in both AC and DC, and high FL predominantly in AC, with the latter represented by more than 50% of those with significant stool retention. Antibiotic use prior to hospitalization was associated with lower odds of having the high FL predominantly in AC pattern. Our study suggested that AC could be an area for significant stool burden in older adults. Further research is recommended to confirm these findings and clinical significance.

CONFLICTS OF INTERESTS

All authors declare that they have no competing interests nor financial conflicts of interest to report.

AUTHOR CONTRIBUTIONS

Study concept: Gau, Patel, and Pan. *Study design:* Gau and Patel. *Supervision:* Gau and Kao. *Resources:* Gau. *Materials:* Gau. *Data collection and/or processing:* Gau and Patel. *Analysis and/or interpretation:* Gau, Patel, Pan, and Kao. *Literature search:* Gau, Patel, and Pan. *Writing of the manuscript:* Gau and Patel. *Critical review:* Pan and Kao.

DISCLAIMER

The views expressed in this paper are those of the authors and do not necessarily reflect the official views of the institutions or the USA Department of Defense.

Data can be available by contacting Jen-Tzer Gau at gau@ohio.edu.

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