



Degree of transverse colon ptosis: an alternative surrogate for evaluation of slow transit constipation

Kongliang Sun^{1,2#^}, Xiaoyu Xie^{1#}, Jinxiang Hu^{3#}, Qun Qian^{1,4,5,6,7}, Weicheng Liu^{1,4,5,6}, Yuntian Hong^{1,4,5}, Baoxiang Chen^{1,4,5}, Huixuan Xie¹, Hong Yan⁸, Xianghai Ren^{1,4,5,6,7^}, Congqing Jiang^{1,4,5,6,7}

¹Department of Colorectal and Anal Surgery, Zhongnan Hospital of Wuhan University, Wuhan, China; ²Department of Ophthalmology, Zhongnan Hospital of Wuhan University, Wuhan, China; ³Department of Radiology, Zhongnan Hospital of Wuhan University, Wuhan, China; ⁴Clinical Center of Intestinal and Colorectal Diseases of Hubei Province, Wuhan, China; ⁵Key Laboratory of Intestinal and Colorectal Diseases of Hubei Province, Wuhan, China; ⁶Colorectal and Anal Disease Research Center, Medical School of Wuhan University, Wuhan, China; ⁷Quality Control Center of Colorectal and Anal Surgery, Health Commission of Hubei Province, Wuhan, China; ⁸School of Health Sciences, Wuhan University, Wuhan, China

Contributions: (I) Conception and design: C Jiang, X Ren, K Sun; (II) Administrative support: C Jiang, Q Qian; (III) Provision of study materials or patients: All authors; (IV) Collection and assembly of data: K Sun, X Ren, X Xie, J Hu, H Xie; (V) Data analysis and interpretation: K Sun, X Ren, H Yan; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

[#]These authors contributed equally to this work.

Correspondence to: Congqing Jiang, MD, PhD; Xianghai Ren, MD, PhD. Department of Colorectal and Anal Surgery, Zhongnan Hospital of Wuhan University, No. 169, East Lake Road, Wuchang District, Wuhan 430071, China; Clinical Center of Intestinal and Colorectal Diseases of Hubei Province, Wuhan, China; Key Laboratory of Intestinal and Colorectal Diseases of Hubei Province, Wuhan, China; Colorectal and Anal Disease Research Center, Medical School of Wuhan University, Wuhan, China; Quality Control Center of Colorectal and Anal Surgery, Health Commission of Hubei Province, Wuhan, China. Email: wb002554@whu.edu.cn; xianghai_ren@qq.com.

Background: Although transverse colon ptosis (TCP) is commonly diagnosed in patients with constipation, it has not attracted significant attention in the evaluation of constipation. Herein, we assessed the correlation between TCP-related radiological parameters and the severity of slow transit constipation (STC).

Methods: This study was a single-center retrospective cohort study, with participants enrolled between 2012 and 2020 in Zhongnan Hospital of Wuhan University, China. STC was diagnosed according to Rome IV criteria and results of colonic transit test (CTT); healthy volunteers were also recruited as controls. All participants were examined using abdominal X-rays (AXRs) to acquire the radiological parameters related to TCP. Among these parameters, the degree of TCP (DTCP) was defined as the vertical distance from the top of the splenic flexure to the lowest point of the reverse colon. The Wexner Constipation Score and Hospital Anxiety and Depression Scale were used to assess clinical severity. After multivariable linear regression, the correlations between radiological parameters and severity of STC were investigated. We also explored the differences in radiological parameters between the operation and the conservative group.

Results: The study included 139 patients with STC and 125 healthy people in as the normal control (NC). Patients with STC probably had larger DTCPs than those in the NC group (242.27±25.86 vs. 93.00±32.57 mm; P<0.001). Pearson correlation analysis showed that TCP-related parameters were consistent with the symptom severity of STC [e.g., parameter DTCP was strongly correlated with Wexner Constipation Score, with a β coefficient (95% CI) of 8.63 (8.24–9.02), P<0.001]. Multivariable linear regression models showed that patients with a larger DTCP were more likely to undergo surgery (23.67; 95% CI: 1.40–45.94; P=0.04).

Conclusions: TCP-related parameters, especially the DTCP, may serve as novel and feasible alternative indices for the assessment of STC. However, the potential value of DTCP in assisting the evaluation of STC

[^] ORCID: Kongliang Sun, 0000-0002-3643-4797; Xianghai Ren, 0000-0001-8092-6687.

needs to be confirmed in study with a larger sample size.

Keywords: Slow transit constipation (STC); colonic transit; abdominal X-ray (AXR); degree of transverse colon ptosis

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Introduction

Slow transit constipation (STC) is a clinical syndrome characterized by constipation and delayed colonic transit which accounts for 13–37% of all cases of constipation (1-4). The primary symptoms include reduced bowel movements, decreased or absent urge to defecate, difficulty in defecating, and dry stools (1,2). STC seriously affects the mental state and quality of life of patients.

Colonic transit is evaluated predominantly via radiopaque markers on plain film abdominal X-ray (AXR) [colonic transit tests (CTT)]. This is an inexpensive method of visualization that is widely applied in clinical settings and plays an important role in distinguishing different constipation subgroups, such as slow or normal transit constipation (5-7). Despite the high frequency at which AXR is applied, studies have suggested that the model shapes of the markers vary from hospital to hospital, and there is still no unified standard for the inspection and evaluation process (5-8). Further, the number of radiopaque markers remaining in the CTT may not necessarily correlate with the severity of constipation (9).

Gamma scintigraphy, magnetic tracking system approaches, and stool burden have also been introduced and have proven to be effective methods to identify colonic transit disorder (10-12). However, these methods are difficult to apply in areas with disadvantaged healthcare settings in the short term. Thus, it is important to explore concise and efficient STC evaluation methods.

Transverse colonic proptosis (TCP), defined as the abnormal downward displacement of the transverse colon without ptosis of other viscera, is a common phenomenon in patients with chronic constipation. As early as the 1920s, Cannon reported two cases of TCP and suggested that this anatomical anomaly was associated with constipation (13). It is speculated that the ptosis of transverse colon and the elevated splenic flexure are not conducive to the fecal propulsion in the upright state as stool accumulated in the transverse colon may further aggravate the degree of enteroptosis due to gravity and in

turn, this vicious cycle relationship may be an important anatomic factor in intractable constipation (13-16). This suggests a potential relationship between TCP and the progression of constipation. However, the assessment of TCP has not yet gained attention, particularly in patients with STC. Given the paucity of research on the topic, whether there is a correlation between TCP and the severity of STC aroused our interest. Hence, this study aimed to investigate the correlation between TCP-related radiological parameters and the severity of STC, and to explore the usefulness of TCP in the diagnosis and treatment of patients with STC. We present this article in accordance with the STROBE reporting checklist (available at <https://qims.amegroups.com/article/view/10.21037/qims-23-28/rc>).

Methods

Participants

We retrospectively reviewed the files of patients with chronic constipation admitted to Zhongnan Hospital of Wuhan University between 1 January 2012 and 31 December 2020. The data were collected between 1 March 2021 and 31 March 2021.

The inclusion criteria were: (I) age >18 years; and (II) a confirmed diagnosis of simple STC according to the Rome IV criteria and CTT (17). Symptoms of constipation must be present for at least 6 months before the diagnosis, which was made based on the following criteria: no loose stools without the use of laxative, inadequate evidence for the diagnosis of irritable bowel syndrome, and the symptoms were not caused by opioids (17).

The exclusion criteria were: (I) evidence of obstructed defecation syndrome; (II) evidence of secondary causes of constipation; (III) known or suspected gastric or small bowel disorders, including dysmotility; and (IV) missing data (CTT was not performed).

A group of healthy participants (volunteers) who underwent plain abdominal radiography during the same

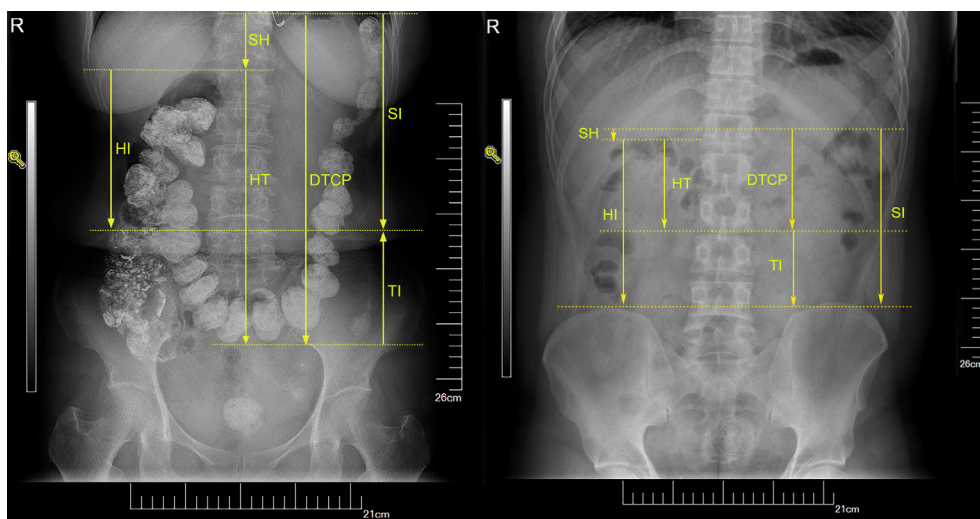


Figure 1 TCP-related indices measured on abdominal X-ray for STC group (left) and NC group (right). HI, the vertical distance from the hepatic flexure to the right iliac crest; SH, the vertical distance from the splenic flexure to the hepatic flexure; HT, the vertical distance from the hepatic flexure to the lowest point of transverse colon; DTCP, degree of transverse colon ptosis; SI, the vertical distance from the splenic flexure to the left iliac crest; TI, the vertical distance from the lowest point of transverse colon to the L4-L5 interspace; TCP, transverse colon ptosis; STC, slow transit constipation; NC, normal control.

period were also recruited as the normal control group (NC). The inclusion criteria were: (I) normal bowel function; (II) no digestive diseases; (III) no lower urinary tract or reproductive system diseases; (IV) no history of gastrointestinal (including anorectum) or urogenital surgery; (V) no history of pelvic trauma; (VI) no history of endocrine or metabolic diseases, including diabetes and thyroid diseases. We recorded data on the demographics, radiographic imaging data, and bowel movements for each participant (the bowel movements of healthy individuals were acquired via telephone follow-up). The severity of constipation, depression score, and therapeutic measures for patients with STC were also collected.

CTT

The CTT is an important method for the diagnosis of STC, and its procedure has been described in previous articles (6,11,18,19). Briefly, patients were prohibited from using laxatives, enemas, or other treatments that might affect gastrointestinal motility for the 3 days before the examination. Plain radiographs of the abdomen were taken 6, 24, 48, and 72 hours after a single ingestion of radiopaque markers [Sitzmarks capsule, Konsyl Pharmaceuticals, Easton, MD, USA (containing 24 markers)] or barium

solution (50 mL, 20%) to reveal traces of markers/barium movement. Small bowel dysmotility was defined as the retention of two or more markers in the ileum after 6 hours, and a positive test for STC was considered if more than 20% of the markers were not eliminated after 3 days (11). The contour and position of the colon could be effectively identified by the scattered distribution of gas/markers/barium in the colon on AXR plain films.

Radiological parameters

Based on the abdominal plain films, the degree of TCP (DTCP) was defined as the vertical distance from the top of the splenic flexure to the lowest point of the transverse colon (Figure 1). To provide a more intuitive understanding of the TCP configuration, we defined the novel TCP-related indices, as shown in Figure 1. Based on abdominal plain films, the vertical distances from the hepatic flexure to the right iliac crest were recorded as HI; from the splenic flexure to the left iliac crest as SI; from the lowest point of transverse colon to the L4-L5 interspace [of the same height to the attachment of both sides of the iliac crest (20)] as TI; from the hepatic flexure to the lowest point of transverse colon as HT; and from the splenic flexure to the hepatic flexure as SH.

Assessment of symptom severity for STC

The severity of constipation was assessed according to the symptoms and bowel habits stated by patients during the initial visit. The Wexner Constipation Score (WCS) and the Hospital Anxiety and Depression Scale (HADS) were used to assess each patient with STC. The WCS is an eight-term measure of constipation severity scores; scores range from 0 to 30, with 0 indicating normal and 30 indicating severe constipation (21,22). Similarly, the HADS, a 14-term measure for the detection of anxiety and depression, was applied to determine the psychological condition (23). Scores $\geq 8/21$ for both depression and anxiety are considered diagnostic with a sensitivity and specificity of approximately 0.80 (24). Symptoms related to constipation, including interval of bowel movement, length of time per attempt, and desire to defecate were also recorded.

Therapeutic measures

Conservative therapies, such as nonpharmacological interventions or systematic drug treatment, were recommended to patients with STC during their first visit to a doctor. The patients who opted for surgical treatment had to meet the following criteria (25–27): (I) at least 5 years of severe refractory STC (unresponsive to conservative treatment); (II) frequency of defecation less than two times per week; (III) no obvious obstructed defecation syndrome; (IV) no small bowel dysmotility; (V) no severe mental disease; and (VI) strong desire to undergo surgery.

Statistical analysis

Normally distributed variables were presented as the mean (standard deviation), and the independent-sample *t*-test was used to compare variables between the STC group and the NC group. Categorical variables were described as the frequency or percentage and examined by the Chi-squared test. Pearson correlations were applied to assess the correlations between the indices. Multivariable linear regression models were used to determine the linear regression coefficient (B) and 95% confidence intervals (CIs) of radiological parameters according to the STC group, severity of symptoms, operation group, and diseased colonic segments with adjustment for potential covariates. Receiver operating characteristic (ROC) curves were created, and an area under the ROC curve (AUC) was calculated. Subsequently, Youden's J statistic was used to determine

an optimal cut-off point (maximizing both sensitivity and specificity) for the DTCP. Statistical significance was established when the two-tailed P value was <0.05 . Statistical analyses were performed using R version 4.0.2 (R Foundation).

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the medical ethics committee of Zhongnan Hospital of Wuhan University. Written informed consent was obtained from the participants.

Results

Cohort characteristics

A total of 264 individuals were included in this cohort study: 139 patients with STC and 125 healthy people in the NC group (Figure 2) (the original data can be found in Table S1). The characteristics of these patients are presented in Table 1. Overall, the mean age of all participants was 55.03 ± 13.75 years, and the majority were female (71.21%), with 76.26% and 65.60% female patients in the STC and NC groups, respectively. Compared with those in the NC group, patients in the STC group showed a longer interval of bowel movement (7.13 ± 1.95 vs. 1.28 ± 0.67 days), increased length of time per attempt (27.45 ± 12.27 vs. 6.63 ± 4.01 min), reduced defecation desire (75.54% vs. 0%), and higher WCS (17.51 ± 2.12 vs. 0.53 ± 0.78), all with P values <0.001 .

TCP-related indices between STC and NC groups

Most patients (132 out of 139) in the STC group underwent CTT through barium solution. To rule out the effect of baseline information on the radiological parameters, multivariable linear regression models were applied after adjusting for sex, age, height, weight, and body mass index (BMI). As shown in Table 2, the HI (B, -39.43 ; 95% CI: -49.21 to -29.65 ; $P < 0.001$) and TI (B, -155.81 ; 95% CI: -166.64 to -144.98 ; $P < 0.001$) in the STC group were significantly lower than those in the NC group, and patients in the STC group had elevated DTCP (B, 147.29 ; 95% CI: 139.85 – 154.73 ; $P < 0.001$), HT (B, 116.38 ; 95% CI: 107.27 – 125.49 ; $P < 0.001$) and SH (B, 30.91 ; 95% CI: 22.10 – 39.72 ; $P < 0.001$) compared to those in the NC group. However, the difference in the SI between the groups was not significant ($P = 0.07$).

ROC curves were drawn for the groups, the results of

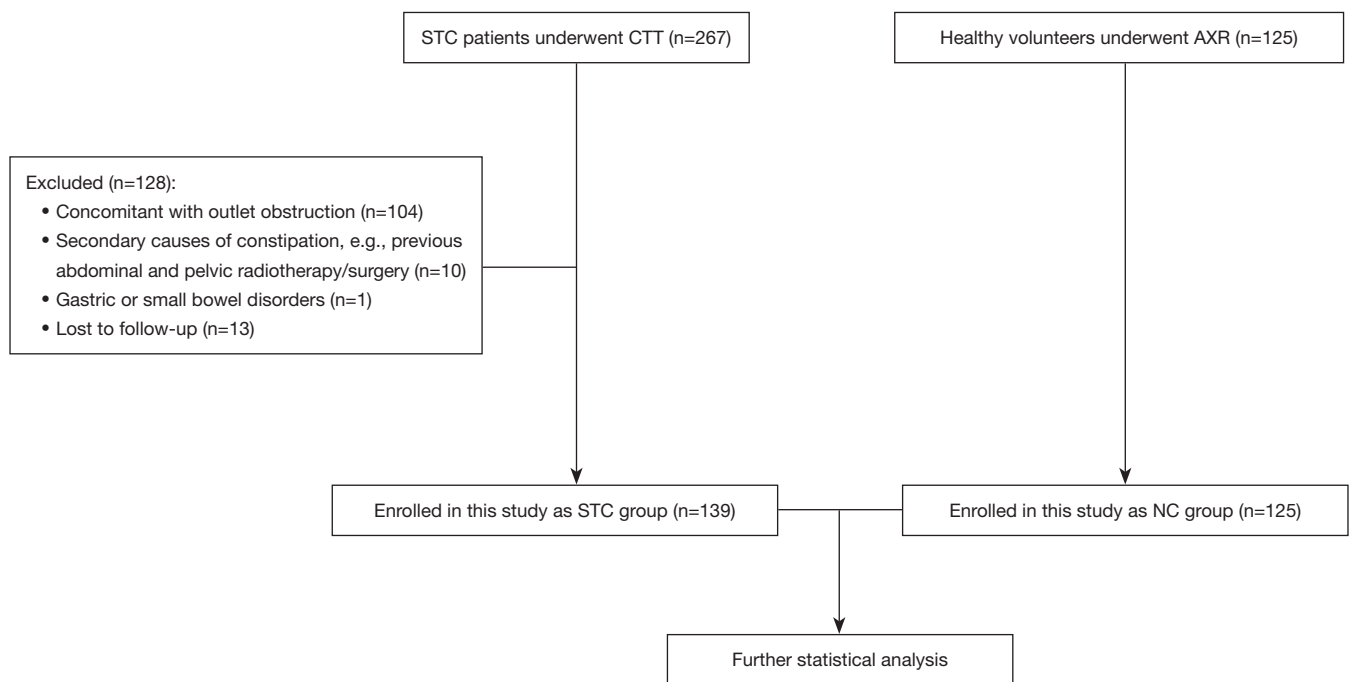


Figure 2 Patient selection flowchart. AXR, abdominal X-ray; CTT, colonic transit test; STC, slow transit constipation; NC, normal control.

which are shown in [Figures S1-S7](#). A cutoff DTCP value of 165.17 mm could clearly segregate patients with STC from healthy people with high specificity and sensitivity (sensitivity 0.978 and specificity 0.984). TI (a cutoff value of -46.87 mm, with the sensitivity of 0.935 and the specificity of 0.984) and HT (a cutoff value of 109.45 mm, with the sensitivity of 0.942 and the specificity of 0.976) also achieved similar ideal results.

Correlation analysis between severity of STC and TCP-related indices

The correlations between TCP-related indices and clinical features after adjustment are listed in [Table 3](#). The DTCP, TI, HT, HI and SH were well correlated with WCS, while the DTCP, TI, and HT exhibited good linear correlations with HADS.

Correlation analysis between the therapeutic regimen and TCP-related indices

A total of 72 patients with STC who underwent systematic treatment in our single medical group were screened for further investigation. Among them, 43 patients (38 females, mean age 54.77 ± 11.30 years) underwent surgical treatment

(operation group) and 29 patients (27 females, average age 56.21 ± 12.37 years) underwent conservative treatment (conservative group). Patients with STC who required surgical intervention often had more severe symptoms of constipation. In this subgroup analysis, the WCS in the operation group was significantly higher than that in the conservative group (17.67 ± 3.30 vs. 16.21 ± 2.09 ; $P=0.03$). After adjustment, multivariable linear regression models revealed that the DTCP (B, 23.67; 95% CI: 1.40–45.94; $P=0.04$) and TI (B, 23.95; 95% CI: 1.15–46.74; $P=0.04$) in the operation group were significantly higher than those in the conservative group ([Table 4](#)).

Discussion

In patients with chronic constipation, particularly those with STC, it is common for TCP to be identified on AXR (13-16). This was first reported in 1922 by Cannon *et al.* (13), who concluded that a pendulous transverse colon assumed a “V” shape in the pelvis, with angulations at the hepatic and splenic flexures that were closely related to the symptoms. However, no related studies followed. In 2012, Sawa *et al.* recruited 43 healthy volunteers and reported that ptotic transverse colons were partially located below the fifth lumbar vertebra in four female volunteers (16). In

Table 1 Comparison of baseline information, bowel habits and radiological parameters between STC group and NC group

Variables	Total (n=264)	Groups		P
		NC (n=125)	STC (n=139)	
Sex				0.08
Male	76 (28.79)	43 (34.40)	33 (23.74)	
Female	188 (71.21)	82 (65.60)	106 (76.26)	
Age (years)	55.03±13.75	53.98±15.25	55.99±12.23	0.24
Height (m)	1.62±0.06	1.63±0.07	1.62±0.06	0.47
Weight (kg)	61.63±8.69	64.92±8.05	58.66±8.18	<0.001
BMI (kg/m ²)	23.40±3.36	24.58±3.21	22.33±3.13	<0.001
Interval of bowel movement (days)	4.36±3.28	1.28±0.67	7.13±1.95	<0.001
Length of time per attempt (min)	17.59±13.96	6.63±4.01	27.45±12.27	<0.001
WCS	9.47±8.65	0.53±0.78	17.51±2.12	<0.001
Desire to defecate				<0.001
Reduced	105 (39.77)	0 (0)	105 (75.54)	
Normal	159 (60.23)	125 (100.00)	34 (24.46)	
HI (mm)	99.57±42.86	121.28±42.37	80.05±32.82	<0.001
SI (mm)	148.02±36.12	154.26±38.41	142.42±33.08	0.008
TI (mm)	-23.57±90.96	61.25±47.70	-99.85±36.67	<0.001
HT (mm)	123.15±69.49	60.03±24.53	179.90±42.54	<0.001
SH (mm)	48.45±37.07	32.97±30.42	62.36±37.07	<0.001
DTCP (mm)	171.59±80.17	93.00±32.57	242.27±25.86	<0.001

Data are shown as n (%) or mean ± SD. STC, slow transit constipation; NC, normal control; BMI, body mass index; WCS, Wexner Constipation Scale; HI, the vertical distance from the hepatic flexure to the right iliac crest; SI, the vertical distance from the splenic flexure to the left iliac crest; TI, the vertical distance from the lowest point of transverse colon to the L4-L5 interspace; HT, the vertical distance from the hepatic flexure to the lowest point of transverse colon; SH, the vertical distance from the splenic flexure to the hepatic flexure; DTCP, degree of transverse colon ptosis; SD, standard deviation.

the study of Chen *et al.* in 2020 (15), TCP was considered as one of three crucial criteria in the diagnosis of superior mesenteric artery compression syndrome secondary to chronic constipation. To date, however, the relationship between chronic constipation and TCP has not been systematically studied.

The DTCP, a value that can be conveniently obtained from the AXR, represents the height difference between the uppermost and lowermost regions of the transverse colon in the standing position that can intuitively reflect its degree of decline. After adjustments for age, sex, height, weight, and BMI, the DTCP, as well as the values of HI, HT, TI, and SH in patients with STC, were significantly different from those in patients without STC. More importantly,

ROC curve analysis showed that the DTCP may have the potential to distinguish STC patients from healthy individuals. However, large sample multi-center data are still required to confirm the effectiveness of DTCP in evaluating STC.

Some results suggest that TCP is more pronounced in patients with STC, and one possible explanation for this might be due to the gravity of feces. When the colon's motor function is impaired, stool accumulates. Because the transverse colon is not anchored to the retroperitoneum, it is more susceptible to the effects of gravity, and is thus more prone to colonic ptosis (13). In contrast, the splenic flexure of the colon, which is connected to the diaphragm and the tail of the pancreas by the phrenic colon ligament

Table 2 Comparisons of TCP-related indexes between STC and NC groups

Variables	Unadjusted			Adjusted [†]	
	N	β coefficient (95% CI)	P	β coefficient (95% CI)	P
HI (mm)					
NC	125	0 (reference)		0 (reference)	
STC	139	-41.23 (-50.32 to -32.14)	<0.001	-39.43 (-49.21 to -29.65)	<0.001
SI (mm)					
NC	125	0 (reference)		0 (reference)	
STC	139	-11.84 (-20.46 to -3.21)	0.008	-8.52 (-17.77 to 0.73)	0.07
TI (mm)					
NC	125	0 (reference)		0 (reference)	
STC	139	-161.11 (-171.32 to -150.90)	<0.001	-155.81 (-166.64 to -144.98)	<0.001
HT (mm)					
NC	125	0 (reference)		0 (reference)	
STC	139	119.88 (111.38 to 128.38)	<0.001	116.38 (107.27 to 125.49)	<0.001
SH (mm)					
NC	125	0 (reference)		0 (reference)	
STC	139	29.39 (21.16 to 37.63)	<0.001	30.91 (22.10 to 39.72)	<0.001
DTCP (mm)					
NC	125	0 (reference)		0 (reference)	
STC	139	149.27 (142.21 to 156.33)	<0.001	147.29 (139.85 to 154.73)	<0.001

[†], adjusted model includes sex, age, height, weight and BMI. Data are presented as 95% CI. TCP, transverse colon ptosis; STC, slow transit constipation; NC, normal control; HI, the vertical distance from the hepatic flexure to the right iliac crest; SI, the vertical distance from the splenic flexure to the left iliac crest; TI, the vertical distance from the lowest point of transverse colon to the L4-L5 interspace; HT, the vertical distance from the hepatic flexure to the lowest point of transverse colon; SH, the vertical distance from the splenic flexure to the hepatic flexure; DTCP, degree of transverse colon ptosis; BMI, body mass index.

Table 3 Correlation analysis between severity of STC and TCP-related indexes

Variables	Unadjusted		Adjusted [†]	
	β coefficient (95% CI)	P	β coefficient (95% CI)	P
HI (mm)				
Interval of bowel movement (days)	-5.65 (-7.08 to -4.22)	<0.001	-5.28 (-6.77 to -3.78)	<0.001
Length of time per attempt (min)	-1.20 (-1.54 to -0.85)	<0.001	-1.10 (-1.46 to -0.74)	<0.001
WCS	-2.36 (-2.88 to -1.83)	<0.001	-2.24 (-2.81 to -1.68)	<0.001
Desire to defecate	34.47 (24.74 to 44.20)	<0.001	31.40 (21.15 to 41.65)	<0.001
HADS-A	0.54 (-2.23 to 3.30)	0.71	0.52 (-2.30 to 3.35)	0.72
HADS-D	-1.85 (-4.96 to 1.26)	0.25	-1.72 (-4.94 to 1.50)	0.30
SI (mm)				
Interval of bowel movement (days)	-1.59 (-2.91 to -0.27)	0.02	-1.11 (-2.49 to 0.27)	0.12
Length of time per attempt (min)	-0.54 (-0.85 to -0.24)	0.001	-0.44 (-0.77 to -0.11)	0.009

Table 3 (continued)

Table 3 (continued)

Variables	Unadjusted		Adjusted [†]	
	β coefficient (95% CI)	P	β coefficient (95% CI)	P
WCS	-0.65 (-1.14 to -0.15)	0.01	-0.45 (-0.99 to 0.08)	0.10
Desire to defecate	11.10 (2.28 to 19.92)	0.01	7.89 (-1.41 to 17.18)	0.10
HADS-A	-1.26 (-3.94 to 1.41)	0.36	-0.99 (-3.71 to 1.73)	0.48
HADS-D	-3.52 (-6.49 to -0.55)	0.02	-3.22 (-6.29 to -0.16)	0.04
TI (mm)				
Interval of bowel movement (days)	-23.24 (-25.07 to -21.41)	<0.001	-22.04 (-23.90 to -20.19)	<0.001
Length of time per attempt (min)	-4.54 (-5.10 to -3.97)	<0.001	-4.18 (-4.77 to -3.60)	<0.001
WCS	-9.40 (-9.97 to -8.83)	<0.001	-9.08 (-9.69 to -8.48)	<0.001
Desire to defecate	125.05 (108.46 to 141.64)	<0.001	113.33 (96.28 to 130.39)	<0.001
HADS-A	-7.39 (-10.29 to -4.50)	<0.001	-7.12 (-10.04 to -4.19)	<0.001
HADS-D	-7.73 (-11.05 to -4.40)	<0.001	-7.18 (-10.60 to -3.76)	<0.001
HT (mm)				
Interval of bowel movement (days)	17.59 (16.16 to 19.02)	<0.001	16.76 (15.29 to 18.23)	<0.001
Length of time per attempt (min)	3.34 (2.90 to 3.79)	<0.001	3.08 (2.62 to 3.55)	<0.001
WCS	7.04 (6.57 to 7.51)	<0.001	6.84 (6.34 to 7.34)	<0.001
Desire to defecate	90.58 (77.39 to 103.78)	<0.001	81.93 (68.27 to 95.59)	<0.001
HADS-A	7.93 (4.49 to 11.37)	<0.001	7.64 (4.12 to 11.16)	<0.001
HADS-D	5.88 (1.81 to 9.95)	0.005	5.45 (1.24 to 9.67)	0.01
SH (mm)				
Interval of bowel movement (days)	21.65 (20.27 to 23.02)	<0.001	4.17 (2.83 to 5.51)	<0.001
Length of time per attempt (min)	3.99 (3.49 to 4.49)	<0.001	0.66 (0.33 to 0.99)	<0.001
WCS	8.75 (8.39 to 9.12)	<0.001	1.79 (1.28 to 2.30)	<0.001
Desire to defecate	-113.96 (-128.15 to -99.76)	<0.001	-23.51 (-32.70 to -14.33)	<0.001
HADS-A	-1.80 (-4.94 to 1.35)	0.27	-1.51 (-4.72 to 1.69)	0.36
HADS-D	-1.67 (-5.23 to 1.90)	0.36	-1.50 (-5.18 to 2.18)	0.43
DTCP (mm)				
Interval of bowel movement (days)	21.65 (20.27 to 23.02)	<0.001	20.93 (19.55 to 22.32)	<0.001
Length of time per attempt (min)	3.99 (3.49 to 4.49)	<0.001	3.74 (3.22 to 4.26)	<0.001
WCS	8.75 (8.39 to 9.12)	<0.001	8.63 (8.24 to 9.02)	<0.001
Desire to defecate	-113.96 (-128.15 to -99.76)	<0.001	-105.45 (-120.12 to -90.78)	<0.001
HADS-A	6.13 (4.27 to 7.99)	<0.001	6.13 (4.24 to 8.02)	<0.001
HADS-D	4.21 (1.89 to 6.53)	0.001	3.95 (1.55 to 6.36)	0.002

Data are presented as 95% CI. [†], adjusted model includes sex, age, height, weight and BMI. STC, slow transit constipation; TCP, transverse colon ptosis; WCS, Wexner Constipation Scale; HADS-A, Hospital Anxiety and Depression Scale subscales of Anxiety; HADS-D, Hospital Anxiety and Depression Scale subscales of Depression; HI, the vertical distance from the hepatic flexure to the right iliac crest; SI, the vertical distance from the splenic flexure to the left iliac crest; TI, the vertical distance from the lowest point of transverse colon to the L4–L5 interspace; HT, the vertical distance from the hepatic flexure to the lowest point of transverse colon; SH, the vertical distance from the splenic flexure to the hepatic flexure; DTCP, degree of transverse colon ptosis; BMI, body mass index.

Table 4 Comparisons of TCP-related indexes between conservative group and operation group

Variables	Unadjusted			Adjusted [†]	
	N	β coefficient (95% CI)	P	β coefficient (95% CI)	P
HI (mm)					
Conservative group	29	0 (reference)		0 (reference)	
Operation group	43	5.45 (-12.04 to 22.94)	0.54	7.33 (-9.93 to 24.59)	0.41
SI (mm)					
Conservative group	29	0 (reference)		0 (reference)	
Operation group	43	3.02 (-16.04 to 22.09)	0.76	7.05 (-11.43 to 25.53)	0.46
TI (mm)					
Conservative group	29	0 (reference)		0 (reference)	
Operation group	43	26.30 (4.08 to 48.53)	0.02	23.95 (1.15 to 46.74)	0.04
HT (mm)					
Conservative group	29	0 (reference)		0 (reference)	
Operation group	43	-20.85 (-45.74 to 4.03)	0.11	-16.62 (-40.83 to 7.59)	0.18
SH (mm)					
Conservative group	29	0 (reference)		0 (reference)	
Operation group	43	-2.43 (-17.29 to 12.44)	0.75	-0.27 (-15.30 to 14.76)	0.97
DTCP (mm)					
Conservative group	29	0 (reference)		0 (reference)	
Operation group	43	23.88 (2.21 to 45.54)	0.03	23.67 (1.40 to 45.94)	0.04

Data are presented as 95% CI. [†], adjusted model includes sex, age, height, weight and BMI. TCP, transverse colon ptosis; HI, the vertical distance from the hepatic flexure to the right iliac crest; SI, the vertical distance from the splenic flexure to the left iliac crest; TI, the vertical distance from the lowest point of transverse colon to the L4-L5 interspace; HT, the vertical distance from the hepatic flexure to the lowest point of transverse colon; SH, the vertical distance from the splenic flexure to the hepatic flexure; DTCP, degree of transverse colon ptosis; BMI, body mass index.

and the transverse mesocolon, respectively, is a relatively fixed part of the colon (28). Therefore, compared with patients without STC, patients with STC have higher DTCP, TI, HT and SH values, but a lower HI value. Another explanation could relate to the characteristics of colonic propulsion. In addition to high-propagating contractions (HAPCs), colonic propulsion also includes retrograde propulsion (24), which may return intestinal contents back to the transverse colon from the descending colon. Interestingly, the frequency of propulsive HAPCs was decreased or even absent in patients with STC, leading to increased fecal accumulation in the transverse colon. In turn, ptosis of transverse colon resulted in a significantly greater fecal climb distance and higher potential energy difference in the standing position, which increased the

static energy needed for fecal evacuation and further aggravated intestinal transmission function (15). Briefly, this indicates that the ptosis transverse colon may be both the result of colonic motor dysfunction and the cause of aggravated constipation.

Previous research studies that predominantly focused on the relationship between radiological parameters and severity scales had unsatisfactory results (28,29). Rao *et al.* reported a moderate correlation between barium distribution through CTT and quality of life (29), whereas similar research by Staller *et al.* revealed no such correlation (9). Overall, our data showed that the DTCP, TI and HT, which directly reflect ptosis of the transverse colon, were significantly associated with the WCS (the crucial comprehensive scale developed for severity assessment of constipation), and the

depression indices (HADS-A and HADS-D). Since ptosis of the transverse colon may be caused by gravity, colonic movement disorder, neurasthenia, and other factors (13,25), it may become more obvious over time, which is consistent with the aggravating progression of STC to some extent. In addition, HI and SH also correlated well with WCS. As previously mentioned, the ligaments in the hepatic flexure are not as strong as those in the splenic flexure (28), which may result in hepatic flexure being more susceptible to the gravity of transverse colon and secondary ptosis, and be the cause of the lower HI value. This results in a greater gravitational potential energy difference between the splenic flexure and the hepatic flexure, which is a secondary result of the TCP. Hence, individuals with lower HI or higher SH values may have more severe constipation and a higher WCS.

In the present study, we further explored the relationships between treatment methods and TCP. In our center, all patients with STC received standard treatment regimens, and only those who had failed systematic drug therapy were considered for surgical treatment. It appeared that patients with STC who underwent surgery may have more severe symptoms and poorer responses to conservative treatment. The DTCP and TI values of patients in the surgical group were significantly higher than those of patients in the conservative group, indicating that greater DTCP or TI values may indicate severe constipation.

Our study contained several limitations. First, this was a single-center retrospective study, which inevitably contains selection biases. Second, our cohort included more severe cases of constipation meaning the results may be less generalizable to the population at large. Third, the DTCP and other indices were based on a small-sample study, and large-sample clinical trials are needed to verify this system. Fourthly, the radiopaque markers used for CTT in this study were not completely uniform. Despite these limitations, our novel study preliminarily discussed the causes of TCP and the relationships between the degree of ptosis and severity of constipation. More importantly, our study revealed that the DTCP could be regarded as an alternative sensitive indicator to assess the severity of constipation and may provide a reference for the clinical diagnosis of constipation.

Conclusions

In this novel study, we systematically evaluated the relationship between TCP and STC. Overall, we found that

some TCP-related indicators show good correlation with the severity of STC. Among them, as a dependable and intuitive index that reflects the distance from the splenic flexure to the lowest point of the transverse colon, the DTCP has unique value in the auxiliary diagnosis of STC and definition of the severity of STC. Thus, we propose that the DTCP may be a novel and feasible alternative index in the assessment of constipation. However, data from a larger sample, that includes patients with and without constipation, are required to verify and optimize the value of these ptosis-related indices in the diagnosis and treatment of STC.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the medical ethics committee of Zhongnan Hospital of Wuhan University. Written informed consent was obtained from the participants.

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