

Development of clinical prediction models for dyssynergic defecation and rectal sensitivity in patients with functional constipation using patient-reported outcomes

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Research Article

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Abstract

Background

Dyssynergic defecation and altered rectal sensation are important physiological abnormalities in functional constipation. We developed models combining patient-reported outcomes with clinical information to identify these abnormalities before high-resolution anorectal manometry.

Methods

We prospectively enrolled 130 patients with functional constipation at Lu'an People's Hospital between July 2024 and June 2026. Clinical characteristics, stool form, constipation symptoms, constipation-related quality of life, anxiety and depression were assessed before manometry. Separate logistic regression models were developed for manometry-defined dyssynergic defecation, rectal hypersensitivity and rectal hyposensitivity using univariable analysis and least absolute shrinkage and selection operator regression. Performance was assessed using discrimination, calibration, decision curves and internal validation with 1000 bootstrap resamples.

Results

Manometry indicated dyssynergic defecation in 98 participants and its absence in 32. The model included age, Bristol score, constipation stool symptom score and anxiety status. Its apparent and bootstrap-corrected areas under the receiver operating characteristic curve were 0.804 and 0.782, respectively, with a corrected Brier score of 0.145. Rectal sensation was hypersensitive in 47 participants, hyposensitive in 40 and normal in 36; seven indeterminate cases were excluded from sensory analyses. The hypersensitivity model, comparing 47 cases with 36 normal controls, included constipation-related quality of life, abdominal and stool symptom scores, and anxiety. Its apparent and corrected areas under the curve were 0.826 and 0.791, with a corrected Brier score of 0.191. The hyposensitivity model, comparing 40 cases with 36 normal controls, included age, Bristol score and stool symptom score; the corresponding values were 0.812, 0.786 and 0.194. Calibration showed overall agreement between predicted and observed probabilities. Decision curves suggested potential net benefit within the assessed threshold ranges.

Conclusions

Prediction models based on PROs and clinical data may help identify patients at risk of DD and rectal sensory abnormalities and could serve as preliminary risk-screening tools before HR-ARM.

Background

Functional constipation (FC) is a common functional gastrointestinal disorder characterised by straining, hard stools, infrequent bowel movements, incomplete evacuation and a sensation of anorectal blockage [1, 2]. Its often persistent course can impair quality of life and contribute to healthcare use and economic burden [3]. Identifying the underlying physiological abnormalities is therefore important for targeted assessment and treatment.

FC is primarily diagnosed using the Rome criteria and relevant clinical guidelines. However, symptoms alone do not reliably distinguish impaired colonic transit, defecatory dysfunction and altered rectal sensation, which can complicate treatment selection [2, 4]. High-resolution anorectal manometry (HR-ARM) provides information on anorectal motor function, coordination during defecation and rectal sensation, and is an important investigation for further physiological assessment [5, 6]. Its use requires specialised equipment and trained personnel, which may limit access to physiological assessment [7].

Patient-reported outcomes (PROs) and commonly used constipation assessment instruments capture stool form, symptom burden and constipation-related quality of life [8, 9, 10]. Psychological status can also be assessed using self-report scales. Integrating these measures with routine clinical information may help identify patients who warrant further physiological investigation. This study aimed to develop clinical prediction models for HR-ARM-defined dyssynergic defecation (DD), rectal hypersensitivity and rectal hyposensitivity in patients with FC, with the intended role of supporting preliminary risk stratification before HR-ARM.

Methods

Study design and participants

We prospectively enrolled 130 patients with FC who underwent HR-ARM at Lu'an People's Hospital between July 2024 and June 2026. Participants met the Rome IV diagnostic criteria for FC used during the study period, and case selection also referred to relevant constipation guidelines and consensus statements [2, 4]. Clinical information, PRO questionnaires and HR-ARM findings were collected for all participants.

Inclusion criteria were age of at least 18 years, fulfilment of the Rome IV criteria for FC, the ability to understand and independently complete the questionnaires, and complete clinical and HR-ARM data. Exclusion criteria were organic intestinal disease, such as inflammatory bowel disease, colorectal malignancy or bowel obstruction; previous major abdominal, pelvic or anorectal surgery that could affect defecation; severe cardiac, pulmonary, hepatic or renal dysfunction or neurological disease; pregnancy or breastfeeding; severe cognitive or psychiatric impairment preventing questionnaire completion or examination; and missing clinical information or incomplete examination results. Ethics approval and written informed consent are described in the Declarations section.

High-resolution anorectal manometry and outcome definitions

After digital rectal examination, participants underwent HR-ARM in the left lateral position with their knees flexed. A 24-channel water-perfused system (GAP-24A; Ningbo Medkinetic Medical Device Co., Ltd., Ningbo, Zhejiang, China) was used, and measurements were recorded and analysed using the accompanying software. Testing included a resting baseline recording, three anal squeeze manoeuvres, three simulated defecation manoeuvres, rectal sensory testing and assessment of the rectoanal inhibitory reflex (RAIR). Resting, squeeze, simulated defecation and rectal sensory parameters were recorded, with reference to the International Anorectal Physiology Working Group protocol [5].

Rectal sensory function was classified according to sensory thresholds during rectal balloon distension. The International Anorectal Physiology Working Group recommends evaluating rectal sensation relative to reference limits [5]. Reference values depend on equipment, testing protocols and the population examined [11]. In this study, the reference intervals were 10–30 mL for first sensation, 40–90 mL for the desire to defecate and 90–180 mL for maximum tolerable sensation, as reported in a previous study of FC [12]. Rectal hypersensitivity was defined as any threshold below its corresponding lower reference limit, whereas rectal hyposensitivity was defined as any threshold above its corresponding upper reference limit. Rectal sensitivity was considered normal when all three thresholds were within their respective reference intervals.

DD was determined from the HR-ARM findings. If at least one of the three simulated defecation maneuvers showed inadequate rectal propulsion, paradoxical contraction of the anal sphincter, incomplete anal sphincter relaxation, or an abnormal rectoanal pressure gradient, the HR-ARM findings were considered indicative of DD. This definition was consistent with the core pathophysiological feature of DD—impaired coordination between rectal propulsion and relaxation of the pelvic floor muscles and anal sphincter during defecation [13, 14].

Clinical information and patient-reported outcomes

Clinical information included age, sex, body mass index (BMI), constipation duration, bowel movement frequency, hypertension, diabetes, smoking, alcohol use, previous abdominal or pelvic surgery, family history of similar constipation symptoms and childbirth history in women. All PRO assessments were completed before HR-ARM.

Stool form was assessed using the Bristol Stool Form Scale [8]. Constipation symptom severity was measured using the Patient Assessment of Constipation Symptoms (PAC-SYM), comprising abdominal, rectal and stool symptom domains; higher scores indicate more severe symptoms [9]. The Patient Assessment of Constipation Quality of Life (PAC-QOL) assessed constipation-related impairment in quality of life, with higher scores indicating greater impairment [10]. The standardised scores used in the models were item-mean scores: PAC-SYM total, abdominal, rectal and stool raw scores were divided by 12, 4, 3 and 5, respectively, and the PAC-QOL total raw score was divided by 28. These scores were not z scores. Anxiety and depression were assessed using the Self-Rating Anxiety Scale (SAS) and Self-Rating Depression Scale (SDS). SAS standard scores ≥ 50 and SDS standard scores ≥ 53 indicated positive

anxiety and depression screens, respectively [15]. Candidate predictor definitions and coding are provided in Additional file 1, Table S4.

Statistical analysis and model development

Analyses were performed using IBM SPSS Statistics 27.0 and R 4.5.2. Continuous variables were assessed for normality. Normally distributed data are presented as mean $\pm$ standard deviation and were compared using a t test or one-way analysis of variance. Non-normally distributed data are presented as median (25th, 75th percentiles) and were compared using the Mann–Whitney U test or Kruskal–Wallis test. Categorical variables are presented as n (%) and were compared using the chi-square test or Fisher's exact test. Where reported, post hoc pairwise comparisons of squeeze duration across the sensory groups were adjusted using the Holm method. All tests were two-sided, with $P < 0.05$ considered statistically significant.

Separate binary logistic regression models were developed for DD versus non-DD ($n = 130$), hypersensitivity versus normal sensitivity ($n = 83$), and hyposensitivity versus normal sensitivity ($n = 76$). Univariable logistic regression was used to identify candidate associations, with $P < 0.10$ used for preliminary screening. Least absolute shrinkage and selection operator (LASSO) logistic regression with 10-fold cross-validation was also performed. Variables retained by LASSO and showing $P < 0.05$ in univariable logistic regression were included in the final multivariable models after assessment of collinearity. The one-standard-error penalty (λ_{1se}) was used for the DD and hyposensitivity models, and the minimum-deviance penalty (λ_{min}) for the hypersensitivity model. PAC-SYM total and domain scores were not included together in the final DD model because of their structural correlation. Associations are reported as odds ratios (ORs) with 95% confidence intervals (CIs). Complete univariable results are presented in Additional file 1, Table S3, and LASSO plots in Figures S1–S3.

Model discrimination was assessed using the area under the receiver operating characteristic curve (AUC), and calibration was assessed using calibration curves, intercepts and slopes. The Brier score summarised overall predictive accuracy. Internal validation used 1000 bootstrap resamples to estimate optimism-corrected performance by refitting each fixed final model. The reported intervals were the 2.5th and 97.5th percentiles of the replicate optimism-corrected AUC statistics. Decision curve analysis (DCA) compared model-guided HR-ARM testing with testing all or no participants across threshold probabilities of 0.01–0.80. Model coefficients were presented as nomograms.

Use of artificial intelligence tools

OpenAI Codex was used to assist with Chinese-to-English translation, language editing, manuscript formatting and reference checking.

Results

Participant inclusion and clinical characteristics

All 130 participants were included in the DD analysis: 98 had an HR-ARM-defined DD pattern and 32 did not. Rectal sensory phenotype was classified as hypersensitive in 47 participants, hyposensitive in 40 and normal in 36. Seven clinically indeterminate cases were excluded from the sensory phenotype analyses. Thus, 123 participants contributed to the three-group descriptive comparison, while the hypersensitivity and hyposensitivity models included 83 and 76 participants, respectively, each using the same 36 participants with normal sensitivity as the reference group (Fig. 1).

Participants with DD were older than those without DD (median 55.00 [48.00, 64.00] versus 47.00 [32.25, 56.25] years; $P = 0.003$). They had higher PAC-SYM stool scores (2.60 [2.20, 3.20] versus 2.10 [1.75, 2.45]; $P < 0.001$), more frequent SAS-positive anxiety (56.1% versus 28.1%; $P = 0.006$) and lower Bristol scores (2.00 [1.00, 3.00] versus 3.00 [2.00, 4.00]; $P < 0.001$) (Table 1). Anal sphincter length was greater in the DD group (4.20 [3.40, 4.70] versus 3.60 [2.90, 3.95] cm; $P < 0.001$), and squeeze duration was longer (14.75 [13.70, 15.70] versus 13.90 [12.80, 15.20] s; $P = 0.027$). Complete manometric characteristics are provided in Additional file 1, Table S1.

Table 1

Clinical characteristics and patient-reported outcomes according to dyssynergic defecation status

Characteristic	Non-DD (n = 32)	DD (n = 98)	Statistic	P value
Age (years)	47.00 (32.25, 56.25)	55.00 (48.00, 64.00)	Z=-2.969	0.003
Female sex	20 (62.5)	63 (64.3)	$\chi^2=0.033$	0.855
BMI (kg/m ²)	22.52 $\pm$ 2.77	22.30 $\pm$ 3.01	t = 0.368	0.713
<18.5	1 (3.1)	6 (6.1)	$\chi^2=1.058$	0.589
18.5–24.0	21 (65.6)	69 (70.4)	$\chi^2=1.058$	0.589
>24.0	10 (31.2)	23 (23.5)	$\chi^2=1.058$	0.589
Smoking history	8 (25.0)	19 (19.4)	$\chi^2=0.462$	0.497
Alcohol use	5 (15.6)	17 (17.3)	$\chi^2=0.051$	0.822
Hypertension	8 (25.0)	23 (23.5)	$\chi^2=0.031$	0.860
Diabetes	2 (6.2)	17 (17.3)	$\chi^2=2.380$	0.123
Family history of similar constipation	8 (25.0)	37 (37.8)	$\chi^2=1.734$	0.188
Childbirth history among women	9 (45.0)	39 (61.9)	$\chi^2=1.779$	0.182
Bristol Stool Form Scale score	3.00 (2.00, 4.00)	2.00 (1.00, 3.00)	Z=-3.352	< 0.001
Constipation duration (years)	1.95 (0.47, 4.00)	2.00 (0.85, 4.60)	Z=-0.666	0.505
PAC-SYM total score	1.83 (1.56, 2.08)	2.00 (1.77, 2.25)	Z=-2.820	0.005
PAC-SYM stool score	2.10 (1.75, 2.45)	2.60 (2.20, 3.20)	Z=-3.897	< 0.001
PAC-SYM rectal score	1.67 (1.33, 2.00)	1.67 (1.08, 2.00)	Z=-1.504	0.133
PAC-SYM abdominal score	1.50 (1.19, 2.00)	1.50 (1.00, 2.00)	Z=-0.461	0.644
PAC-QOL total score	2.71 $\pm$ 0.51	2.55 $\pm$ 0.62	t = 1.340	0.183

Data are mean $\pm$ standard deviation, median (25th, 75th percentiles), or n (%). For binary characteristics, the positive category is shown; sex is presented as the number of women. PAC-SYM and PAC-QOL scores are item means. BMI, body mass index; PAC-SYM, Patient Assessment of Constipation Symptoms; PAC-QOL, Patient Assessment of Constipation Quality of Life; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale. Z, Mann–Whitney statistic; t, t statistic; F, analysis-of-variance statistic; H, Kruskal–Wallis statistic; χ^2 , chi-square statistic. Childbirth history uses denominators of 20 women without DD and 63 women with DD. HR-ARM parameters are reported in Additional file 1, Table S1.

Characteristic	Non-DD (n = 32)	DD (n = 98)	Statistic	P value
SAS standard score	45.50 (35.00, 56.50)	51.00 (41.00, 60.00)	Z=-1.519	0.129
SDS standard score	43.00 (38.75, 52.25)	49.00 (40.25, 60.00)	Z=-1.619	0.105
Anxiety (SAS-positive)	9 (28.1)	55 (56.1)	$\chi^2=7.565$	0.006
Depression (SDS-positive)	8 (25.0)	37 (37.8)	$\chi^2=1.734$	0.188
Data are mean $\pm$ standard deviation, median (25th, 75th percentiles), or n (%). For binary characteristics, the positive category is shown; sex is presented as the number of women. PAC-SYM and PAC-QOL scores are item means. BMI, body mass index; PAC-SYM, Patient Assessment of Constipation Symptoms; PAC-QOL, Patient Assessment of Constipation Quality of Life; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale. Z, Mann–Whitney statistic; t, t statistic; F, analysis-of-variance statistic; H, Kruskal–Wallis statistic; χ^2 , chi-square statistic. Childbirth history uses denominators of 20 women without DD and 63 women with DD. HR-ARM parameters are reported in Additional file 1, Table S1.				

Age, Bristol score, PAC-SYM total, stool and abdominal scores, PAC-QOL total score and anxiety status differed among the three rectal sensory groups (Table 2). Participants with hyposensitivity tended to be older and have greater stool symptom burden, whereas participants with hypersensitivity had higher abdominal symptom and PAC-QOL scores and a higher prevalence of anxiety. Squeeze duration differed overall ($P = 0.026$), but no pairwise comparison remained significant after Holm adjustment. Differences in sensory thresholds (all $P < 0.001$) describe the phenotypes used for grouping rather than providing independent evidence of group separation (Additional file 1, Table S2).

Table 2

Clinical characteristics and patient-reported outcomes according to rectal sensory phenotype

Characteristic	Normal (n = 36)	Hyposensitivity (n = 40)	Hypersensitivity (n = 47)	Statistic	P value
Age (years)	47.19 ± 16.31	57.48 ± 12.19	49.62 ± 15.11	F = 5.297	0.006
Female sex	21 (58.3)	24 (60.0)	33 (70.2)	$\chi^2=1.538$	0.464
BMI (kg/m ²)	22.15 (20.68, 24.10)	21.90 (20.15, 24.20)	22.10 (20.05, 24.00)	H = 0.317	0.853
<18.5	0 (0.0)	3 (7.5)	3 (6.4)	$\chi^2=2.955$	0.565
18.5–24.0	27 (75.0)	26 (65.0)	33 (70.2)	$\chi^2=2.955$	0.565
>24.0	9 (25.0)	11 (27.5)	11 (23.4)	$\chi^2=2.955$	0.565
Smoking history	6 (16.7)	9 (22.5)	10 (21.3)	$\chi^2=0.441$	0.802
Alcohol use	6 (16.7)	7 (17.5)	9 (19.1)	$\chi^2=0.092$	0.955
Hypertension	7 (19.4)	11 (27.5)	9 (19.1)	$\chi^2=1.066$	0.587
Diabetes	3 (8.3)	10 (25.0)	6 (12.8)	$\chi^2=4.448$	0.108
Family history of similar constipation	12 (33.3)	15 (37.5)	16 (34.0)	$\chi^2=0.173$	0.917
Childbirth history among women	14 (66.7)	14 (58.3)	19 (57.6)	$\chi^2=0.496$	0.780
Bristol Stool Form Scale score	2.00 (1.75, 3.25)	2.00 (1.00, 2.00)	3.00 (2.00, 3.00)	H = 19.260	< 0.001
Constipation duration (years)	1.00 (0.50, 3.00)	2.40 (1.00, 4.00)	3.00 (0.65, 4.85)	H = 3.293	0.193
PAC-SYM total score	1.96 ± 0.35	2.09 ± 0.38	1.91 ± 0.23	F = 3.361	0.038

Data are mean ± standard deviation, median (25th, 75th percentiles), or n (%). For binary characteristics, the positive category is shown; sex is presented as the number of women. PAC-SYM and PAC-QOL scores are item means. BMI, body mass index; PAC-SYM, Patient Assessment of Constipation Symptoms; PAC-QOL, Patient Assessment of Constipation Quality of Life; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale. Z, Mann–Whitney statistic; t, t statistic; F, analysis-of-variance statistic; H, Kruskal–Wallis statistic; χ^2 , chi-square statistic. Seven indeterminate cases were excluded. Childbirth history uses denominators of 21, 24 and 33 women in the normal, hyposensitivity and hypersensitivity groups. P values are for overall group comparisons. HR-ARM parameters are reported in Additional file 1, Table S2.

Characteristic	Normal (n = 36)	Hyposensitivity (n = 40)	Hypersensitivity (n = 47)	Statistic	P value
PAC-SYM stool score	2.50 (2.20, 3.00)	3.00 (2.60, 3.45)	2.20 (2.00, 2.40)	H = 47.013	< 0.001
PAC-SYM rectal score	1.67 (1.33, 2.00)	1.33 (1.00, 2.00)	1.67 (1.33, 2.00)	H = 2.782	0.249
PAC-SYM abdominal score	1.50 (1.19, 1.75)	1.00 (0.75, 1.75)	2.00 (1.50, 2.00)	H = 17.079	< 0.001
PAC-QOL total score	2.43 ± 0.57	2.43 ± 0.61	2.82 ± 0.56	F = 6.723	0.002
SAS standard score	45.50 (37.50, 52.75)	49.00 (39.75, 60.75)	53.00 (41.00, 63.00)	H = 4.530	0.104
SDS standard score	49.00 (40.00, 57.25)	47.00 (38.00, 58.25)	49.00 (42.00, 64.00)	H = 1.472	0.479
Anxiety (SAS-positive)	12 (33.3)	20 (50.0)	30 (63.8)	$\chi^2=7.588$	0.023
Depression (SDS-positive)	12 (33.3)	13 (32.5)	20 (42.6)	$\chi^2=1.173$	0.556
Data are mean ± standard deviation, median (25th, 75th percentiles), or n (%). For binary characteristics, the positive category is shown; sex is presented as the number of women. PAC-SYM and PAC-QOL scores are item means. BMI, body mass index; PAC-SYM, Patient Assessment of Constipation Symptoms; PAC-QOL, Patient Assessment of Constipation Quality of Life; SAS, Self-Rating Anxiety Scale; SDS, Self-Rating Depression Scale. Z, Mann–Whitney statistic; t, t statistic; F, analysis-of-variance statistic; H, Kruskal–Wallis statistic; χ^2 , chi-square statistic. Seven indeterminate cases were excluded. Childbirth history uses denominators of 21, 24 and 33 women in the normal, hyposensitivity and hypersensitivity groups. P values are for overall group comparisons. HR-ARM parameters are reported in Additional file 1, Table S2.					

Dyssynergic defecation model

PAC-SYM stool score, Bristol score, PAC-SYM total score, age and SAS-positive anxiety met the preliminary univariable screening criterion for DD. LASSO retained age, Bristol score, stool score and anxiety at λ_{1se} (Additional file 1, Table S3 and Fig. S1). The final model retained all four variables. Older age, greater stool symptom burden and anxiety were positively associated with DD, while a higher Bristol score was inversely associated with DD (Table 3). The strongest binary association was with anxiety (OR 3.012, 95% CI 1.148–7.899; $P = 0.025$). In an alternative model containing the PAC-SYM total score, that score was not statistically significant (OR 1.178, 95% CI 0.164–8.446; $P = 0.870$).

Table 3
Final multivariable prediction models for anorectal functional phenotypes

HR-ARM-defined DD

Predictor	β	SE	OR (95% CI)	P value
Intercept	-2.417	1.449	—	—
Age (per year)	0.034	0.016	1.035 (1.002–1.069)	0.036
Bristol score (per point)	-0.488	0.245	0.614 (0.380–0.993)	0.047
PAC-SYM stool score (per point)	1.075	0.424	2.929 (1.276–6.726)	0.011
Anxiety (yes versus no)	1.103	0.492	3.012 (1.148–7.899)	0.025

Rectal hypersensitivity

Predictor	β	SE	OR (95% CI)	P value
Intercept	-2.074	1.908	—	—
PAC-QOL total score (per point)	1.061	0.472	2.891 (1.145–7.294)	0.025
PAC-SYM abdominal score (per point)	1.135	0.568	3.111 (1.021–9.480)	0.046
PAC-SYM stool score (per point)	-1.247	0.514	0.287 (0.105–0.787)	0.015
Anxiety (yes versus no)	1.128	0.536	3.090 (1.082–8.827)	0.035

Rectal hyposensitivity

Predictor	β	SE	OR (95% CI)	P value
Intercept	-3.771	2.331	—	—
Age (per year)	0.046	0.021	1.048 (1.005–1.092)	0.028
Bristol score (per point)	-0.915	0.386	0.401 (0.188–0.853)	0.018
PAC-SYM stool score (per point)	1.145	0.571	3.143 (1.027–9.618)	0.045

The DD model compares DD with non-DD (n = 130). The hypersensitivity and hyposensitivity models compare each phenotype with normal sensitivity (n = 83 and 76, respectively). β , regression coefficient; SE, standard error; OR, odds ratio; CI, confidence interval. Anxiety is coded 1 for SAS ≥ 50 and 0 otherwise. Score units and coding are defined in Additional file 1, Table S4. Coefficients are on the original predictor scale, with item-mean PAC scores. Coefficients and intervals are rounded to three decimal places.

For each model, the linear predictor η equals the intercept plus the sum of each coefficient multiplied by its predictor value. The predicted probability is calculated as follows:

$$P = 1 / [1 + \exp(-\eta)]$$

The DD nomogram is shown in Fig. 2A. At the reported optimal predicted-probability threshold of 0.755, sensitivity was 76.5% and specificity was 75.0%. The apparent AUC was 0.804, and the bootstrap-corrected AUC was 0.782 (95% CI 0.697–0.875). Calibration was broadly satisfactory, with a corrected intercept near zero and a slope below one (Fig. 3A and D; Table 4). DCA indicated higher net benefit than the test-all and test-none strategies over thresholds of 0.12–0.80 (Fig. 4A).

Table 4
Performance of the three prediction models after bootstrap internal validation

Measure	DD	Hypersensitivity	Hyposensitivity
Analysis sample	130	83	76
Events / non-events	98 / 32	47 / 36	40 / 36
Apparent AUC	0.804	0.826	0.812
Corrected AUC (95% interval)	0.782 (0.697–0.875)	0.791 (0.708–0.885)	0.786 (0.700–0.886)
Corrected Brier score	0.145	0.191	0.194
Corrected calibration intercept	-0.010	-0.032	-0.043
Corrected calibration slope	0.896	0.842	0.874
Valid bootstrap resamples	1000	1000	1000
AUC, area under the receiver operating characteristic curve. Internal validation refitted each fixed final model in 1000 bootstrap samples. The intervals are the reported 2.5th and 97.5th percentiles of the replicate optimism-corrected AUC statistics. The two sensory models use normal sensitivity as the comparator; performance estimates.			

Rectal hypersensitivity model

PAC-QOL total score, PAC-SYM abdominal score, PAC-SYM stool score and SAS-positive anxiety met the univariable screening criterion and were retained by LASSO at lambda.min (Additional file 1, Table S3 and Fig. S2). In the final model, greater impairment in quality of life, greater abdominal symptom burden and anxiety were positively associated with hypersensitivity. Stool symptom burden was inversely associated after adjustment (OR 0.287, 95% CI 0.105–0.787; P = 0.015) (Table 3). This inverse association should be interpreted within the comparison with normal sensitivity.

The nomogram is shown in Fig. 2B. The apparent AUC was 0.826, and the bootstrap-corrected AUC was 0.791 (95% CI 0.708–0.885). Calibration showed some deviation at high predicted probabilities (Fig. 3B and E; Table 4). DCA suggested potential net benefit over thresholds of 0.07–0.80 (Fig. 4B).

Rectal hyposensitivity model

Bristol score, PAC-SYM stool score, age and diabetes history met the preliminary univariable screening criterion. Age, Bristol score and stool score were retained by LASSO at λ_{1se} and met the final univariable entry criterion (Additional file 1, Table S3 and Fig. S3). Older age and greater stool symptom burden were positively associated with hyposensitivity, while Bristol score was inversely associated (OR 0.401, 95% CI 0.188–0.853; $P = 0.018$) (Table 3). Diabetes showed a relatively large estimate in preliminary analyses but did not meet the joint selection criterion and was not retained in the final model.

The nomogram is shown in Fig. 2C. The apparent AUC was 0.812, and the bootstrap-corrected AUC was 0.786 (95% CI 0.700–0.886). Calibration was broadly satisfactory (Fig. 3C and F; Table 4). DCA suggested potential net benefit over thresholds of 0.01–0.80 (Fig. 4C). The complete coefficients and intercepts for all three models are provided in Table 3; their internal validation results are summarised in Table 4.

Discussion

Chronic constipation is a common functional gastrointestinal disorder with a pathogenesis involving interactions among multiple factors. In addition to impaired colonic transit, dyssynergic defecation and altered rectal sensation are important underlying pathophysiological mechanisms [4, 6]. Although clinical symptoms reflect the burden of constipation, symptoms overlap across different pathophysiological subtypes, making it difficult to determine accurately whether patients have DD or abnormal rectal sensitivity based on subjective symptoms alone. HR-ARM objectively evaluates anorectal motor function, defecatory coordination and rectal sensory function and is an important investigation for further classification of chronic constipation [5, 7]. However, HR-ARM requires expensive equipment and is an invasive procedure, limiting its availability in primary care settings. Classification based solely on patients' subjective symptoms is prone to misdiagnosis, highlighting the need for a non-invasive, convenient tool for preliminary risk assessment. Therefore, investigating associated factors and developing prediction models using PROs and general clinical information may have practical clinical value.

The results of this study showed that age, Bristol Stool Form Scale score, standardised PAC-SYM stool symptom score and SAS-positive anxiety were independently associated with DD. With increasing age, the elasticity of the striated pelvic floor muscles and their neural regulatory capacity progressively decline, making paradoxical anal sphincter contraction more likely during simulated defecation and reducing coordination between abdominal pressure generation and pelvic floor relaxation. These changes contribute to the development of DD, consistent with previous findings [13, 14]†. The Bristol Stool Form Scale is a simple tool that reflects stool form and intestinal transit [8]. Lower scores indicate

harder, drier stools, which increase resistance to evacuation, aggravate straining and the sensation of incomplete evacuation, and consequently promote the development of DD. Anxiety can affect defecatory coordination through excessive attention to symptoms, autonomic dysfunction and increased pelvic floor muscle tension. These effects make inadequate pelvic floor relaxation or paradoxical contraction more likely during defecation, thereby increasing the risk of DD. The DD nomogram developed from these independently associated factors had an apparent AUC of 0.804 and a corrected AUC of 0.782 after internal validation with 1000 bootstrap resamples, indicating good discrimination and acceptable overall calibration. DCA showed that, across the evaluated threshold probability range of 0.12–0.80, the model provided greater net benefit than strategies of performing HR-ARM in all patients or in none, suggesting potential clinical utility.

For rectal hypersensitivity, this study identified the standardised PAC-QOL total score, standardised PAC-SYM abdominal symptom score and SAS-positive anxiety as independent associated factors. Higher PAC-QOL scores indicate greater impairment in constipation-related quality of life and can collectively reflect symptom burden, psychosocial effects and defecation-related anxiety [10]. The PAC-SYM abdominal symptom domain primarily includes abdominal discomfort, bloating and pain. Bloating and abdominal discomfort are characteristic clinical manifestations of rectal hypersensitivity, distinguishing it from the DD subtype, which is predominantly characterised by difficulty with defecation. These symptoms therefore have substantial value for identifying abnormalities in rectal sensation. As a form of emotional stress, anxiety can enhance the central amplification of visceral pain signals through brain–gut axis signalling pathways, lower the perceptual threshold for rectal distension and exacerbate visceral hypersensitivity. This interpretation is broadly consistent with existing research on the brain–gut axis [16]†. The rectal hypersensitivity nomogram developed from these variables had an apparent AUC of 0.826 and a corrected AUC of 0.791 after internal validation with 1000 bootstrap resamples, indicating good discrimination and acceptable overall calibration, although some deviation was observed at higher predicted probabilities. DCA showed that, across the evaluated threshold probability range of 0.07–0.80, the model provided greater net benefit than strategies of performing HR-ARM in all patients or in none, indicating potential clinical value.

For rectal hyposensitivity, the results showed that age, Bristol score and standardised PAC-SYM stool symptom score were independent predictors. In older adults, degenerative changes in rectal wall mechanoreceptors and pelvic afferent nerves raise perceptual thresholds for rectal distension and blunt the perception of the urge to defecate. These changes favour prolonged stool retention in the rectum and consequently contribute to rectal hyposensitivity, consistent with previous research [17]†. Lower Bristol scores indicate harder, drier stools. Sustained stretching of the rectal mucosa by these stools can blunt local sensory receptor responses, further increase sensory thresholds and promote the development of rectal hyposensitivity. Higher PAC-SYM stool symptom scores increase the risk of rectal hyposensitivity. Persistently prolonged intervals between bowel movements and straining indicate sustained stimulation from rectal filling and are typical clinical features of reduced rectal sensation. The rectal hyposensitivity nomogram developed from these variables had an apparent AUC of 0.812 and a corrected AUC of 0.786 after internal validation with 1000 bootstrap resamples, indicating good

discrimination and acceptable overall calibration. DCA showed that, across the evaluated threshold probability range of 0.01–0.80, the model provided greater net benefit than strategies of performing HR-ARM in all patients or in none, suggesting potential clinical utility.

Limitations and future research

In summary, this study developed separate prediction models for DD, rectal hypersensitivity and rectal hyposensitivity using general clinical information and PRO scores. The findings suggest that DD is primarily associated with age, stool form, stool symptom burden and anxiety; rectal hypersensitivity with abdominal symptoms, impaired quality of life and anxiety; and rectal hyposensitivity with age, harder stools and greater stool symptom severity. PRO scores combined with clinical information can, to some extent, reflect the risk of anorectal motor and sensory dysfunction in patients with functional constipation and may serve as a non-invasive adjunctive screening tool before HR-ARM. This study also has several limitations. First, its single-centre design and relatively limited sample size restrict model stability and generalisability. Second, DD and rectal sensitivity were assessed primarily using HR-ARM findings without incorporating balloon expulsion testing, defecography or colonic transit testing, which may limit comprehensive characterisation of the pathophysiological subtypes of chronic constipation. Future studies could externally validate and refine these models in larger, multicentre cohorts by incorporating objective findings from balloon expulsion testing, defecography and colonic transit testing. The prediction models could also be translated into nomograms, online calculators or outpatient screening forms to improve their clinical usability and provide further approaches to individualised diagnosis and treatment of functional constipation.

Conclusions

This study developed separate prediction models for an HR-ARM-defined DD pattern, rectal hypersensitivity and rectal hyposensitivity using clinical data and PRO scores. The DD model included age, stool form, stool symptom burden and anxiety. The hypersensitivity model included abdominal and stool symptoms, constipation-related quality of life and anxiety; the hyposensitivity model included age, stool form and stool symptom burden. These models may support preliminary risk stratification before HR-ARM, but their performance and clinical usefulness require external validation.

Abbreviations

AUC, area under the receiver operating characteristic curve

BMI, body mass index

CI, confidence interval

DCA, decision curve analysis

DD, dyssynergic defecation

FC, functional constipation

HR-ARM, high-resolution anorectal manometry

LASSO, least absolute shrinkage and selection operator

OR, odds ratio

PAC-QOL, Patient Assessment of Constipation Quality of Life

PAC-SYM, Patient Assessment of Constipation Symptoms

PRO, patient-reported outcome

RAIR, rectoanal inhibitory reflex

SAS, Self-Rating Anxiety Scale

SDS, Self-Rating Depression Scale

SE, standard error

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Lu'an Hospital of Anhui Medical University . Written informed consent was obtained from all participants before enrolment. The study was conducted in accordance with the principles of the Declaration of Helsinki. This study was not registered.

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, subject to institutional and ethical approval requirements.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

XW contributed to conceptualisation, methodology, investigation, data curation and writing the original draft. YX contributed to figure preparation, project administration and resources. XL contributed to supervision and manuscript review and editing. All authors read and approved the final manuscript.

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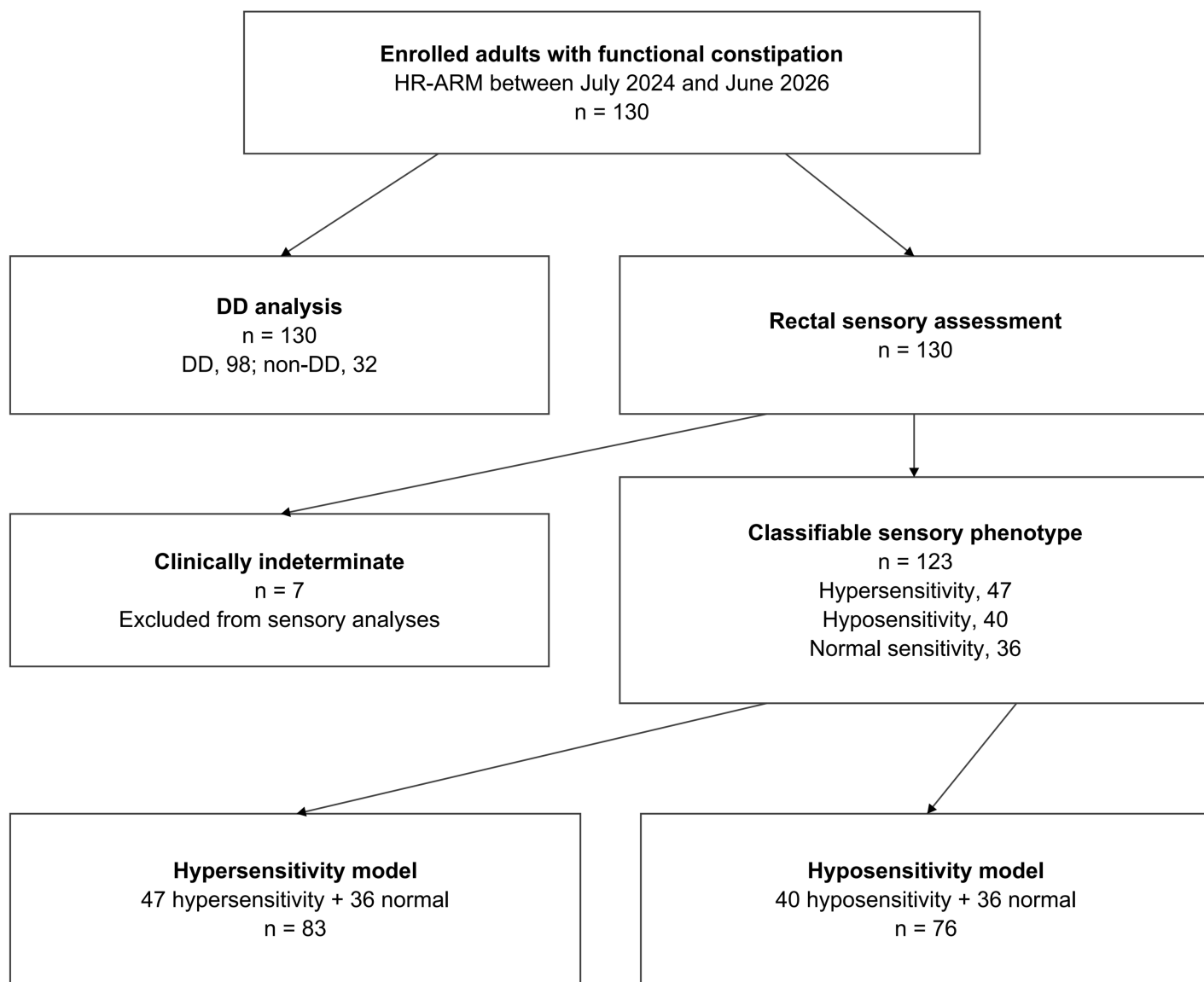
Not applicable.

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Figures



The same 36 normal controls contribute to both sensory models.

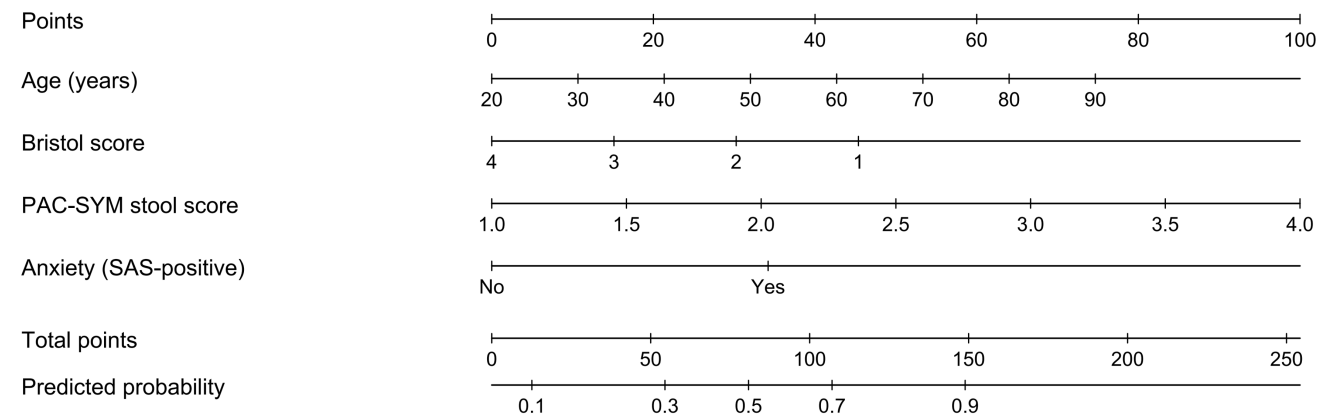
Figure 1

Participant inclusion and model-specific analysis populations

All 130 participants entered the DD analysis. Rectal sensory phenotype was classifiable in 123 participants; seven clinically indeterminate cases were excluded from sensory analyses. The hypersensitivity model included 47 cases and 36 normal controls (n = 83), and the hyposensitivity model included 40 cases and the same 36 normal controls (n = 76). HR-ARM, high-resolution anorectal manometry; DD, dyssynergic defecation.

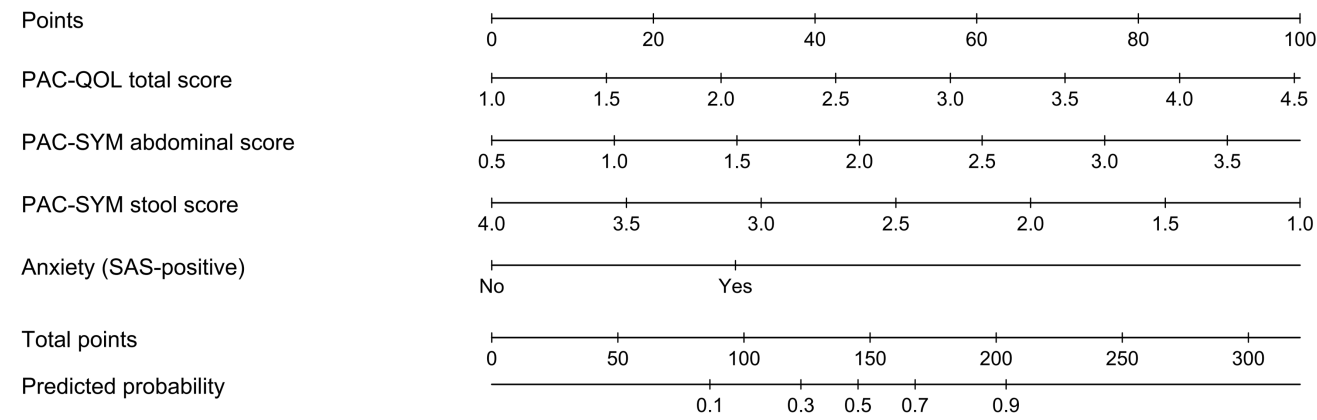
A HR-ARM-defined DD

n = 130; events = 98



B Rectal hypersensitivity

n = 83; events = 47



C Rectal hyposensitivity

n = 76; events = 40

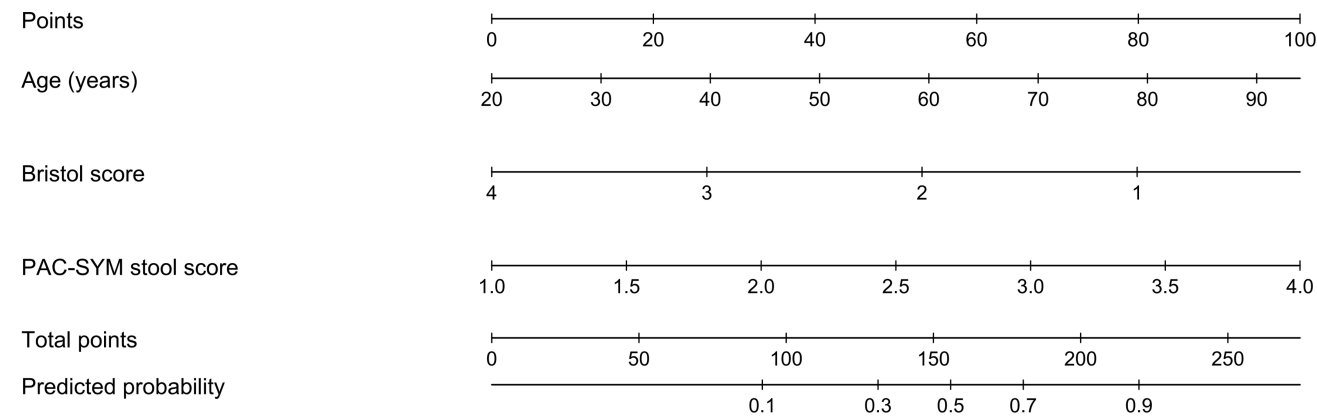


Figure 2

Nomograms of the three prediction models

A, HR-ARM-defined DD (n = 130). B, rectal hypersensitivity versus normal sensitivity (n = 83). C, rectal hyposensitivity versus normal sensitivity (n = 76). Predictor values are converted into points, summed and mapped to the predicted probability. PAC-SYM and PAC-QOL scores are item means. Anxiety

indicates an SAS standard score ≥ 50 . Sensory-model probabilities are conditional on the corresponding binary comparison.

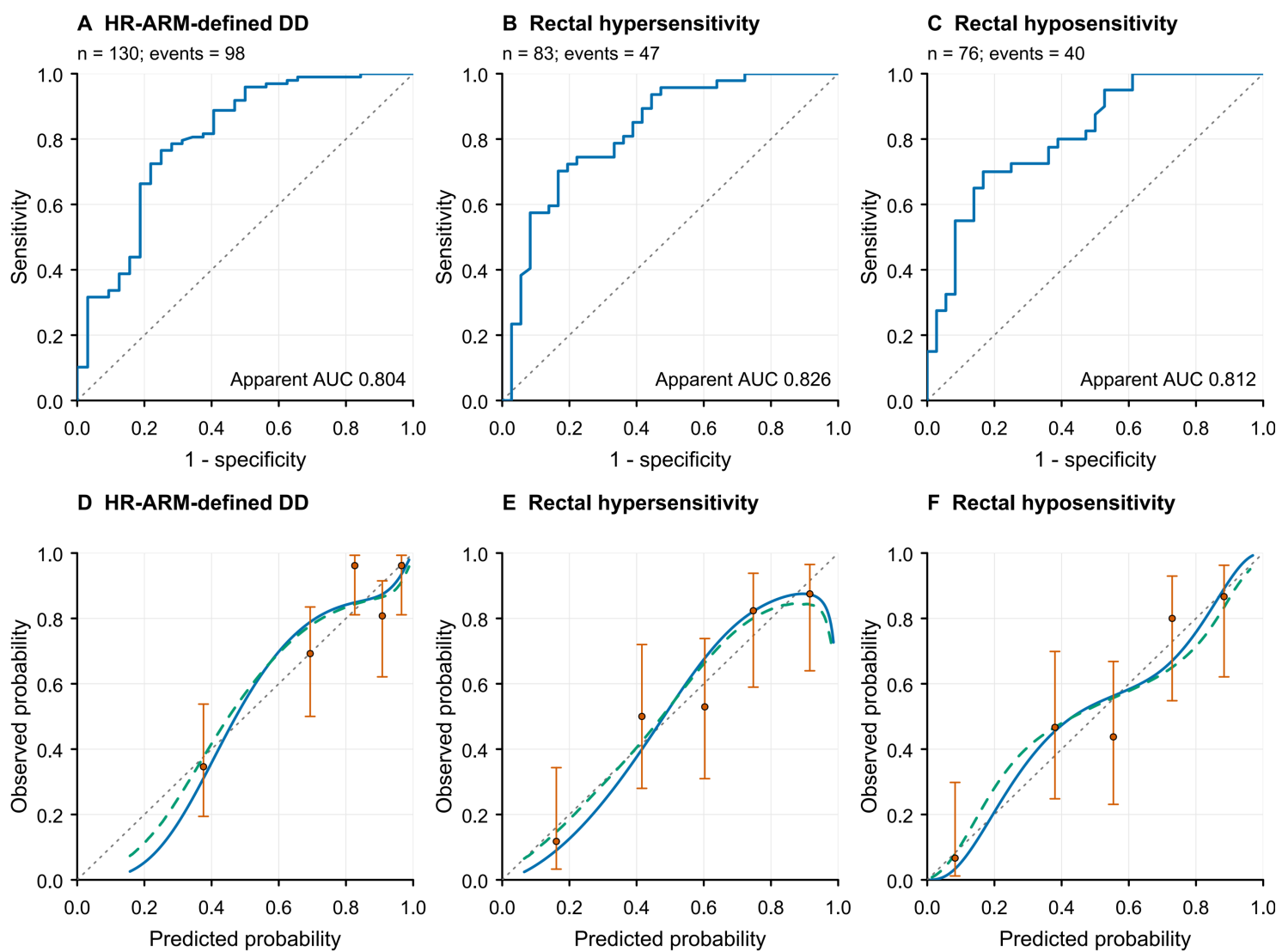


Figure 3

Discrimination and calibration of the three prediction models

A–C, receiver operating characteristic curves for DD, hypersensitivity and hyposensitivity, respectively. D–F, calibration curves in the same model order. Sample sizes were 130, 83 and 76, respectively. The blue solid line is the apparent natural-spline calibration curve; the green dashed line is the bootstrap-corrected curve; the grey dotted diagonal indicates ideal calibration. Orange points show observed event proportions in quintiles of predicted probability, with Wilson 95% confidence intervals. Internal validation used 1000 bootstrap resamples. Numerical performance estimates are reported in Table 4.

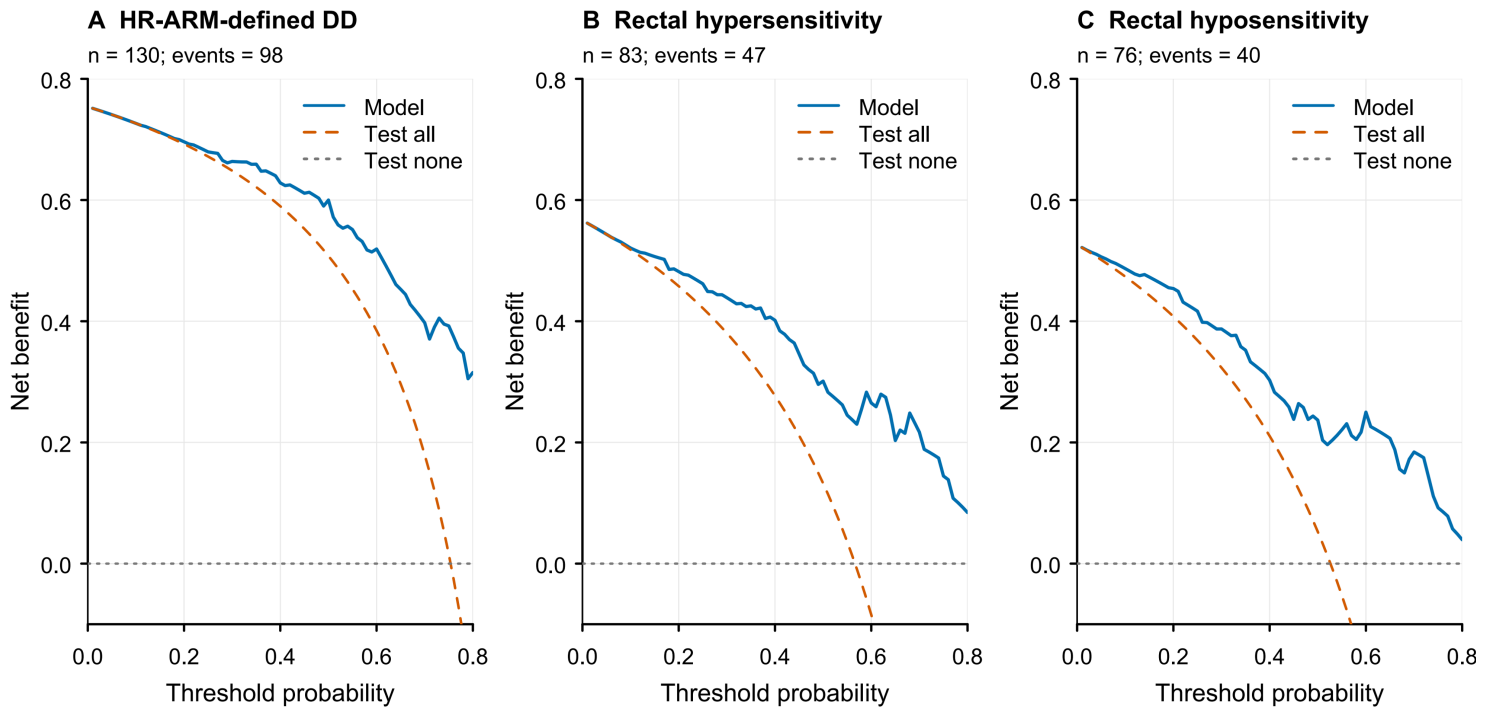


Figure 4

Decision curve analyses of the three prediction models

A, DD (n = 130). B, hypersensitivity versus normal sensitivity (n = 83). C, hyposensitivity versus normal sensitivity (n = 76). Blue solid curves show model-guided net benefit, orange dashed curves represent testing all participants with HR-ARM, and grey dotted lines represent testing none. Threshold probabilities from 0.01 to 0.80 were assessed. Reported ranges with model net benefit above both reference strategies were 0.12–0.80, 0.07–0.80 and 0.01–0.80, respectively. These exploratory decision curves describe the development samples and indicate potential clinical utility.

Supplementary Files

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