

Preparation-to-Colonoscopy Interval and Bowel Cleansing Quality With Split-Dose Oral Sodium Phosphate in Chinese Adults A Prospective Two-Center Real-World Observational Study

Rongyu Zhang

Shantou University Medical College

Guiquan Chen

Dongguan People's Hospital

Zhiliang Huang

Dongguan People's Hospital Shuixiang Hospital

Yanfang Weng

Dongguan People's Hospital Shuixiang Hospital

Bingsheng Li

1606262647@qq.com

Huizhou First People's Hospital

Research Article

Keywords: sodium phosphate, bowel preparation, colonoscopy, preparation-to-colonoscopy interval, Boston Bowel Preparation Scale, real-world study

Posted Date: October 23rd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11174266/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Evidence on preparation-to-colonoscopy (PC) timing in Chinese adults receiving sodium phosphate (NaP) remains limited. We evaluated how PC interval relates to cleansing adequacy and quality under a standardized split-dose NaP regimen to inform routine scheduling.

Methods

This prospective observational study at two Chinese centers included 427 adults with PC intervals of 3–9 h and 22 with intervals > 9 h. PC was measured from second-dose completion to colonoscope insertion. The protocol-defined primary endpoint was adequate preparation (total Boston Bowel Preparation Scale [BBPS] ≥ 6 and each segment ≥ 2). Supplementary analyses examined high-quality preparation (BBPS ≥ 8), adjusted associations, and continuous curve shape.

Results

Adequacy rates were 98.6%, 97.3%, and 96.4% in the 3–5-h, > 5–7-h, and > 7–9-h groups, respectively ($P = 0.515$). Corresponding high-quality preparation rates were 85.8%, 62.8%, and 42.8% ($P < 0.001$); mean total BBPS scores were 8.39, 7.83, and 7.33. Each additional PC hour was associated with lower odds of high-quality preparation (adjusted odds ratio 0.580; 95% confidence interval 0.498–0.675). The segmented curve peaked at 3.75 h, although the search-adjusted test did not establish a stable breakpoint ($P = 0.159$). All 22 participants with PC > 9 h had adequate preparation; 40.9% had high-quality preparation.

Conclusions

Split-dose NaP maintained high adequacy across the observed intervals, including > 9 h in the extension cohort. A PC interval of 3–5 h yielded the highest cleansing quality and is the preferred scheduling window within the studied range. These real-world findings distinguish a favorable window for high-quality cleansing from a broader observed window of adequate preparation.

1 Introduction

High-quality bowel cleansing is essential for mucosal inspection and lesion detection during colonoscopy. Chinese, European, and US guidelines emphasize split-dose preparation [1–3]. Beyond achieving adequate preparation, higher Boston Bowel Preparation Scale (BBPS) scores have been associated with improved adenoma and proximal serrated lesion detection [4–6]. The 2025 US Multi-Society Task Force recommends starting the second portion of the purgative 4–6 h before colonoscopy

and completing it at least 2 h before the procedure [3]. The 2026 Korean guideline recommends colonoscopy at least 2 h and within 5 h after completion of the last preparation dose [7].

The preparation-to-colonoscopy (PC) interval is a modifiable component of the endoscopy pathway. Much of the influential timing evidence comes from studies of polyethylene glycol (PEG) conducted outside China. Seo et al. observed the best cleansing with a 3–5-h interval after split-dose PEG [8], and Kim et al. compared different PEG completion times in a randomized trial [9]. A meta-analysis by Gao and Lin associated shorter intervals with higher adequacy rates, although interval definitions varied across studies [10]. Chinese multicenter observational evidence on waiting time is also available [11]. Nevertheless, further regimen-specific evidence is needed to guide preparation timing within local clinical workflows.

Direct evidence on PC timing is less extensive for sodium phosphate (NaP) than for PEG. Kössi et al. reported an inverse association between the interval after the last oral NaP administration and cleansing quality [12]. A 2026 trial at eight Chinese centers provided local efficacy evidence for NaP powder, but primarily compared NaP with PEG rather than examining the continuous PC–quality relationship or a preferred high-quality cleansing window within a fixed NaP regimen [13]. Guidelines and these studies establish a basis for split dosing and timing management; Chinese data on actual completion-to-insertion intervals can further translate these principles into practical dosing and scheduling arrangements.

Real-world evaluation addresses two additional clinical needs. First, actual insertion times vary with routine scheduling and waiting processes, creating a need to quantify cleansing quality under everyday conditions. Second, adequate and high-quality preparation represent different levels of mucosal visibility. A binary adequacy endpoint may conceal clinically relevant differences once most patients meet the minimum standard. Joint assessment of adequacy, total and segmental BBPS, and high-quality preparation can therefore identify opportunities for quality improvement, while observations at longer intervals indicate whether adequate cleansing is retained when examinations are delayed.

We conducted a prospective real-world study at two Chinese endoscopy centers within one hospital system, using a fixed split-dose NaP regimen and timing recorded to the minute. Adequacy remained the protocol-defined primary endpoint; total and segmental BBPS were secondary endpoints. Supplementary analyses evaluated $\text{BBPS} \geq 8$, continuous PC associations, segmented curve shape, and preparation adequacy beyond 9 h. We aimed to identify a preferred interval for high-quality cleansing and provide local evidence on retained adequacy at longer intervals.

2 Methods

2.1 Study design and ethics

This prospective observational study was conducted at the endoscopy units of The Tenth Affiliated Hospital of Southern Medical University (Dongguan People's Hospital) and Dongguan People's Hospital

Shuixiang Hospital (Dongguan Waterfront Zone Central Hospital), both in Dongguan, China. PC intervals arose from routine clinical scheduling without random assignment. The study protocol was approved by the Medical Ethics Committee (Group 1) of The Tenth Affiliated Hospital of Southern Medical University (Dongguan People's Hospital) (Dongguan, China; approval number IRBITKY-2026-201-02), and the Ethics Committee of Dongguan People's Hospital Shuixiang Hospital (Dongguan Waterfront Zone Central Hospital) (Dongguan, China; approval number SX-LL-KY-2026-CS-001). The study was filed in the Medical Research Registration and Filing Information System of China's National Health Information Platform (filing number MR-44-26-073111) after study initiation. The study information was also made publicly available on the Chinese Clinical Trial Registry website through the system's synchronized disclosure process. The protocol required written informed consent. The study began on July 1, 2026, with planned completion on July 1, 2027; this analysis included data collected from July 1 through September 25, 2026.

2.2 Participants and analysis populations

Eligible participants were adults aged 18–75 years undergoing elective colonoscopy, receiving split-dose NaP in routine care, and able to provide accurate preparation and examination times. Contraindications to the preparation and suitability for colonoscopy were assessed according to the protocol. All participants underwent renal-function testing within one week before colonoscopy. Protocol withdrawal criteria included incomplete examination of the entire colon, incomplete ingestion of the second dose, and missing essential timing or BBPS data.

The two datasets contained 450 unique records: 428 with PC intervals of 3–9 h and 22 with intervals > 9 h. One participant with an incomplete colonoscopy was excluded according to the protocol, leaving 427 in the primary cohort. The 22 participants with PC > 9 h formed an extension cohort for descriptive assessment of longer intervals and were combined with the primary cohort in a full-range sensitivity analysis of 449 participants (Fig. 1).

2.3 Preparation regimen and PC interval

All participants took the first sachet of NaP powder at 20:00 on the day before colonoscopy, dissolved in 800 mL of water. The second sachet was also dissolved in 800 mL, with its timing obtained from the case records. PC was defined as the elapsed time from completion of the second dose to colonoscope insertion, calculated from full timestamps in minutes and converted to hours. Dose initiation was not substituted for completion. All 428 records within the primary interval indicated second-dose completion on the examination day. One extension record indicated completion on the preceding evening and was additionally excluded in a sensitivity analysis. The protocol-defined groups were $3 \leq \text{PC} \leq 5$ h, $5 < \text{PC} \leq 7$ h, and $7 < \text{PC} \leq 9$ h.

2.4 Outcomes and BBPS assessment

The BBPS assigns 0–3 points to each of the right, transverse, and left colon, yielding a total of 0–9 after endoscopic washing and suction [14]. Reconstructed totals matched the recorded totals in all 449

analyzed records. The protocol-defined primary endpoint was adequate preparation, requiring total BBPS ≥ 6 and every segment ≥ 2 ; total and segmental scores were secondary endpoints. High-quality preparation (total BBPS ≥ 8) and segment scores of 3 were supplementary exploratory outcomes. The ≥ 8 definition corresponds to the excellent-preparation category used in previous research [6]. Raters underwent standardized training. The accompanying agreement assessment [15] involved six physicians scoring 30 image cases comprising 90 segment units: ICC(2,1) was 0.87 (95% CI 0.82–0.91), mean quadratically weighted kappa was 0.75 (95% CI 0.70–0.80), and complete agreement on adequacy was achieved in 25/30 cases (83.3%). Five clinical endoscopist codes (A–E) were present in the primary dataset; endoscopist effects were assessed in a sensitivity model.

2.5 Statistical analysis

The protocol sample-size calculation assumed adequacy rates of 88%, 76%, and 64% across the three groups, a two-sided α of 0.05, and 80% power. The recorded target was 144 evaluable participants, increased to 180 allowing for 20% attrition. The present primary cohort included 427 evaluable participants. Continuous baseline variables are summarized as mean $\pm$ standard deviation (SD) and compared using Welch analysis of variance; categorical variables are summarized as n (%) and compared using Pearson's chi-square or Fisher–Freeman–Halton exact tests. The primary endpoint was compared using an exact test. With only 11 inadequate preparations, the planned conventional multivariable adequacy model was not fitted to avoid unstable estimates. BBPS scores were compared using Kruskal–Wallis tests. Tests were two-sided with $\alpha = 0.05$; supplementary models, interactions, and covariate findings were interpreted using exploratory nominal P values.

Supplementary maximum-likelihood logistic regression related high-quality preparation to continuous PC, adjusting for center, age, sex, body mass index (BMI), examination type, smoking, constipation, and diabetes. Adjusted odds ratios (aORs) and 95% confidence intervals (CIs) are reported. This endpoint and expanded adjustment set were supplementary to the protocol-defined primary analysis. Required covariates were complete, and no imputation was performed. A likelihood-ratio test assessed effect modification by center using a PC-by-center interaction.

Restricted cubic spline (RCS) models used three knots at the 10th, 50th, and 90th PC percentiles or four knots at the 10th, 35th, 65th, and 90th percentiles, with the same covariates. Likelihood-ratio tests compared spline and linear-PC models to assess nonlinearity. Predicted probabilities were marginally standardized over the primary cohort's covariate distribution, with pointwise 95% CIs calculated using the delta method.

Exploratory segmented linear regression modeled total BBPS using linear PC, a hinge term, and the same adjustment set. Candidate join points were searched from 3.05 to 8.95 h in 0.05-h increments, requiring at least 10% of observations on each side; the location minimizing residual sum of squares was selected. The search was repeated in 1,000 participant-level nonparametric bootstrap samples to estimate percentile 95% CIs for location and slopes. A search-adjusted maximum-F test used 1,999 Rademacher wild-bootstrap samples with HC2-adjusted residuals under the single-line null model,

repeating the entire search. Akaike information criterion (AIC) calculations counted the estimated join point as an additional parameter. A positive-to-negative fitted slope change was described as a sample-specific fitted peak; evidence for a stable breakpoint was assessed separately through the search-adjusted test and resampling.

A supportive logistic model used a segment BBPS score of 3 as the binary outcome in participant-by-segment data. The model included PC, colonic segment, their interactions, and the same covariates, with participant-clustered robust standard errors. A two-degree-of-freedom Wald test assessed the overall PC-by-segment interaction. Segment-specific ORs per additional PC hour are reported.

Sensitivity analyses included extension participants with PC > 9 h; additional adjustment for afternoon examination; additional adjustment for stool frequency and final stool appearance; replacement of center with endoscopist fixed effects; and exclusion of the overnight second-dose record from the full-range cohort. Because endoscopists were nested within centers, complete endoscopist indicators and center were not entered together. Preparation-process variables were used to assess robustness to additional adjustment. Analyses used Python 3.12, NumPy, and SciPy, with random seed 20260926.

3 Results

3.1 Participant characteristics

The primary cohort comprised 427 adults, with mean age 49.25 ± 12.39 years and BMI 23.89 ± 3.49 kg/m²; 215 (50.4%) were women. The main and Shuixiang centers contributed 262 (61.4%) and 165 (38.6%) participants, respectively. Sedated colonoscopy was performed in 392 (91.8%). Constipation and diabetes were recorded in 43 (10.1%) and 24 (5.6%). Center distribution, sedation, and afternoon examination differed across groups. Afternoon examinations increased from 2.1% in the 3–5-h group to 89.9% in the >7–9-h group, demonstrating the close relationship between PC and examination session (Table 1). Preparation-process variables, including stool frequency, the last-drink-to-insertion interval and final stool appearance, are summarized in Table S5 in the Supplementary material.

Table 1. Baseline characteristics by PC interval in the primary cohort

Variable	Overall N=427	3–5 h n=141	>5–7 h n=148	>7–9 h n=138	P value
PC interval (h)	5.96±1.62	4.07±0.56	6.02±0.57	7.83±0.57	—
Age (years)	49.25±12.39	49.96±13.20	47.36±12.60	50.56±11.07	0.061
BMI (kg/m ²)	23.89±3.49	23.61±3.37	23.72±3.52	24.34±3.54	0.173
Women	215 (50.4)	74 (52.5)	70 (47.3)	71 (51.4)	0.646
Main center	262 (61.4)	74 (52.5)	100 (67.6)	88 (63.8)	0.024
Sedated colonoscopy	392 (91.8)	120 (85.1)	136 (91.9)	136 (98.6)	<0.001
Smoking	62 (14.5)	19 (13.5)	20 (13.5)	23 (16.7)	0.685
Constipation	43 (10.1)	16 (11.3)	14 (9.5)	13 (9.4)	0.827
Diabetes	24 (5.6)	6 (4.3)	5 (3.4)	13 (9.4)	0.059
Afternoon examination (≥12:00)	172 (40.3)	3 (2.1)	45 (30.4)	124 (89.9)	<0.001

Values are mean ± SD or n (%). PC defines the groups and was not tested. Age and BMI were compared using Welch analysis of variance; categorical variables were compared using Pearson's chi-square test. BMI, body mass index; PC, preparation-to-colonoscopy.

3.2 Preparation adequacy and cleansing quality

Adequate preparation, the protocol-defined primary endpoint, occurred in 98.6% (139/141), 97.3% (144/148), and 96.4% (133/138) of the 3–5-h, >5–7-h, and >7–9-h groups, respectively. Overall adequacy was 97.4% (416/427), with no significant difference across groups (exact P=0.515). Supplementary high-quality preparation rates were 85.8% (121/141), 62.8% (93/148), and 42.8% (59/138), respectively (overall P<0.001; Table 2 and Figure 2).

Mean total BBPS scores were 8.39±0.81, 7.83±1.10, and 7.33±0.94 across the three groups (Kruskal–Wallis P<0.001). Mean right-colon scores were 2.57±0.52, 2.37±0.54, and 2.12±0.41, and the proportions with a right-colon score of 3 were 58.9%, 39.9%, and 15.2%. Overall comparisons for each colonic segment yielded P<0.001 (Table 2 and Figure 3).

Table 2. Bowel cleansing outcomes by PC interval

Outcome	Overall N=427	3–5 h n=141	>5–7 h n=148	>7–9 h n=138	P value
Adequate (total ≥ 6 ; each segment ≥ 2)	416 (97.4)	139 (98.6)	144 (97.3)	133 (96.4)	0.515
High quality (total BBPS ≥ 8)	273 (63.9)	121 (85.8)	93 (62.8)	59 (42.8)	<0.001
Total BBPS	7.85 $\pm$ 1.05	8.39 $\pm$ 0.81	7.83 $\pm$ 1.10	7.33 $\pm$ 0.94	<0.001
Right-colon BBPS	2.36 $\pm$ 0.53	2.57 $\pm$ 0.52	2.37 $\pm$ 0.54	2.12 $\pm$ 0.41	<0.001
Transverse-colon BBPS	2.76 $\pm$ 0.44	2.90 $\pm$ 0.30	2.77 $\pm$ 0.44	2.59 $\pm$ 0.49	<0.001
Left-colon BBPS	2.74 $\pm$ 0.45	2.91 $\pm$ 0.28	2.69 $\pm$ 0.48	2.61 $\pm$ 0.50	<0.001
Right-colon score 3	163 (38.2)	83 (58.9)	59 (39.9)	21 (15.2)	<0.001
Transverse-colon score 3	324 (75.9)	127 (90.1)	115 (77.7)	82 (59.4)	<0.001
Left-colon score 3	317 (74.2)	129 (91.5)	103 (69.6)	85 (61.6)	<0.001

3.3 Adjusted associations with high-quality preparation

After adjustment for center, age, sex, BMI, examination type, smoking, constipation, and diabetes, each additional PC hour was associated with lower odds of high-quality preparation (aOR 0.580; 95% CI 0.498–0.675; $P<0.001$). This corresponds to approximately 42% lower odds per hour, rather than a 42-percentage-point reduction in the preparation rate.

Women had higher odds of high-quality preparation than men (aOR 2.225; 95% CI 1.386–3.571; $P<0.001$). The aOR for BMI was 0.965 (95% CI 0.907–1.028; $P=0.273$). Other covariate estimates are shown in Table 3; sensitivity estimates are shown in Figure 4.

Table 3. Exploratory multivariable logistic regression for high-quality preparation (n=427)

Variable	β	SE	aOR	95% CI	P value
PC (per hour)	-0.545	0.078	0.580	0.498–0.675	<0.001
Main vs Shuixiang	-0.072	0.233	0.931	0.589–1.470	0.759
Age (per year)	-0.006	0.009	0.994	0.976–1.013	0.517
Female vs male	0.800	0.242	2.225	1.386–3.571	<0.001
BMI (per kg/m ²)	-0.035	0.032	0.965	0.907–1.028	0.273
Sedated vs unsedated	-0.039	0.441	0.962	0.405–2.283	0.929
Smoker vs nonsmoker	-0.017	0.328	0.983	0.518–1.869	0.959
Constipation, yes vs no	-0.338	0.368	0.713	0.347–1.465	0.357
Diabetes, yes vs no	-0.355	0.491	0.701	0.268–1.836	0.470

3.4 Continuous associations and segmented fit

The three-knot RCS locations were 3.717, 6.000, and 8.133 h (nonlinearity likelihood-ratio statistic 0.00005; df=1; P=0.994). Four-knot locations were 3.717, 5.102, 6.915, and 8.133 h (statistic 0.641; df=2; P=0.726). Neither model showed significant nonlinearity on the log-odds scale, supporting a linear-PC term as a summary of the observed association (Figure 5; Table S3).

The exploratory segmented curve reached its fitted maximum at approximately 3.75 h and declined thereafter. The bootstrap 95% CI for the selected join-point location was 3.65–8.10 h, with a median of 4.20 h. Slopes before and after the fitted peak were 0.491 and –0.290 BBPS points/h, respectively. The bootstrap interval for the slope change included zero, and the search-adjusted wild-bootstrap maximum-F test yielded P=0.159. R² increased from 0.244 to 0.251, whereas AIC changed from 1152.95 to 1153.06 after accounting for the estimated location, providing no clear advantage for the segmented model (Table 4 and Figure 6).

Table 4. Exploratory segmented regression of total BBPS

Measure	Estimate
Fitted peak location	3.75 h (95% CI 3.65–8.10)
Slope before peak	0.491 points/h (95% CI -0.354–1.269)
Slope after peak	-0.290 points/h (95% CI -0.373–0.305)
Slope change	-0.781 points/h (95% CI -1.568–0.599)
Search-adjusted test	Wild-bootstrap maximum-F test P=0.159
R ² (linear / segmented)	0.244 / 0.251
AIC (linear / segmented)	1152.95 / 1153.06
Resampling counts	Nonparametric bootstrap: 1,000; wild bootstrap: 1,999

The fitted peak of 3.75 h falls within the 3–5-h interval with the best observed cleansing quality. Clinical scheduling is therefore informed by the observed interval; the precision of the fitted location and slope change is reported in Table 4.

3.5 Segmental cleansing

The participant-by-segment model contained 1,281 observations from 427 participants. ORs per additional PC hour for a segment score of 3 were 0.682 (95% CI 0.586–0.794) for the left colon, 0.604 (95% CI 0.508–0.718) for the transverse colon, and 0.575 (95% CI 0.497–0.664) for the right colon (all $P<0.001$). The overall PC-by-segment interaction was not statistically significant ($P=0.183$; Table S2 and Figure S4).

The proportion with a right-colon score of 3 decreased from 58.9% in the 3–5-h group to 15.2% in the >7–9-h group. The right colon had the lowest segment-specific hourly OR point estimate, indicating a marked reduction in complete right-colon cleansing at longer observed intervals.

3.6 Extension cohort and sensitivity analyses

All 22 participants with PC >9 h achieved adequate preparation (100.0%); nine (40.9%) achieved high-quality preparation. Mean total and right-colon BBPS scores were 7.32 ± 0.89 and 2.09 ± 0.29 , respectively, and two participants (9.1%) had a right-colon score of 3. All were from the main center and underwent sedated colonoscopy. Mean total BBPS was similar to that in the >7–9-h group, demonstrating retained adequate cleansing beyond 9 h in this observed extension cohort (Figure S1).

In the full-range cohort, 282/449 participants (62.8%) had high-quality preparation, and the aOR per additional PC hour was 0.663 (95% CI 0.586–0.751; $P<0.001$). The inverse association persisted after additional adjustment for afternoon examination or preparation-process variables and after replacing center with endoscopist fixed effects (Table 5). Excluding the overnight second-dose record yielded an

aOR of 0.649 (95% CI 0.572–0.737; n=448). The exploratory center interaction was nominally significant (P=0.037); center-specific ORs were 0.461 at Shuixiang and 0.643 at the main center, with consistent directions but potentially different magnitudes (Table S1 and Figure S3).

Table 5. Sensitivity analyses and center-specific associations for PC interval

Analysis	n	High quality, n (%)	PC aOR (95% CI)	P value
Primary cohort	427	273 (63.9)	0.580 (0.498–0.675)	<0.001
Include PC >9 h	449	282 (62.8)	0.663 (0.586–0.751)	<0.001
Add afternoon examination	427	273 (63.9)	0.598 (0.483–0.740)	<0.001
Add stool frequency and appearance	427	273 (63.9)	0.599 (0.512–0.700)	<0.001
Endoscopist replaces center	427	273 (63.9)	0.580 (0.498–0.675)	<0.001
Full range, excluding overnight dose	448	281 (62.7)	0.649 (0.572–0.737)	<0.001
Shuixiang center	165	111 (67.3)	0.461 (0.351–0.606)	<0.001
Main center	262	162 (61.8)	0.643 (0.529–0.781)	<0.001

4 Discussion

4.1 Principal findings and clinical relevance

In this prospective real-world study of a fixed split-dose NaP regimen, overall preparation adequacy was 97.4%, without a significant difference across the three protocol-defined PC groups. Cleansing quality was highest at 3–5 h: mean BBPS was 8.39 and high-quality preparation occurred in 85.8%. Each additional PC hour was associated with approximately 42% lower adjusted odds of high-quality preparation, with consistent directions across sensitivity analyses. All 22 extension participants with PC > 9 h also met the adequacy standard. These findings identify complementary clinical features: adequate cleansing was maintained over a broad observed range, while scheduling within 3–5 h favored higher-quality cleansing.

Adequate and high-quality preparation reflect different degrees of mucosal visibility. A segment BBPS score of 2 permits small amounts of residual staining, stool fragments, or opaque fluid, whereas a score of 3 indicates more complete visualization [14]. Higher scores can therefore remain clinically relevant even when adequacy is common. In a post hoc pooled analysis of 1,749 participants from three randomized trials, Hassan et al. reported adenoma detection rates of 43% versus 26% for total BBPS scores of 9 versus 6 (P < 0.001), and right-colon adenoma detection rates of 15% versus 11% for segment scores of 3 versus 2 (P = 0.033) [4]. In 4,940 colonoscopies, Guo et al. likewise found higher segment-level adenoma detection with scores of 3 than 2 (10.8% versus 7.7%) [5].

Evidence is particularly relevant to proximal serrated lesions. Among 1,069 fecal immunochemical test-positive screening participants, Fantasia et al. found higher proximal serrated polyp detection with BBPS 8–9 than 6–7 (13.7% versus 7.9%), as well as higher sessile serrated lesion detection (7.6% versus 4.0%) [6]. Clark and Laine also identified a greater cleansing requirement for sessile serrated polyp detection [16]. Thus, the higher frequency of BBPS ≥ 8 at 3–5 h has a clinically meaningful interpretation: more favorable mucosal inspection conditions, particularly for subtle proximal lesions.

Although differences in overall adenoma detection between excellent and good preparation vary across studies [6, 17], the literature supports pursuing high-quality cleansing, especially for proximal serrated lesions. Our cleansing outcomes contribute to this goal by identifying a practical timing window associated with better visualization.

4.2 Guideline context and contribution to existing evidence

Guideline recommendations on standardized scoring, split dosing, and shorter post-preparation waiting times provide the clinical foundation for this NaP study [1–3]. Direct NaP evidence is included in the split-dose literature. In the meta-analysis of 47 randomized trials by Martel et al., the analyzable NaP subgroup comprised four trials and 1,018 participants; split dosing improved cleansing compared with day-before administration (OR 9.34; 95% CI 2.12–41.11) [18]. This evidence was incorporated into the ESGE guideline [2]. Accordingly, general split-dose and timing principles can guide NaP preparation, alongside product-specific instructions for dosing, hydration, and patient selection.

Timing associations are consistent across several regimens. Seo et al. observed the best overall and segmental cleansing at 3–5 h in 366 split-dose PEG recipients [8]. Across 20 studies and 10,341 participants, Gao and Lin reported pooled adequacy rates of 94% at shorter intervals and 84% at longer intervals [10]. Ioannou et al. also associated longer second-dose-completion-to-examination intervals with poorer BBPS in 435 recipients of split-dose sulfate salts [19]. Together with the present findings, these studies support avoiding unnecessary waiting after preparation to preserve cleansing quality.

The NaP timing findings of Kössi et al. [12], Chinese waiting-time research [11], and the recent Chinese NaP-versus-PEG trial [13] establish important precedents. Our study adds an assessment of actual timing within one fixed NaP regimen, rather than a comparison between agents. With a first dose at 20:00 and 800 mL of water per sachet, we quantified cleansing gradients among 427 adults with PC 3–9 h and described 22 additional adults with longer intervals. This provides local information on when higher-quality cleansing is most likely and whether adequacy is retained after a longer wait—questions not fully answered by agent comparisons or adequacy rates alone.

The product information specifies administration at least 3 h before examination [20]. We evaluated the protocol-defined 3–9-h range using a consistent interval from second-dose completion to insertion, enabling interpretation in the context of this clinical workflow.

4.3 Preferred interval and fitted peak

The favorable 3–5-h interval aligns with Seo et al.'s findings and the Korean recommendation for examination 2–5 h after preparation completion [7, 8]. Timing definitions remain important: ESGE recommends starting the last dose within 5 h before colonoscopy and completing it at least 2 h beforehand, whereas the US Multi-Society Task Force recommends starting the second portion 4–6 h before the procedure and completing it at least 2 h beforehand [2, 3]. Our PC interval begins at dose completion. Within the studied regimen and administration context [20], 3–5 h is the preferred scheduling window. The fitted peak at 3.75 h lies within this interval; its broad location interval and search-adjusted $P = 0.159$ support using the observed window rather than a minute-specific threshold.

4.4 Right-colon cleansing and waiting time

Previous clinical studies and physiological explanations support deterioration in proximal cleansing with longer waits. In a randomized study of PEG and NaP timing, Parra-Blanco et al. found particularly poor proximal cleansing when all preparation was completed the day before colonoscopy. They proposed that small-bowel contents and continuing gastrointestinal and biliary secretions reaccumulate after cleansing and first affect the right colon [21]. A subsequent review described ongoing gastrointestinal secretion as an explanation for worsening cleansing after delays [22]. The 2025 US Multi-Society Task Force similarly notes that the second dose removes chyme entering the colon overnight after the first dose [3]. These observations support split dosing and reasonably short waiting times to maintain proximal cleanliness.

In the 504-participant randomized trial by Kim et al., right- and transverse-colon BBPS scores were higher when colonoscopy occurred 2–4 h rather than 4–8 h after preparation completion [9]. This provides further evidence for avoiding unnecessary delays. Although BBPS is assessed after endoscopic washing and suction [14], optimizing PC helps maintain a favorable cleansing state at insertion.

In our cohort, the right-colon full-score proportion decreased from 58.9% to 15.2% across increasing PC groups, consistent with prior observations of poorer proximal cleansing after longer waits. Given the relationship between cleansing quality and proximal lesion detection, the right colon deserves particular attention in preparation timing [4, 6, 16].

4.5 Sex and preparation-related factors

Women had higher adjusted odds of high-quality preparation than men (aOR 2.225; 95% CI 1.386–3.571), consistent with previous associations between male sex and inadequate preparation. In a prospective Chinese outpatient study, Yin et al. identified male sex as an independent correlate of inadequate preparation (OR 1.690; 95% CI 1.242–2.300) [23]. Our findings extend this observation to the higher BBPS ≥ 8 standard under split-dose NaP.

Previous studies and reviews identify constipation, diabetes, medications affecting gastrointestinal motility, diet, and adherence as contributors to preparation quality [23, 24]. Sex-related differences may involve several of these factors. The association with female sex persisted after adjustment for constipation, diabetes, and other recorded covariates.

The direction of the PC association also persisted after adjustment for stool frequency and final stool appearance. More detailed information on diet, additional fluid intake, and adherence could help refine preparation pathways for different patient groups.

4.6 Adequacy ceiling and assessment of quality

Adequacy exceeded 96% in all three groups, leaving limited separation on this binary endpoint. Differences were more evident in total BBPS and high-quality preparation. Kim et al. reported a similar pattern: adequacy exceeded 95% in both interval groups, while the shorter-interval group more frequently achieved BBPS 9 (56.5% versus 39.8%) [9]. Reporting total scores, high-quality preparation, and segment scores of 3 therefore captures differences that an adequate/inadequate classification may miss.

Maintaining adequate preparation is fundamental to avoiding early repeat examinations caused by inadequate cleansing [25–27]. Achieving a higher cleansing standard can further improve mucosal inspection conditions. The practical implication of our study is to preserve the high adequacy rate while preferentially scheduling examinations at 3–5 h to obtain better cleansing quality.

4.7 Retained adequacy beyond 9 h

All 22 extension participants with PC > 9 h achieved adequate preparation, with mean total BBPS 7.32 ± 0.89 . Thus, effective cleansing was retained beyond 9 h in the patients observed under this split-dose NaP regimen. Together with adequacy above 96% across the 3–9-h groups, these findings support maintained adequacy over a relatively broad observed interval and provide real-world information relevant to examination delays.

High-quality preparation occurred in 40.9% of the > 9-h cohort compared with 85.8% at 3–5 h. Adequate cleansing at longer intervals and a quality advantage at earlier examination can therefore coexist. These findings address complementary scheduling needs: flexibility when delays occur and selection of a preferred interval when optimizing quality.

4.8 Implications for routine clinical scheduling

This study translates general guideline timing principles into regimen-specific information for Chinese endoscopy practice. Despite consistently high adequacy, high-quality preparation decreased from 85.8% at 3–5 h to 42.8% at > 7–9 h. An adequacy-only assessment could therefore overlook room for improvement. For patients following the same regimen, second-dose completion can be coordinated with the planned insertion time to preferentially achieve a 3–5-h PC interval. Recording actual times to the minute can help endoscopy units assess how closely preparation instructions and examination schedules align.

The retained adequacy in the > 9-h extension cohort adds information on performance when the actual wait is longer. Routine scheduling can target the favorable window, while delayed examinations can be assessed in light of the patient's actual preparation. Real-world observation thus complements

controlled regimen studies by addressing both preferred timing for high-quality cleansing and retained adequacy under routine scheduling variation.

4.9 Strengths and limitations

Strengths include two centers, a fixed split-dose regimen, minute-level timing, and assessment of adequacy, high-quality preparation, and segmental cleanliness. The consistent regimen reduced variation between preparation protocols, while naturally occurring PC differences reflected routine care. Adjustment included relevant comorbidities, with continuous models and sensitivity analyses assessing consistency. The BBPS is validated [14], and the training ICC of 0.87 supported scoring reliability.

The main limitations concern effect estimation and generalizability. First, PC arose from scheduling and was closely associated with examination session; detailed diet, additional fluid intake, long-term medication use, and adherence data were limited, leaving potential residual confounding. Second, only 11 inadequate preparations limited multivariable estimation of inadequacy risk. Third, $\text{BBPS} \geq 8$ and continuous curve analyses were supplementary and exploratory, and the precise fitted location requires independent evaluation. Finally, both centers belonged to one hospital system and only 22 participants had $\text{PC} > 9$ h; larger, more diverse cohorts are needed to estimate longer-interval adequacy and the maximum duration over which it is maintained.

5 Conclusions

Split-dose NaP maintained high adequacy across PC groups within 3–9 h, without a significant between-group difference. Cleansing quality was highest at 3–5 h, and each additional hour was associated with approximately 42% lower adjusted odds of $\text{BBPS} \geq 8$. All 22 participants observed beyond 9 h retained adequate preparation. These Chinese real-world findings support 3–5 h as the preferred scheduling window within the studied range, alongside a broader observed window of adequate cleansing.

Abbreviations

aOR adjusted odds ratio; BBPS Boston Bowel Preparation Scale; BMI body mass index; CI confidence interval; ESGE European Society of Gastrointestinal Endoscopy; ICC intraclass correlation coefficient; NaP sodium phosphate; OR odds ratio; PC preparation-to-colonoscopy; PEG polyethylene glycol; RCS restricted cubic spline; SD standard deviation.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Medical Ethics Committee (Group 1) of The Tenth Affiliated Hospital of Southern Medical University (Dongguan People's Hospital) (Dongguan, China; approval

number IRBIITKY-2026-201-02), and the Ethics Committee of Dongguan People's Hospital Shuixiang Hospital (Dongguan Waterfront Zone Central Hospital) (Dongguan, China; approval number SX-LL-KY-2026-CS-001). The study was filed in the Medical Research Registration and Filing Information System of China's National Health Information Platform (filing number MR-44-26-073111) after study initiation. The study information was also made publicly available on the Chinese Clinical Trial Registry website through the system's synchronized disclosure process. Written informed consent was obtained from all participants. The study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

The authors received no specific funding for this work.

Authors' contributions

Rongyu Zhang conceived and designed the study, analysed the data and drafted the manuscript. Guiquan Chen, Zhiliang Huang and Yanfang Weng contributed to participant recruitment and data collection. Bingsheng Li supervised the study and critically revised the manuscript. All authors read and approved the final manuscript.

Acknowledgements

Not applicable.

References

1. Digestive Endoscopy Committee, Chinese Endoscopist Association; Cancer Endoscopy Committee, China Anti-Cancer Association. Chinese guideline for bowel preparation for digestive endoscopy (2019, Shanghai). *Zhonghua Nei Ke Za Zhi*. 2019;58(7):485–495. doi:10.3760/cma.j.issn.0578-1426.2019.07.002. In Chinese.
2. Hassan C, East J, Radaelli F, et al. Bowel preparation for colonoscopy: European Society of Gastrointestinal Endoscopy (ESGE) Guideline - Update 2019. *Endoscopy*. 2019;51(8):775-794.

doi:10.1055/a-0959-0505.

3. Jacobson BC, Anderson JC, Burke CA, et al. Optimizing bowel preparation quality for colonoscopy: consensus recommendations by the US Multi-Society Task Force on Colorectal Cancer. *Gastrointest Endosc.* 2025;101(4):702-732. doi:10.1016/j.gie.2025.02.010.
4. Hassan C, Manning J, Álvarez González MA, et al. Improved detection of colorectal adenomas by high-quality colon cleansing. *Endosc Int Open.* 2020;8(7):E928-E937. doi:10.1055/a-1167-1359.
5. Guo R, Wang YJ, Liu M, et al. The effect of quality of segmental bowel preparation on adenoma detection rate. *BMC Gastroenterol.* 2019;19:119. doi:10.1186/s12876-019-1019-8.
6. Fantasia S, Kayali S, Cortegoso Valdivia P, et al. Superiority of excellent over good bowel preparation for proximal serrated polyp detection in a fecal immunochemical test-based screening cohort. *Gastrointest Endosc.* 2026;104(1):69-76.e3. doi:10.1016/j.gie.2025.11.033.
7. Kim JH, Nam SJ, Lee BJ, et al. Korean clinical practice guidelines for bowel preparation before colonoscopy. *Clin Endosc.* 2026;59(4):529-556. doi:10.5946/ce.2026.053.
8. Seo EH, Kim TO, Park MJ, et al. Optimal preparation-to-colonoscopy interval in split-dose PEG bowel preparation determines satisfactory bowel preparation quality: an observational prospective study. *Gastrointest Endosc.* 2012;75(3):583-590. doi:10.1016/j.gie.2011.09.029.
9. Kim HM, Kim HS, An YE, et al. Effect of bowel preparation completion time on bowel cleansing efficacy: prospective randomized controlled trial of different bowel preparation completion times precolonoscopy. *Dig Endosc.* 2024;36(12):1347-1354. doi:10.1111/den.14830.
10. Gao Y, Lin XJ. Effect of bowel preparation to colonoscopy interval on preparation quality and colonoscopy outcomes: a meta-analysis. *Turk J Gastroenterol.* 2023;34(1):26-34. doi:10.5152/tjg.2022.22033.
11. Yang WB, Li H, He LP. An observational multicenter study on the relationship between preparation-to-colonoscopy interval and the intestinal preparation quality. *Chin J Nurs.* 2020;55(10):1452–1457. doi:10.3761/j.issn.0254-1769.2020.10.002. In Chinese.
12. Kössi J, Krekelä I, Patrikainen H, et al. The cleansing result of oral sodium phosphate is inversely correlated with time between the last administration and colonoscopy. *Tech Coloproctol.* 2007;11(1):51-54. doi:10.1007/s10151-007-0325-2.
13. Yan P, Zhou Z, Ni M, et al. Efficacy and safety of sodium phosphate powder for bowel cleansing in patients aged 50–70 years: a randomised, multicentre, single-blind trial. *BMC Gastroenterol.* 2026;26:366. doi:10.1186/s12876-026-04864-9.
14. Lai EJ, Calderwood AH, Doros G, et al. The Boston bowel preparation scale: a valid and reliable instrument for colonoscopy-oriented research. *Gastrointest Endosc.* 2009;69(3 Pt 2):620-625. doi:10.1016/j.gie.2008.05.057.
15. Study team. BBPS scoring training materials and agreement assessment report. Unpublished internal study document; undated.
16. Clark BT, Laine L. High-quality bowel preparation is required for detection of sessile serrated polyps. *Clin Gastroenterol Hepatol.* 2016;14(8):1155-1162. doi:10.1016/j.cgh.2016.03.044.

17. Li Y, Meng F, Cao R, et al. Excellent bowel preparation quality is not superior to good bowel preparation quality for improving adenoma/polyp detection rate. *Clin Med Insights Oncol*. 2024;18:11795549241229190. doi:10.1177/11795549241229190.
18. Martel M, Barkun AN, Menard C, et al. Split-dose preparations are superior to day-before bowel cleansing regimens: a meta-analysis. *Gastroenterology*. 2015;149(1):79-88. doi:10.1053/j.gastro.2015.04.004.
19. Ioannou A, Axiaris G, Baxevanis P, et al. Evaluation of parameters influencing the quality of colon preparation with a split-dose regimen of sulfate salts. *Ann Gastroenterol*. 2024;37(2):172-178. doi:10.20524/aog.2024.0868.
20. Sichuan Jianneng Pharmaceutical Co., Ltd. Sodium phosphate powder: prescribing information. Chinese drug approval number H20213838. Approved November 3, 2021. In Chinese.
21. Parra-Blanco A, Nicolás-Pérez D, Gimeno-García A, et al. The timing of bowel preparation before colonoscopy determines the quality of cleansing, and is a significant factor contributing to the detection of flat lesions: a randomized study. *World J Gastroenterol*. 2006;12(38):6161-6166. doi:10.3748/wjg.v12.i38.6161.
22. Parra-Blanco A, Ruiz A, Alvarez-Lobos M, et al. Achieving the best bowel preparation for colonoscopy. *World J Gastroenterol*. 2014;20(47):17709-17726. doi:10.3748/wjg.v20.i47.17709.
23. Yin H, Wang Y, Wang H, et al. Derivation and validation of a prediction model for inadequate bowel preparation in Chinese outpatients. *Sci Rep*. 2025;15(1):1430. doi:10.1038/s41598-025-85816-3.
24. Hernández G, Gimeno-García AZ, Quintero E. Strategies to improve inadequate bowel preparation for colonoscopy. *Front Med*. 2019;6:245. doi:10.3389/fmed.2019.00245.
25. Clark BT, Rustagi T, Laine L. What level of bowel prep quality requires early repeat colonoscopy: systematic review and meta-analysis of the impact of preparation quality on adenoma detection rate. *Am J Gastroenterol*. 2014;109(11):1714-1723. doi:10.1038/ajg.2014.232.
26. Chokshi RV, Hovis CE, Hollander T, et al. Prevalence of missed adenomas in patients with inadequate bowel preparation on screening colonoscopy. *Gastrointest Endosc*. 2012;75(6):1197-1203. doi:10.1016/j.gie.2012.01.005.
27. Saltzman JR, Cash BD, Pasha SF, et al. Bowel preparation before colonoscopy. *Gastrointest Endosc*. 2015;81(4):781-794. doi:10.1016/j.gie.2014.09.048.

Figures

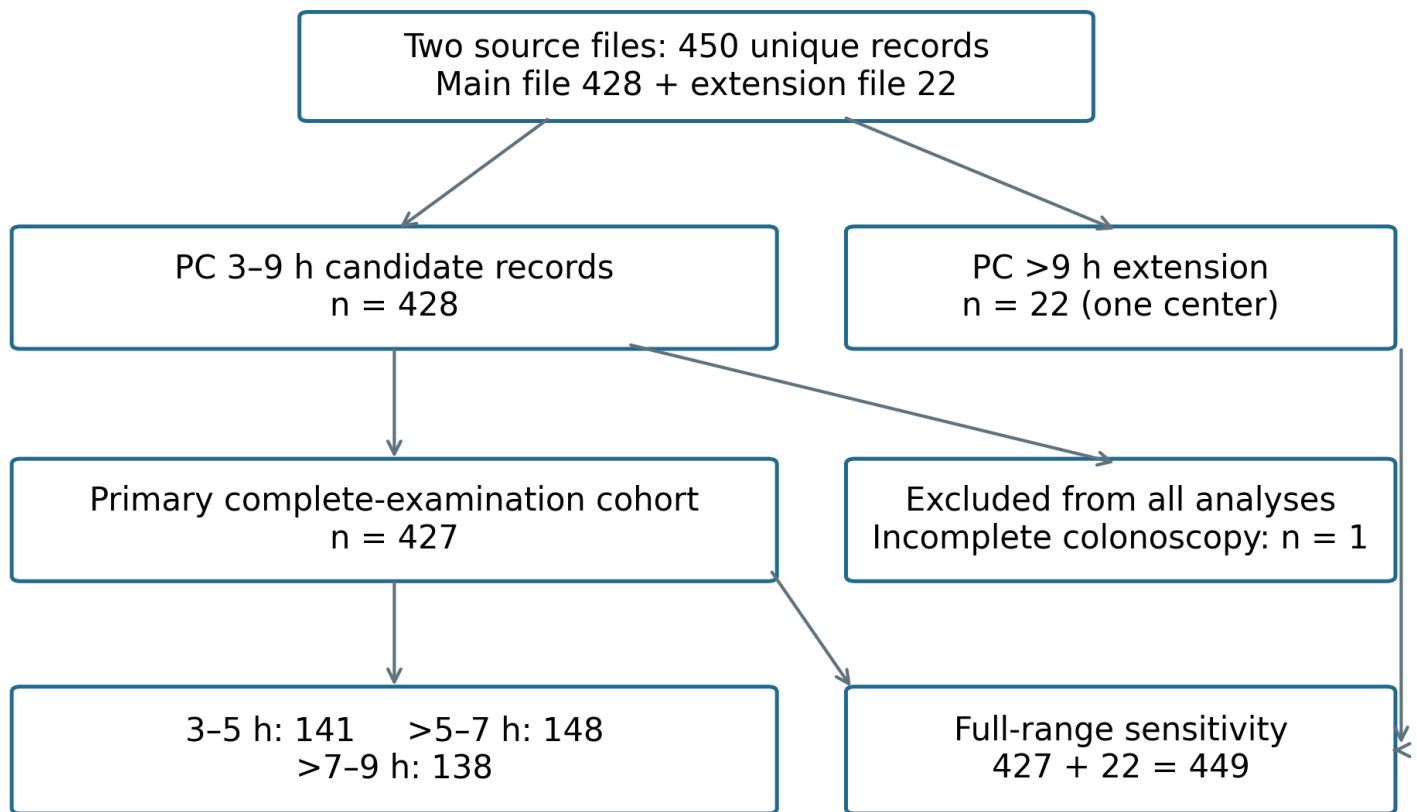


Figure 1

Participant flow and analysis populations. One incomplete colonoscopy was excluded from all analyses. The primary cohort contained 427 participants, and the full-range sensitivity cohort included an additional 22 participants with PC >9 h.

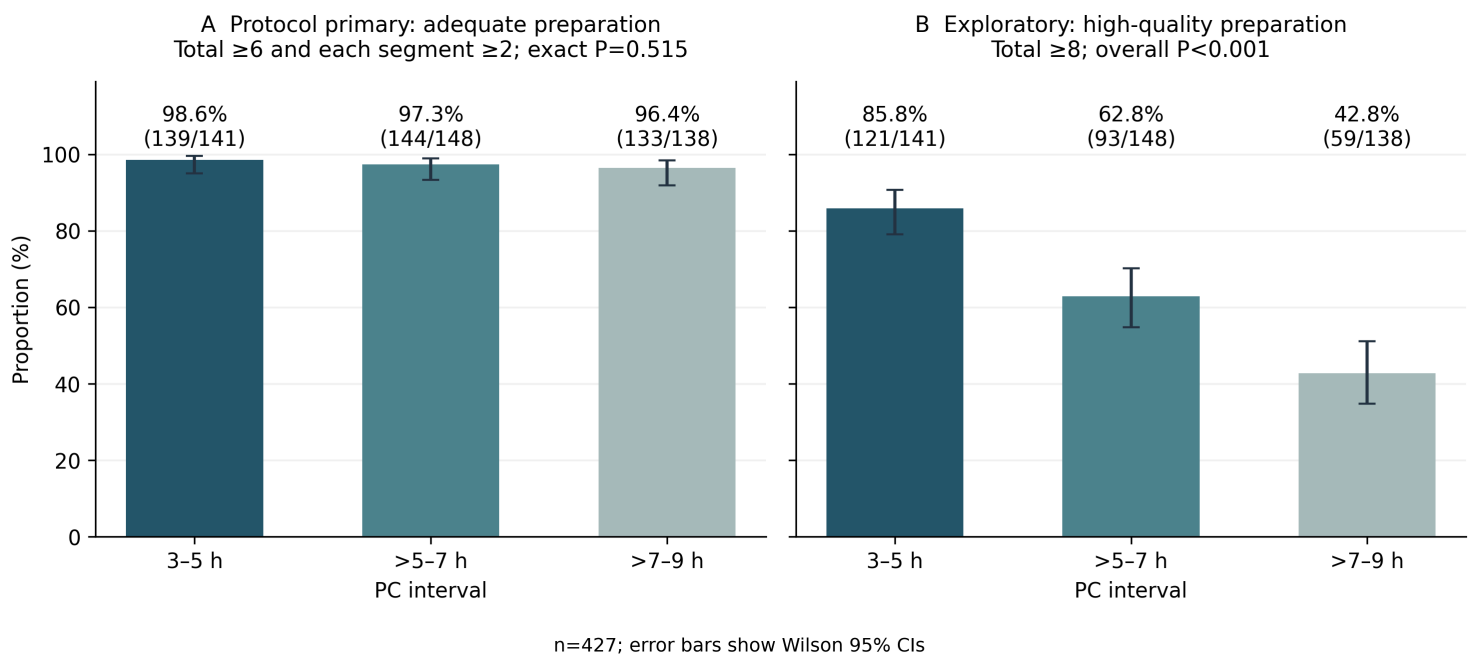


Figure 2

Preparation adequacy and high-quality cleansing by PC interval. A: protocol-defined adequacy (total BBPS ≥ 6 and every segment ≥ 2 ; exact $P=0.515$). B: supplementary high-quality preparation (total BBPS ≥ 8 ; overall $P<0.001$). Error bars indicate Wilson 95% CIs.

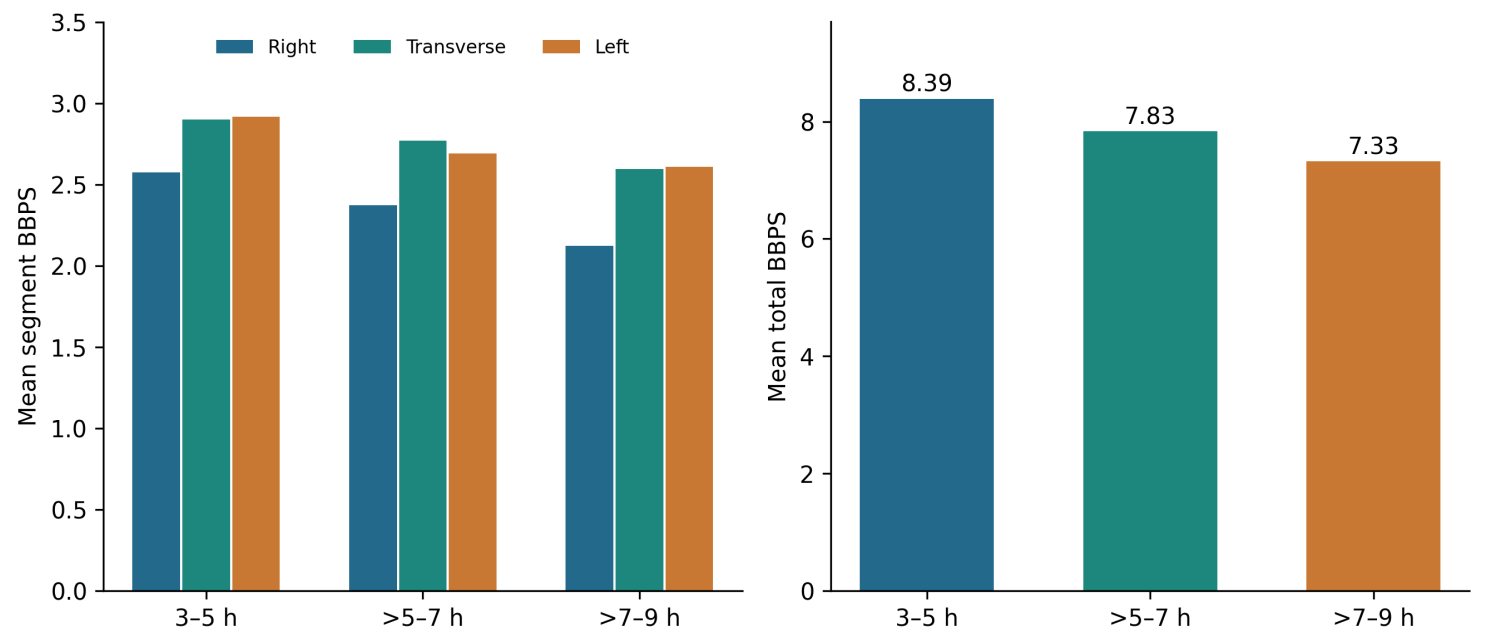


Figure 3

Mean segmental and total BBPS scores by PC interval. Segment scores range from 0 to 3; total scores range from 0 to 9.

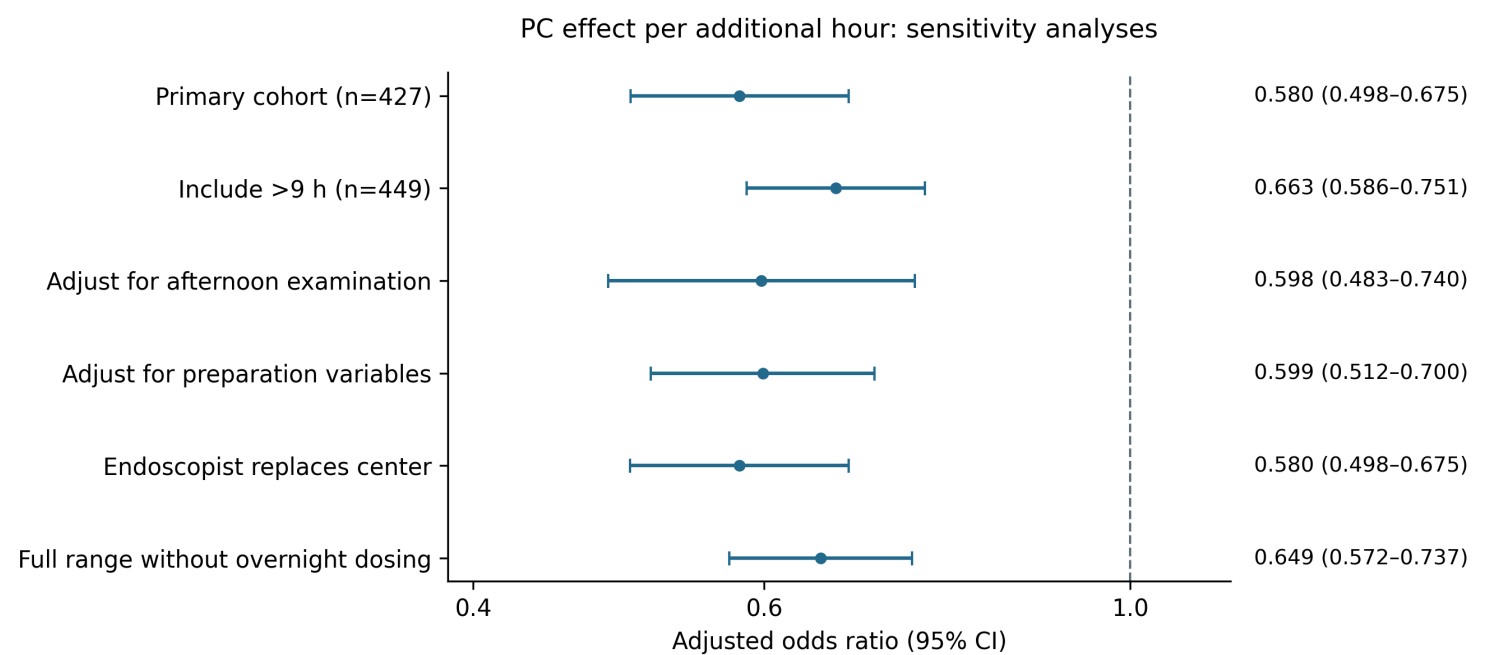


Figure 4

Adjusted associations per additional PC hour and sensitivity analyses. The outcome is high-quality preparation (BBPS ≥ 8). The primary cohort consists of 427 participants with PC 3–9 h; adjustment sets are described in the Methods and Table 5.

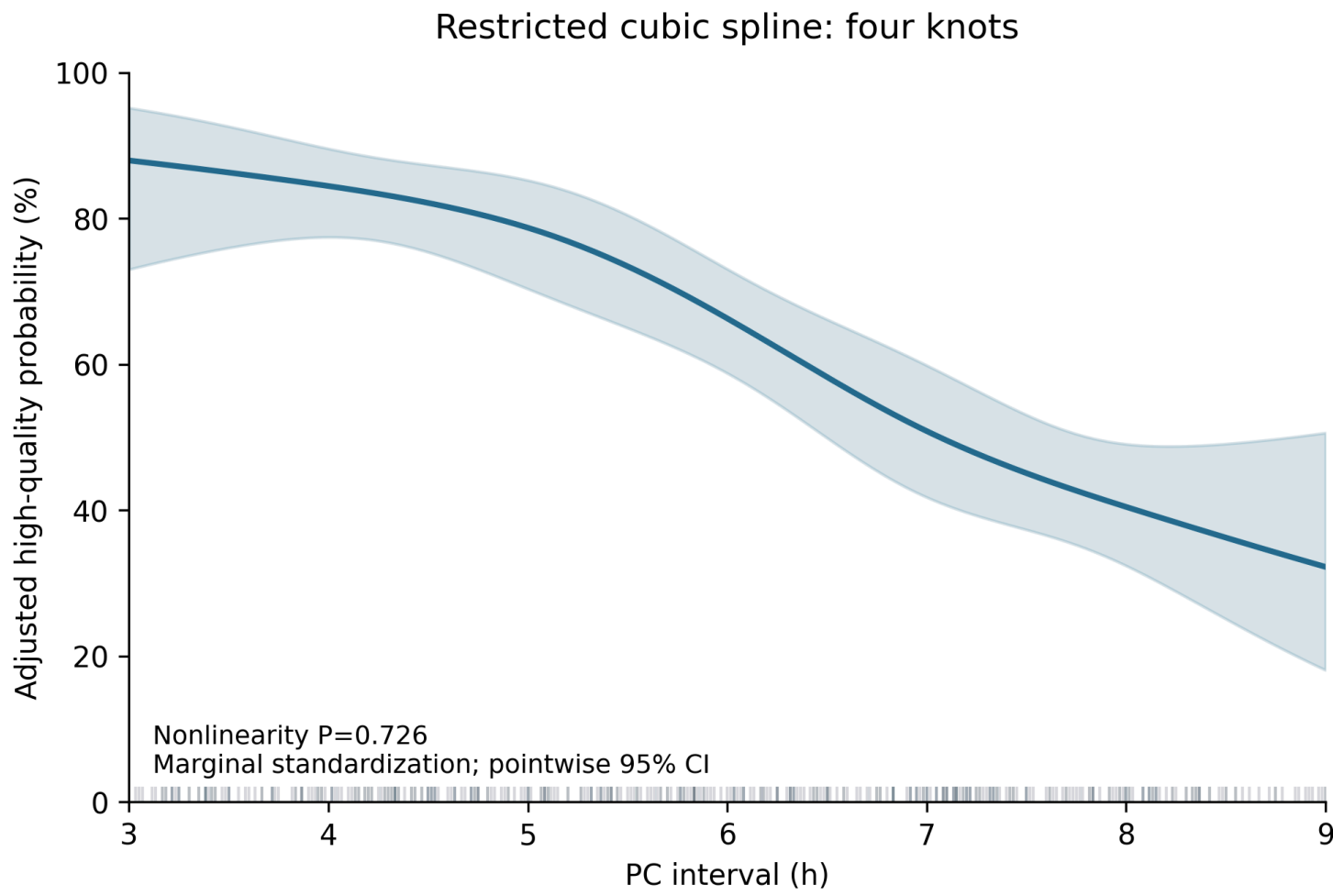


Figure 5

Marginally standardized probability of high-quality preparation from the four-knot RCS model. Shading indicates pointwise 95% CIs; rug marks show the observed PC distribution.

Exploratory segmented regression

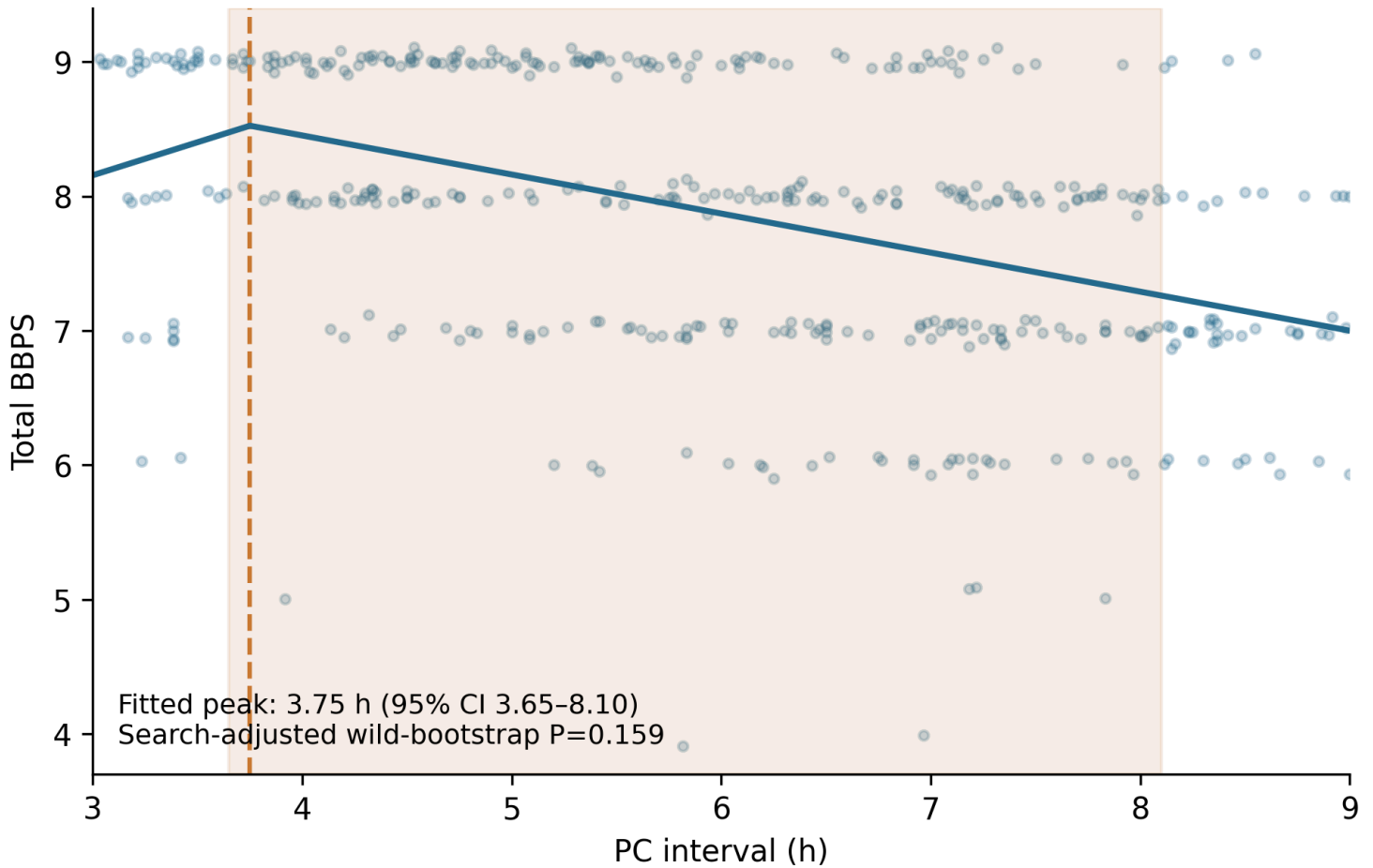


Figure 6

Exploratory segmented fit. The dashed orange line marks the sample-specific fitted peak at 3.75 h. The vertical shaded band represents the bootstrap 95% CI for join-point location, not a confidence band for the fitted curve. The peak is not a validated clinical threshold. Slight vertical jitter separates overlapping scores.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Supplementarymaterial.docx](#)