



IACCS

International Asian Cancer and Chronic Disease Screening Network
國際亞洲癌症與慢性病篩檢聯盟

Precision Screening and Surveillance: Risk-Based Strategies with Fecal Hemoglobin Concentration



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2026/06/05

Outline

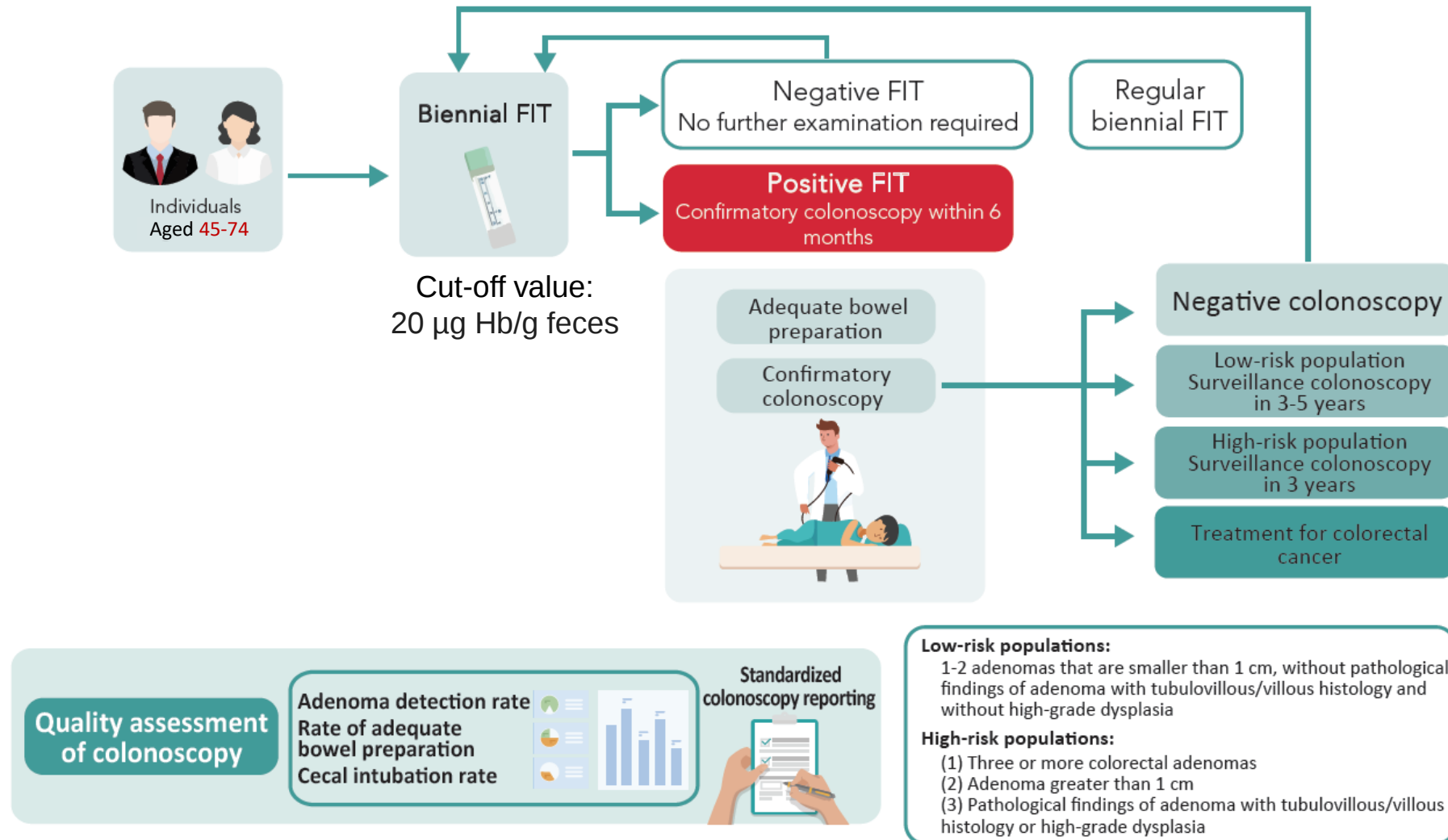
- 1. Fecal Hemoglobin Concentration (FHbC) as an Independent Risk Factor for Advanced Adenoma and CRC**
- 2. Utilizing FHbC to Guide Precision Screening Strategies**
- 3. Future Prospects: Risk-adaptive FIT Screening**

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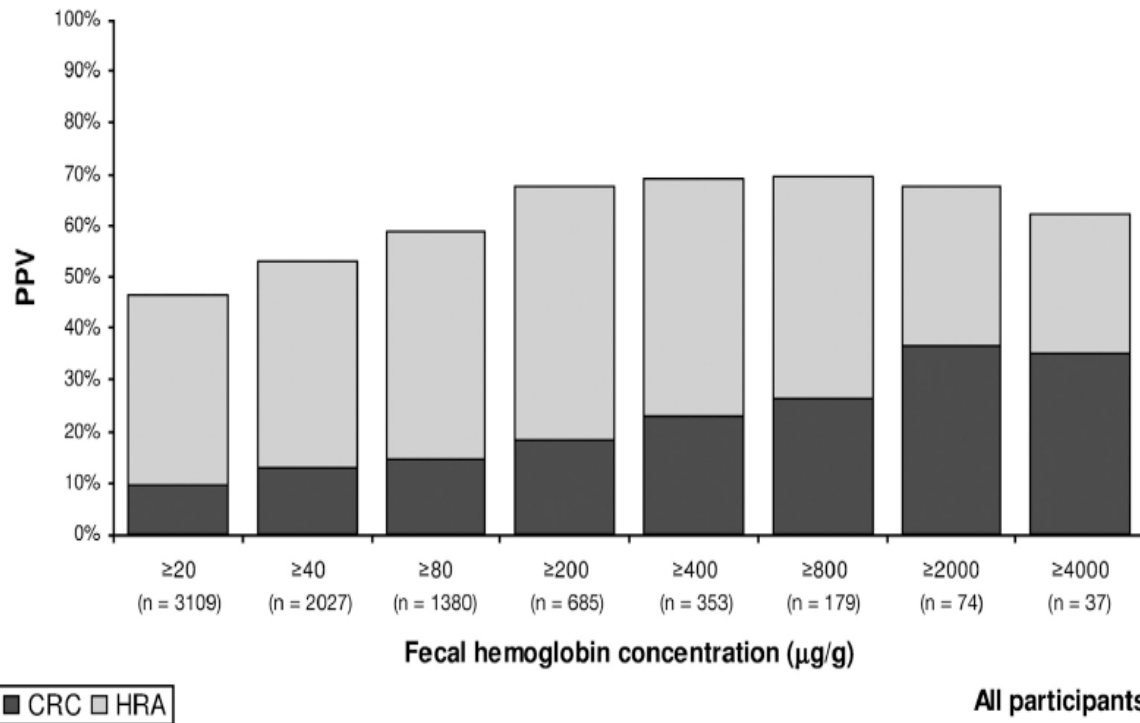
FIT-based CRC Screening Program

– Framework of the Taiwan CRC Screening Program



FHbC is associated with the likelihood of advanced neoplasia at colonoscopy

Barcelona CRC Screening Program

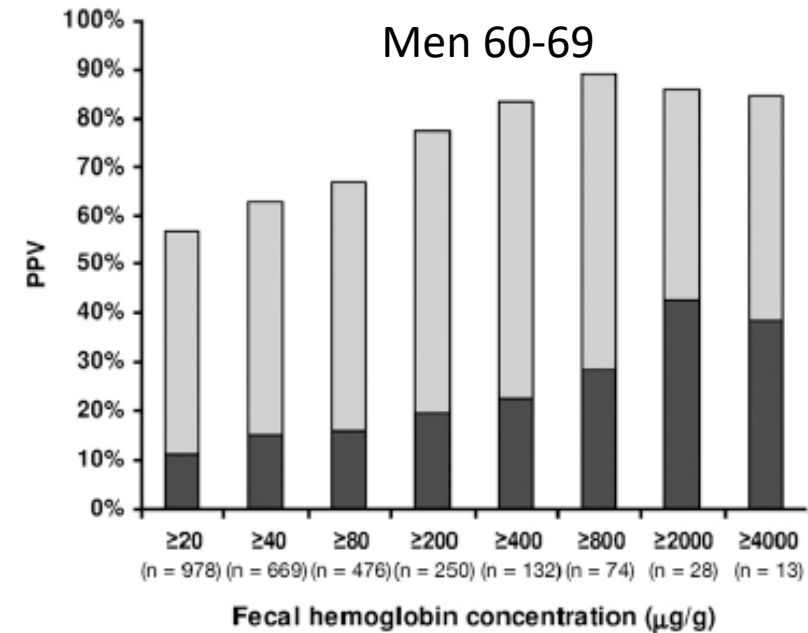
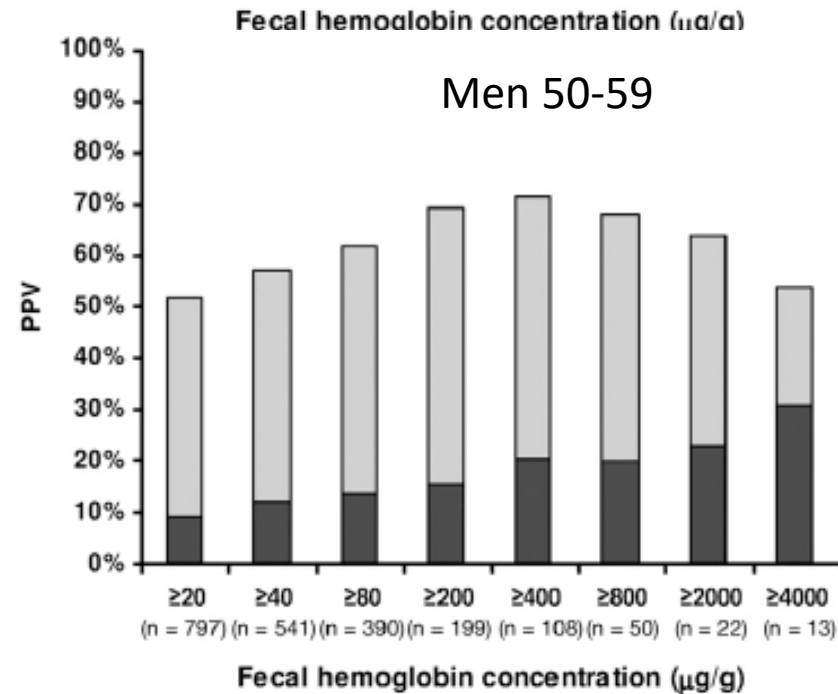
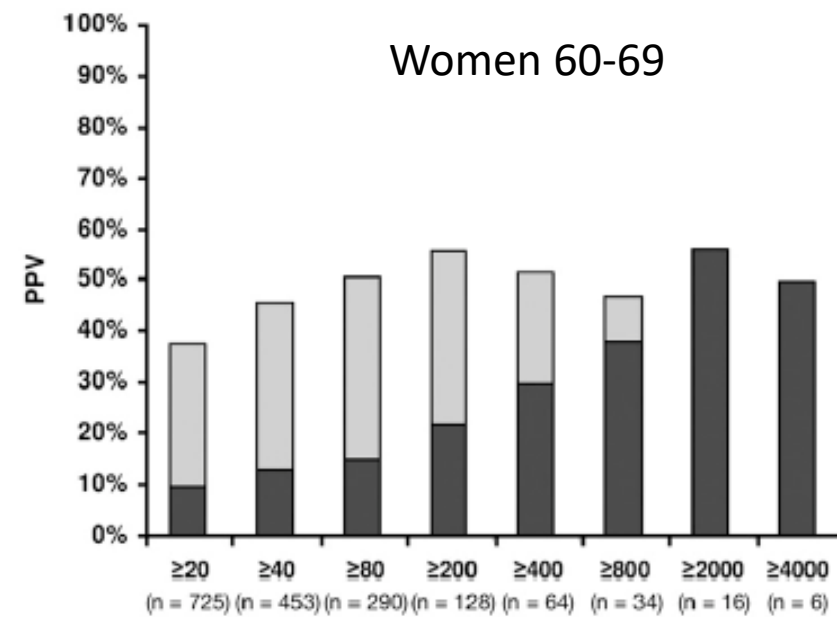
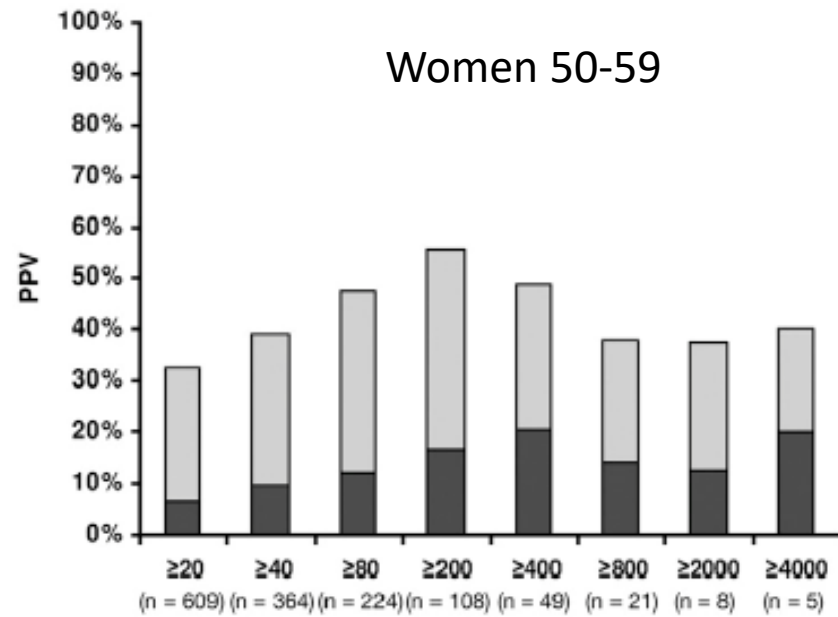


Auge JM, et al. *Gastroenterology* 2014;147:628–636

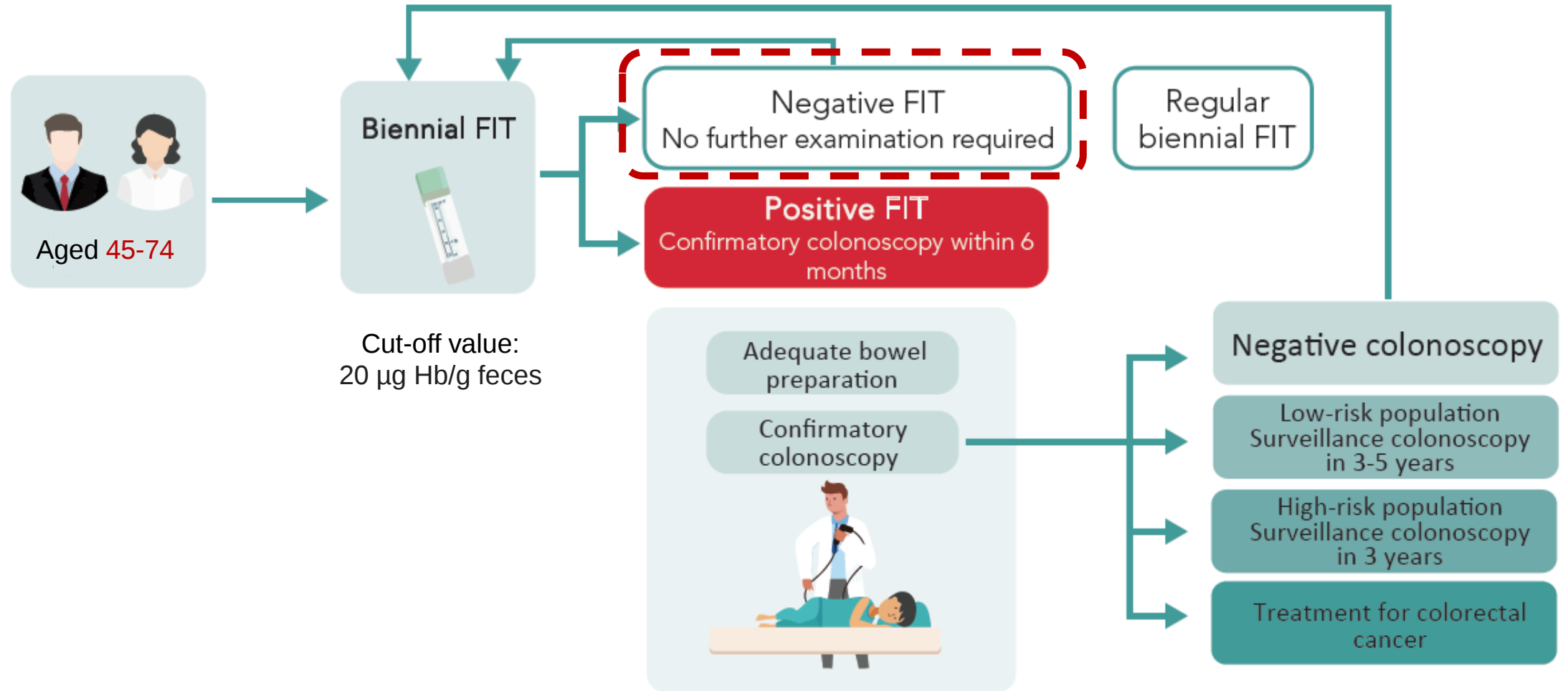
Taiwan CRC Screening Program

FHbC ($\mu\text{g Hb/g feces}$)	PPV for Advanced adenoma, %	PPV for CRC, %
20-49	9.0	2.0
50-99	11.6	3.3
100-149	14.0	5.0
≥ 150	15.9	10.9

Chiu SYH, et al. *Gut* 2017;66:293–300.



FIT-based CRC Screening Program



Negative FIT

– Baseline FHbC predicts the subsequent incidence of colorectal neoplasia

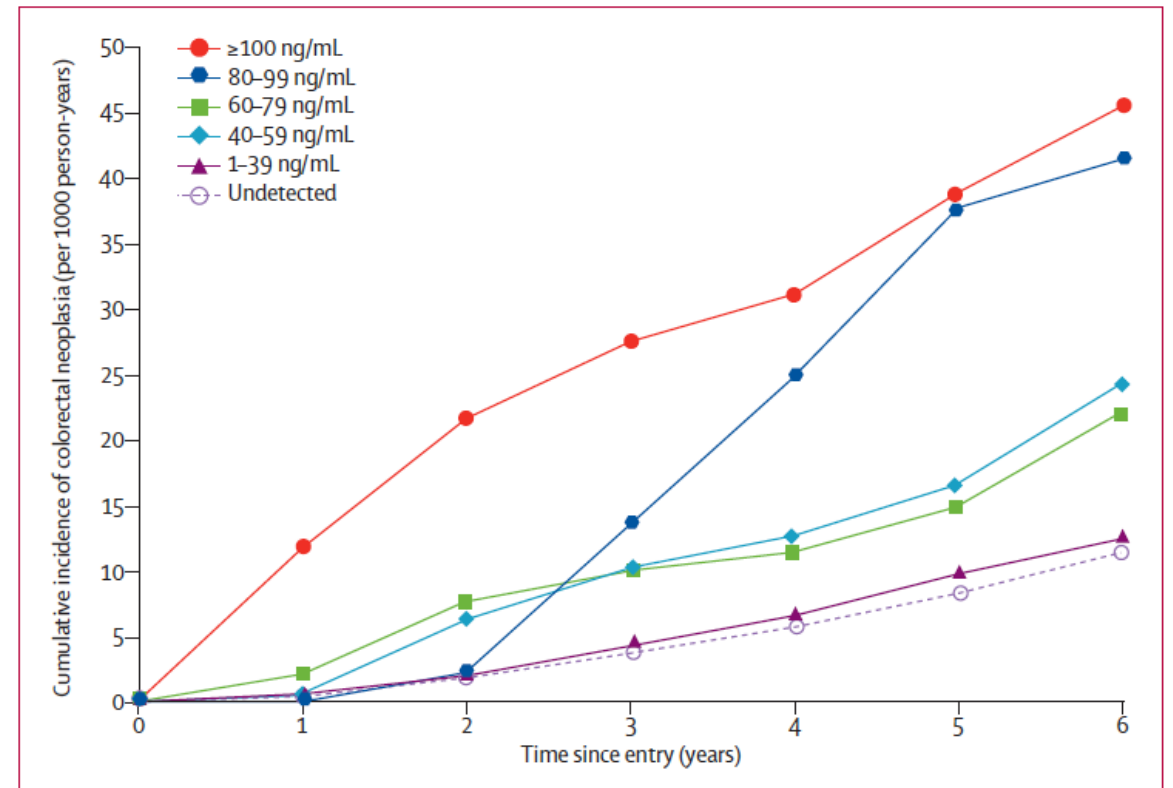


Risk of colorectal neoplasia

Fecal Hb concentration (ng/mL)	aHR
1-19	1.00
20-39	1.43(1.08-1.88)
40-59	1.88(1.31-2.71)
60-79	1.77 (1.06-2.94)
80-99	3.41(2.02-5.75)
≥100	8.46 (6.08-11.76)

Cut-off value: 100ng/mL

Cumulative incidence of adenoma and colorectal cancer by FHbC



Chen LS, et al *Lancet Oncol* 2011; 12: 551–58.

Negative FIT

– Cumulative FHbC predicts AN/CRC risk

Predictors of the DR of CRC and advanced adenoma at the third FIT

		CRC		Advanced adenoma		AN	
		OR	95% CI	OR	95% CI	OR	95% CI
Cumulative f-Hb level at previous 2 FIT tests (FIT1 + FIT2) µg Hb/g faeces	0	1		1		1	
	0.1–3.9	2.26	1.47 to 3.46	1.75	1.47 to 2.07	1.81	1.55 to 2.12
	4–9.9	4.01	2.51 to 6.39	4.64	3.93 to 5.49	4.58	3.91 to 5.36
	10–14.9	10.11	6.04 to 16.93	9.13	7.48 to 11.15	9.32	7.73 to 11.23
	15–19.9	11.63	6.42 to 21.07	12.84	10.32 to 16.00	12.42	10.43 to 15.76
	≥20	38.92	22.50 to 67.31	30.40	24.09 to 38.38	32.52	26.19 to 40.39

AN, advanced neoplasia; CRC, colorectal cancer; DR, detection rate; FIT, faecal immunochemical test.

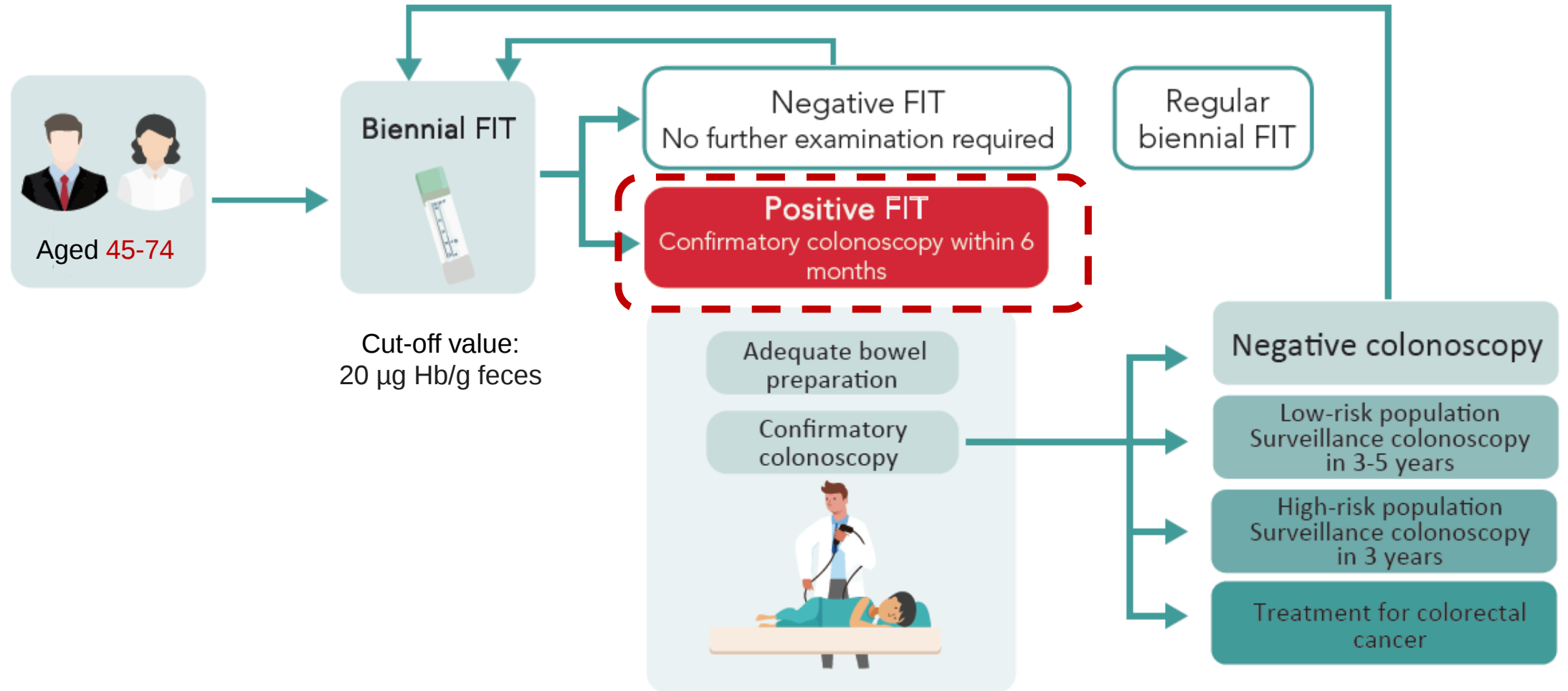
Cumulative DR of an (advanced adenoma or CRC) by cumulative f-Hb concentration over two consecutive FITs and time since the second FIT

µg Hb /g faeces Months	0 % (95% CI)	0.1–3.9 % (95% CI)	4–9.9 % (95% CI)	10–14.9 % (95% CI)	15–19.9 % (95% CI)	≥20 % (95% CI)
24	0.06 (0.05 to 0.08)	0.11 (0.08 to 0.14)	0.38 (0.30 to 0.48)	0.59 (0.41 to 0.84)	0.50 (0.30 to 0.84)	1.30 (0.77 to 2.18)
36	0.44 (0.39 to 0.49)	0.78 (0.70 to 0.87)	1.98 (1.78 to 2.21)	4.24 (3.67 to 4.90)	0.57 (0.48 to 0.67)	14.33 (12.14 to 16.88)
48	0.53 (0.48 to 0.59)	0.90 (0.81 to 0.99)	2.27 (2.04 to 2.52)	4.71 (4.10 to 5.41)	6.84 (5.84 to 8.00)	16.08 (13.70 to 18.82)
54	1.41 (1.27 to 1.57)	1.90 (1.71 to 2.11)	4.79 (4.30 to 5.34)	8.65 (7.44 to 10.06)	11.97 (10.13 to 14.13)	25.46 (21.38 to 30.15)

CRC, colorectal cancer; DR, detection rate; f-Hb, faecal haemoglobin.

Senore C, et al. Gut 2019;69:523–530.

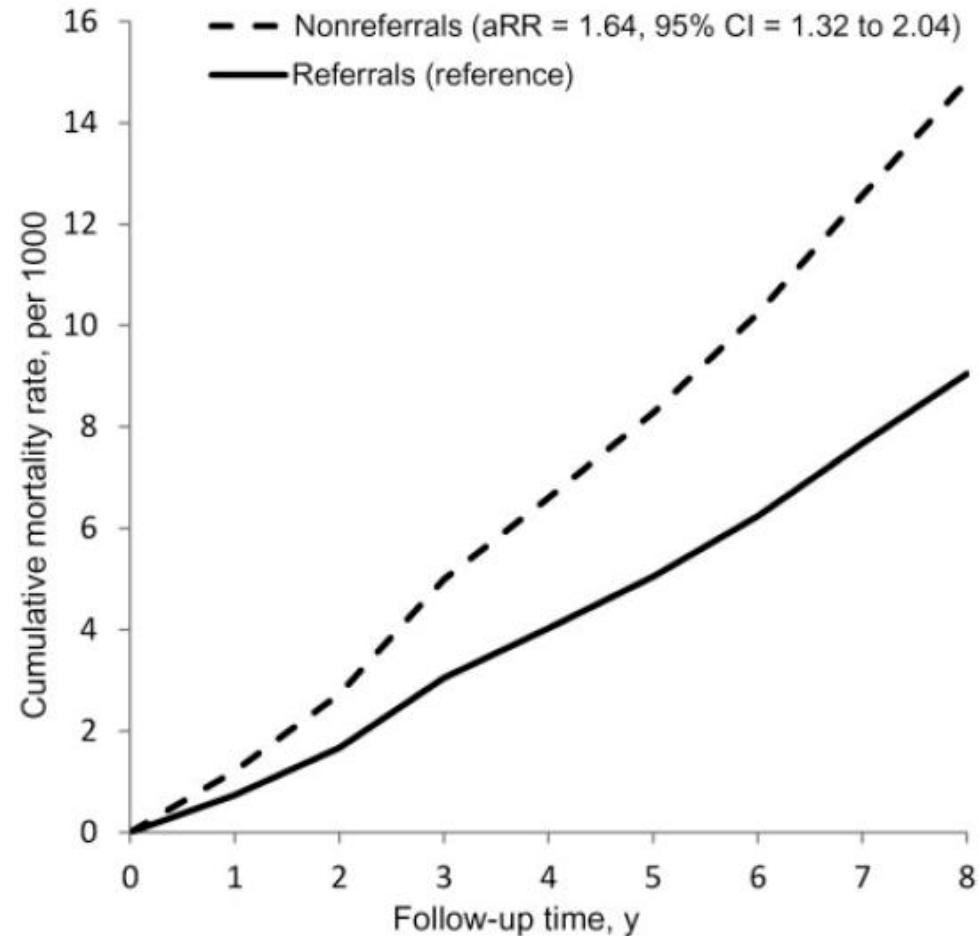
FIT-based CRC Screening Program



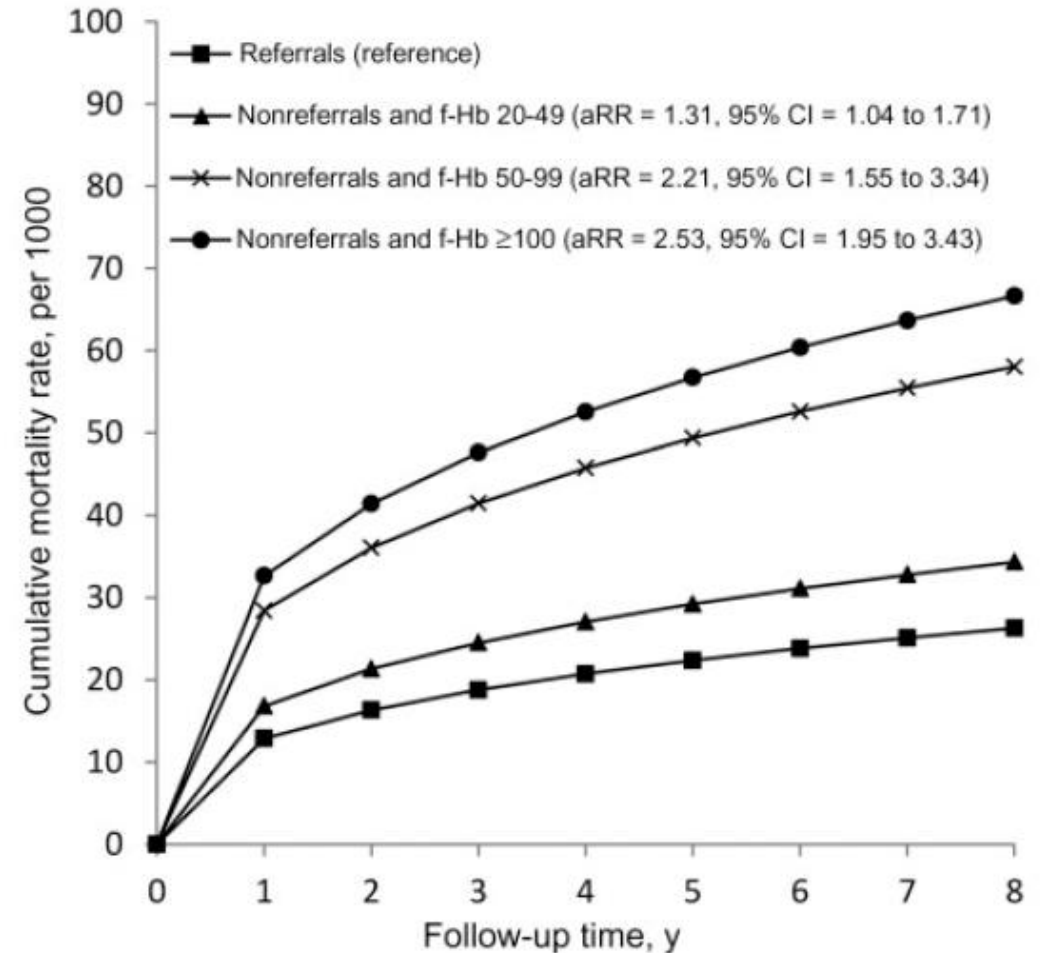
Positive FIT

– Higher FHbC is linked to increased CRC mortality among non-compliers

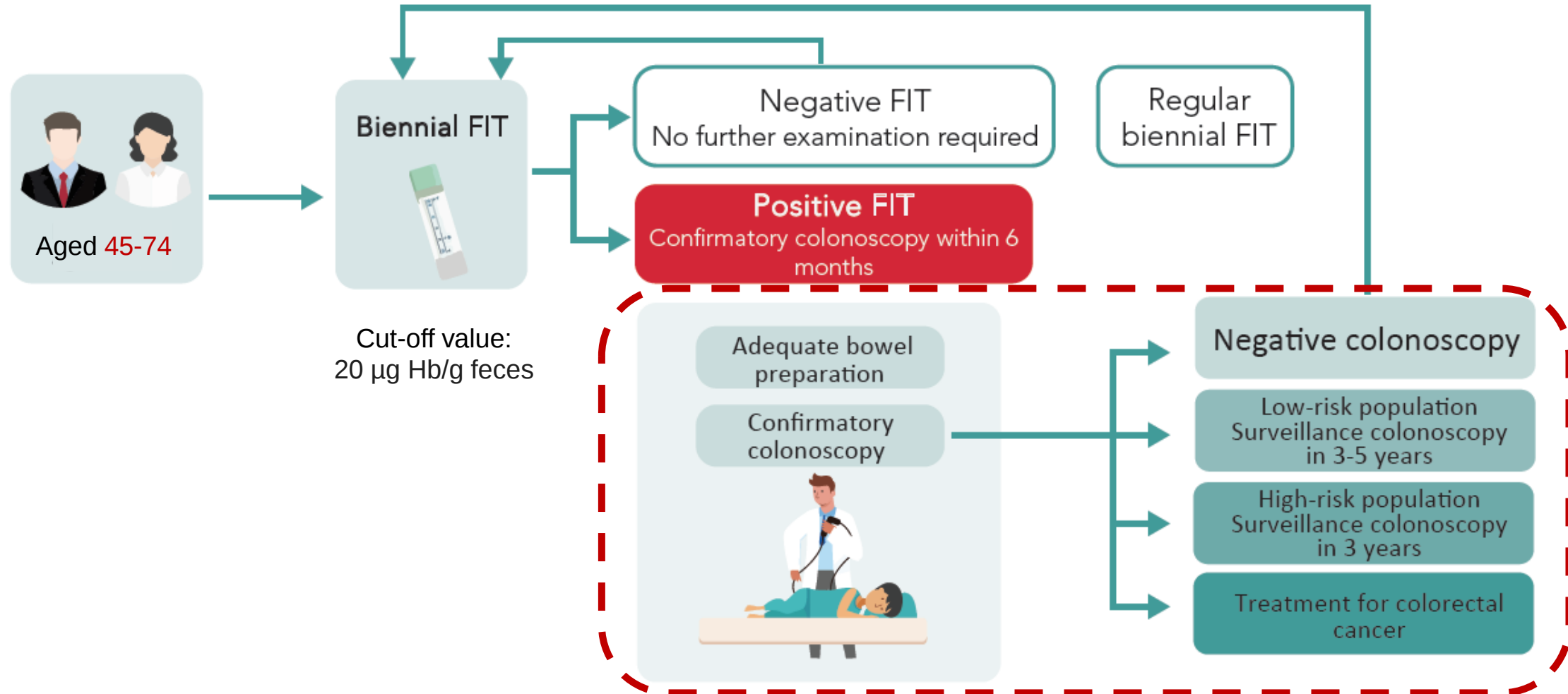
Cumulative mortality of colorectal cancer



Cumulative mortality rates of the non-referral group

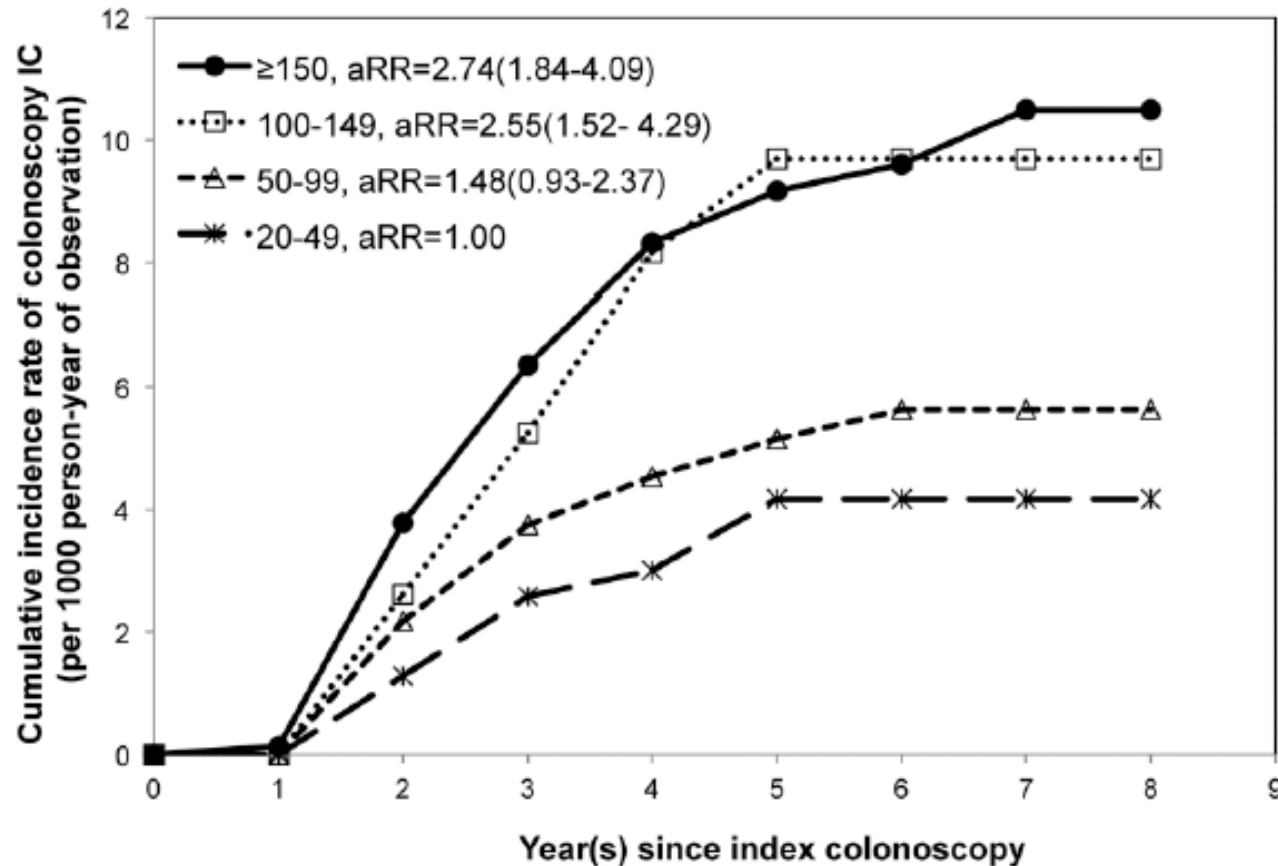


FIT-based CRC Screening Program

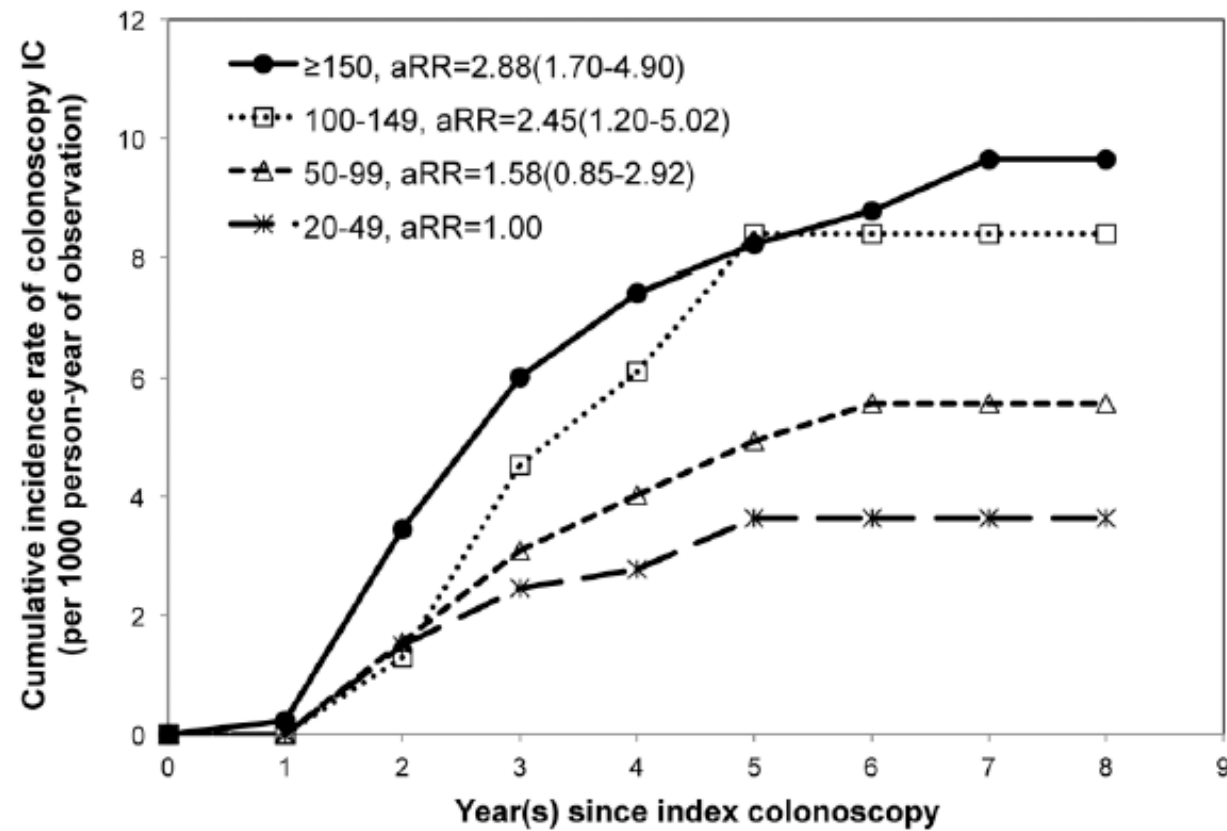


Positive FIT

– Risk of Post-colonoscopy CRC in relation to FHbC



All colonoscopy



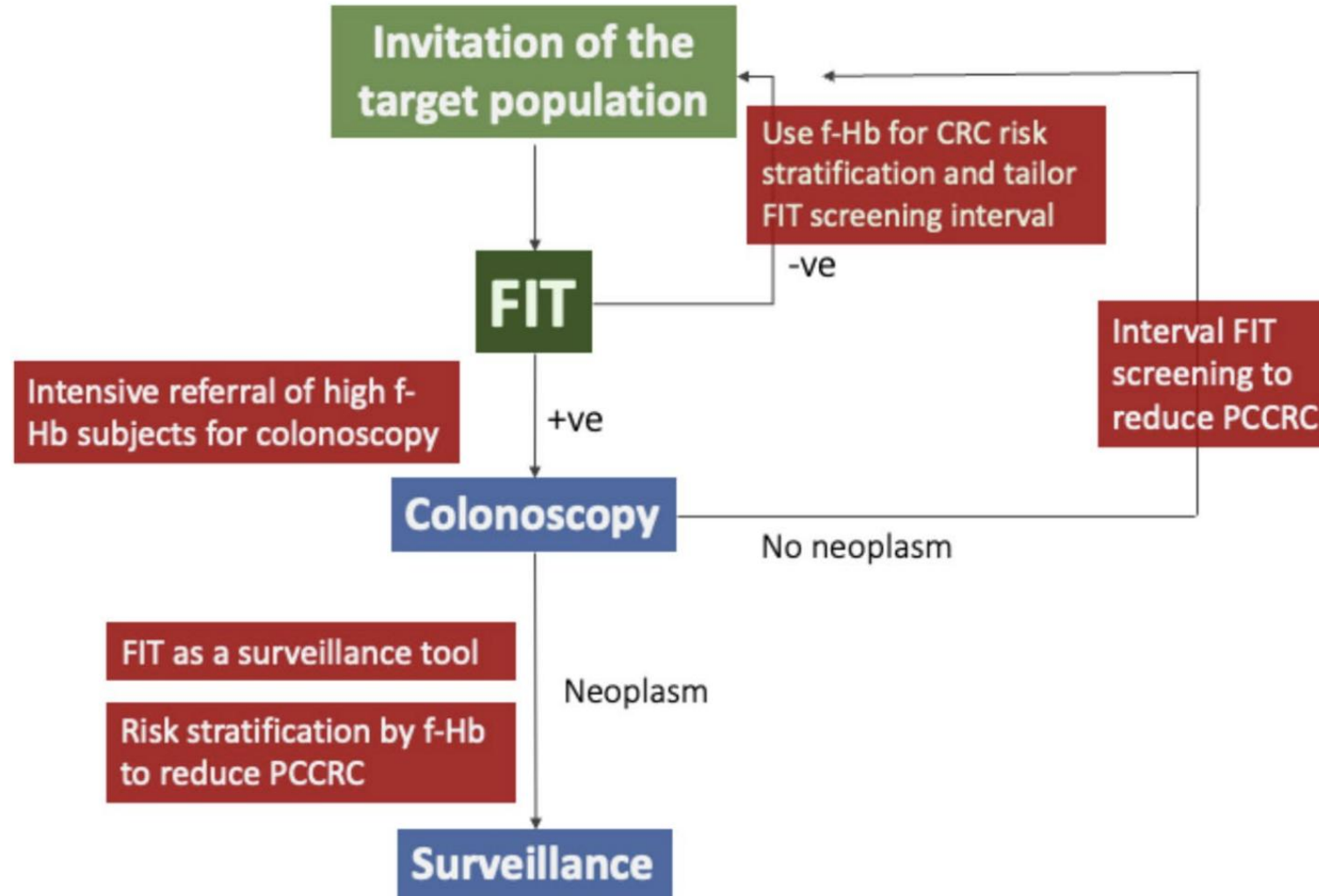
Negative colonoscopy

Negative Colonoscopy

– *Risk of subsequent incident CRC*

FHbC (µg hemoglobin/g faces)	HR	aHR
20-39	Ref	Ref
40-59	1.98(1.07-3.66)	1.94(1.05-3.58)
60-99	1.00 (0.47-2.11)	0.95(0.45-2.01)
100-149	2.40(1.23-4.70)	2.28(1.17-4.46)
≥150	2.59(1.54-4.37)	2.46(1.45-4.15)

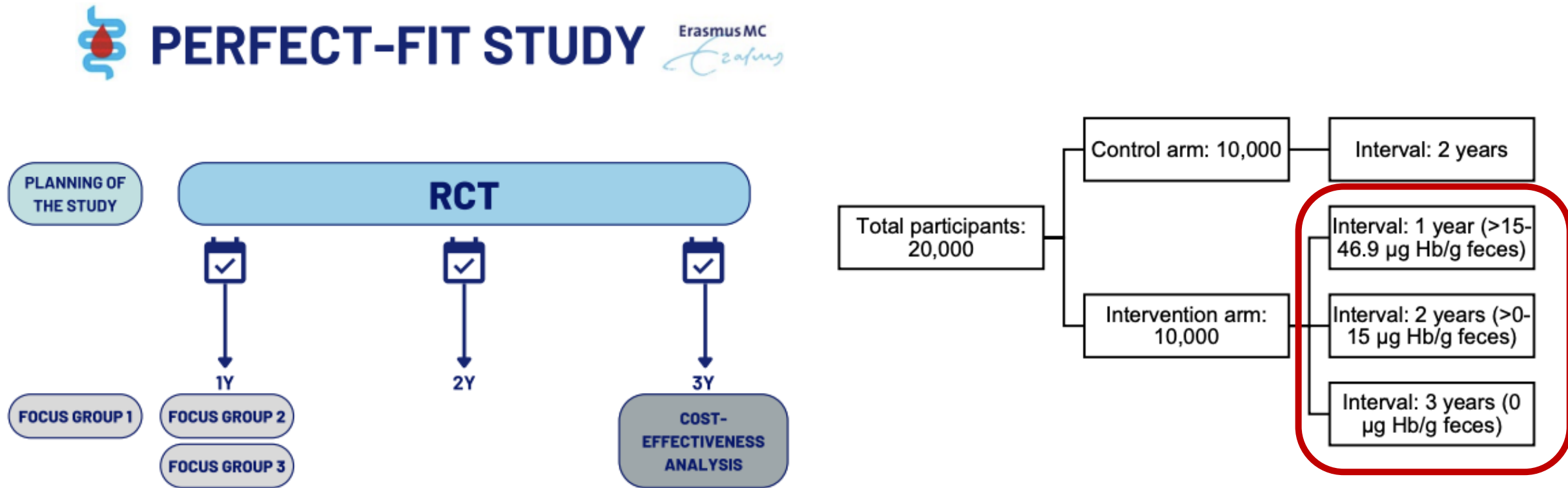
FHbC as a Tool for Precision CRC Screening



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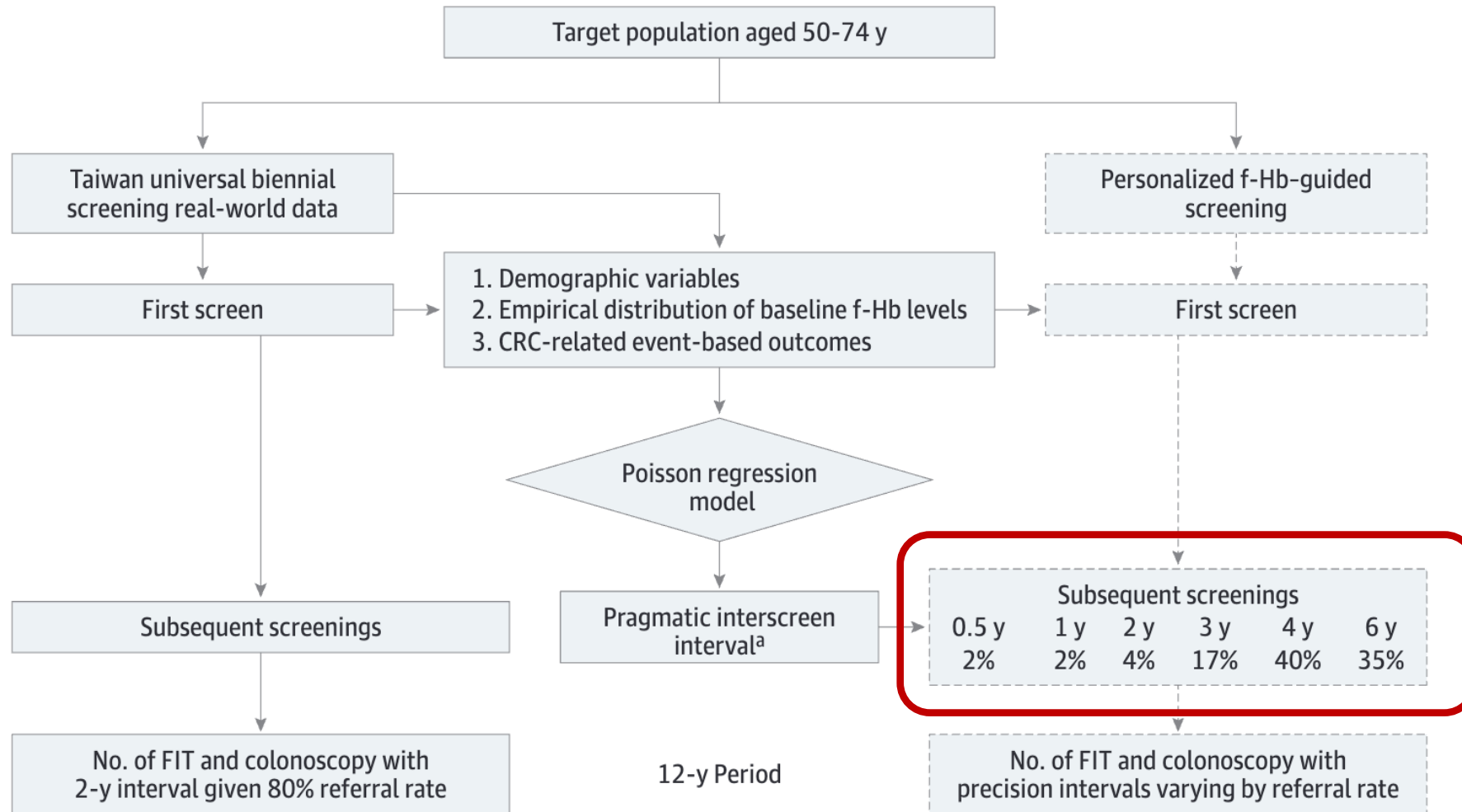
Risk-tailored inter-screening interval using FHbC – *PERFECT-FIT*



The Dutch National CRC Screening Program

Risk-tailored inter-screening interval using FHbC

– Empirical data from the Taiwan CRC Screening Program



Relative Risk of CRC Death and Precision Inter-screening Intervals Determined by FHbC

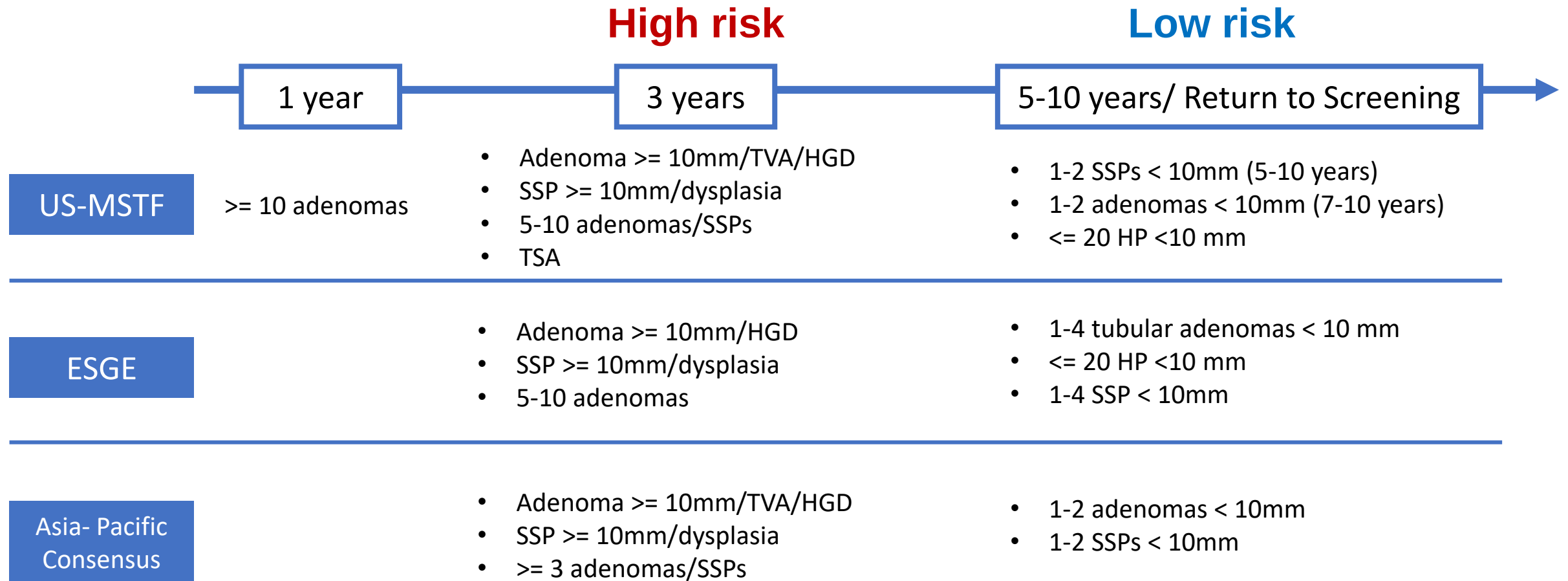
f-Hb, µg Hb/g	Relative risk	Screening interval, y	
		Theoretical recommendation	Pragmatic recommendation
Undetected	0.33	6.00	6
1-9	0.47	4.22	4
10-19	0.53	3.75	3
20-49	1.00	2.00	2
50-99	1.67	1.20	1
100-149	1.68	1.19	1
≥150	4.68	0.43	0.5

Tailored vs. universal intervals

– FIT and colonoscopy utilization

Variable	No.	f-Hb-guided personalized CRC screening		
	Universal biennial screening			100% Referral rate
		60% Referral rate	80% Referral rate	
Tests	19 917 993	10 233 766	NA	NA
Reduction in tests	1 [Reference]	9 684 228	NA	NA
Reduction in tests, %	1 [Reference]	49	NA	NA
Colonoscopies	1 279 680	686 570	915 427	1 144 284
Reduction in colonoscopies	1 [Reference]	593 110	364 253	135 396
Reduction in colonoscopies, %	1 [Reference]	46	28	11

Current Global Surveillance Guidelines



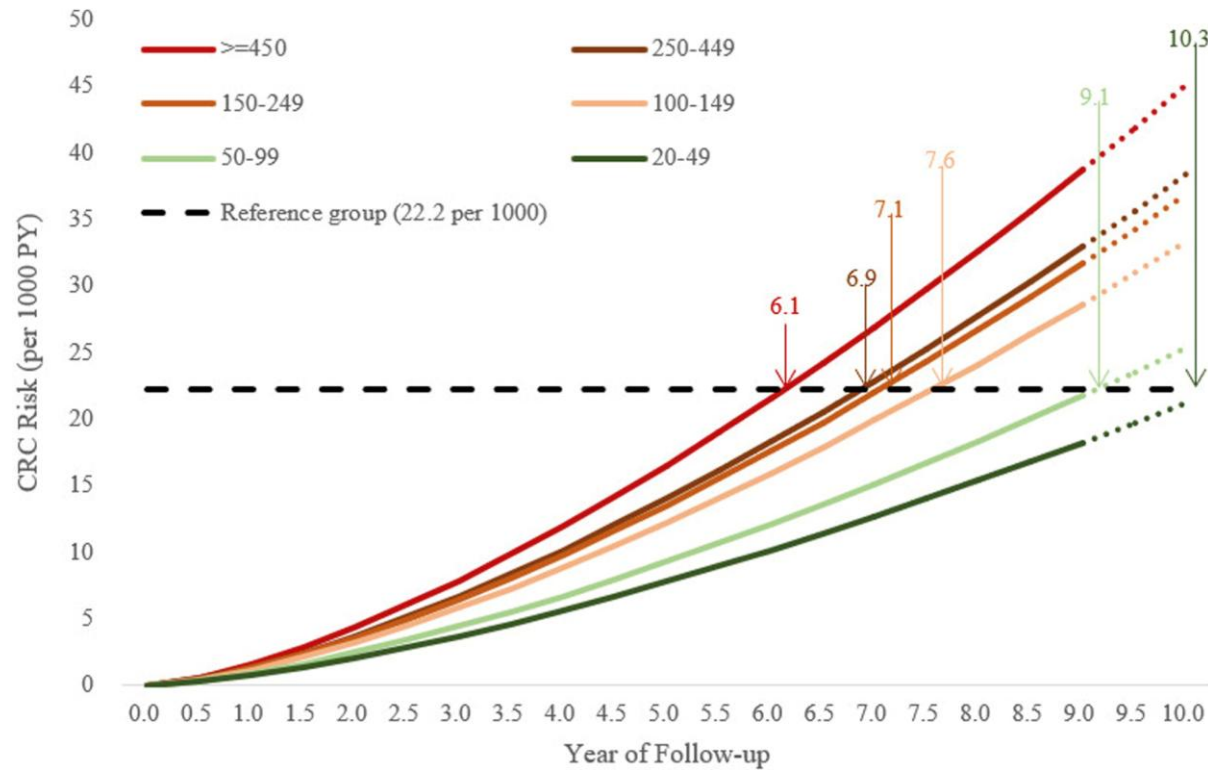
*TVA=Tubovillious adenoma, HGD=High- grade Dysplasia, SSP= Sessile serrated polyp, TSA=Traditional Serrated adenoma, HP=Hyperplastic polyp

**ESGE, European Society of Gastrointestinal Endoscopy; USMSTF, US Multi-Society Task Force.

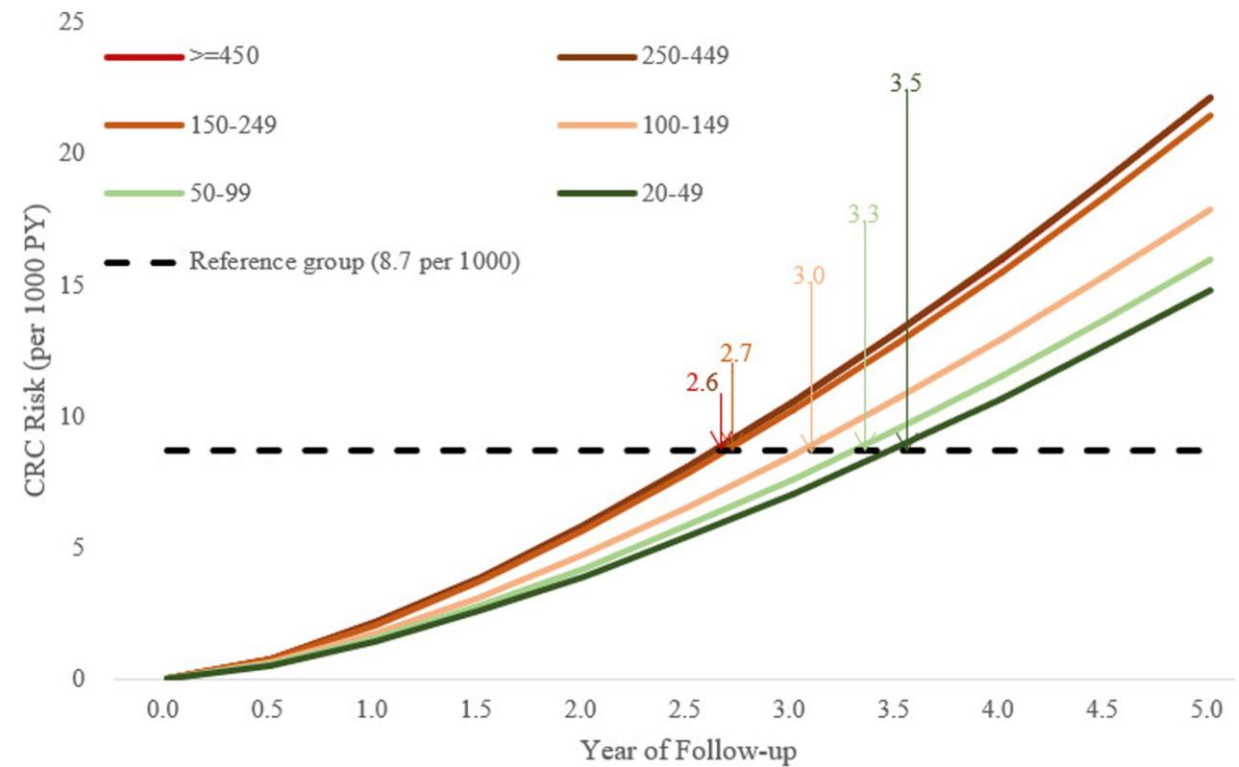
Cumulative CRC Risk by FHbC Level in Low- and High-Risk Adenomas



Low risk



High risk



Pragmatic Intervals by FHbC Level for Low- and High-Risk Adenomas Within the USMSTF Guideline

FHbC Level	Estimated Risk, aHR (95%CI)		Average hazard approach interval (Years)	
	Low-risk	High-risk	Low-risk	High-risk
20-49	Reference	Reference	11	3
50-99	1.19 (0.95-1.51)	1.08 (0.89-1.32)	9	3
100-149	1.57 (1.18-2.08)	1.21 (0.95-1.54)	7	2
150-249	1.74 (1.32-2.28)	1.45 (1.17-1.80)	6	2
250-449	1.80 (1.30-2.50)	1.50 (1.16-1.93)	6	2
>=450	2.12 (1.62-2.77)	1.50 (1.20-1.86)	5	2
Current Suggestion			7-10	3

Future Surveillance Intervals and Colonoscopy Capacity

– *Personalized Strategy vs. Current Recommendation*

Strategy	Colonoscopy capacity requirement	Reduction in CRC risk for subjects with f-Hb > 250 µg Hb/g feces		Change in colonoscopy capacity requirement (%)
Current guidelines	177,766	-		Reference
Personalized strategy	160,316	Low-risk	↓ 4.8% (CI: 3.8%- 5.7%)	↓ 17,689 (↓39.0%)
		High-risk	↓ 8.7% (CI: 8.0%- 9.5%)	↑ 239 (↑ 0.2%)
		Overall	↓ 6.7% (CI: 6.3%- 7.1%)	↓ 17,450 (↓9.8%)

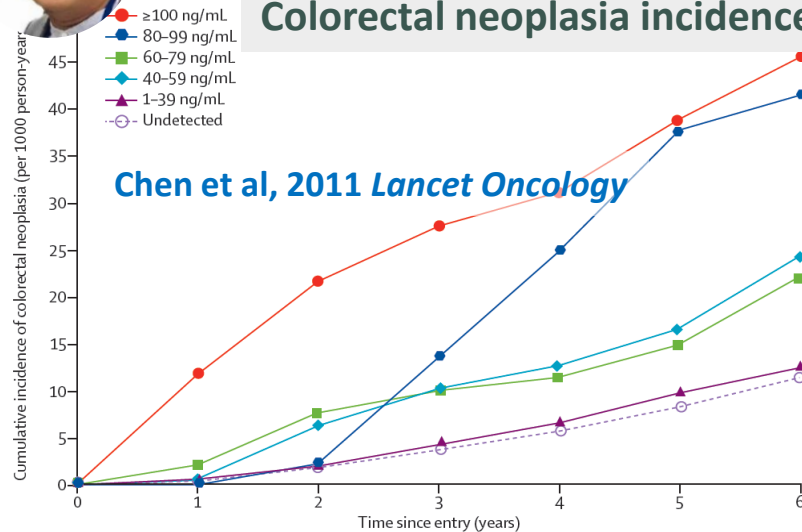
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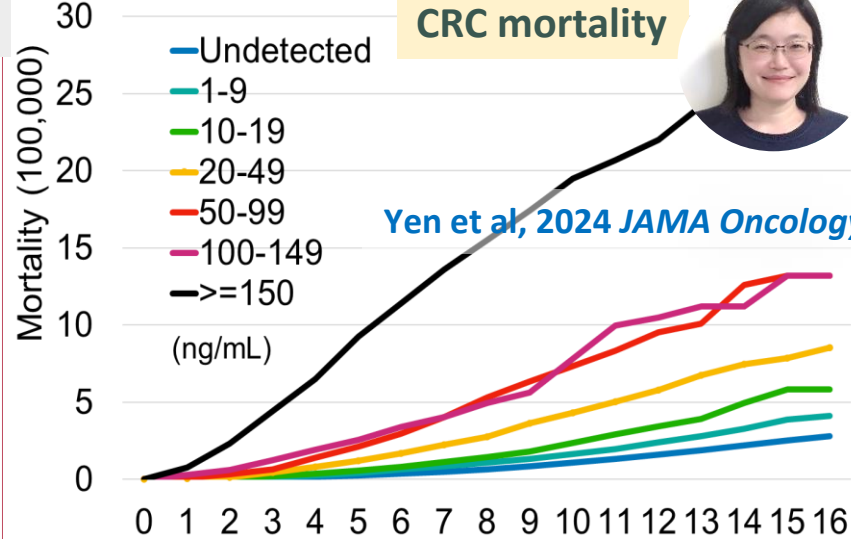
Evolution from Qualitative to Quantitative FIT



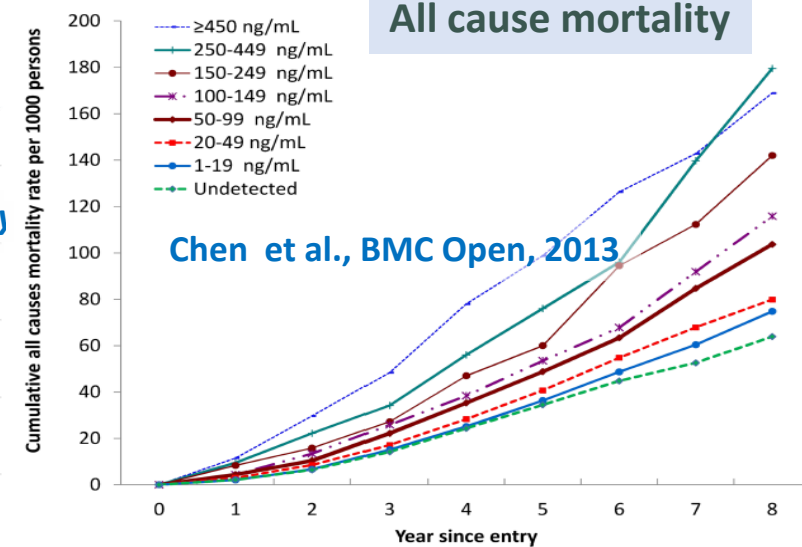
Colorectal neoplasia incidence



CRC mortality



All cause mortality



Chen, 2011		Taiwan
Chen, 2013		Taiwan
Digby, 2017		Scotland
Grobbee, 2017		Netherlands
Gibson, 2019		Ireland
Burón, 2019		Spain
Kim, 2019		Korea
Senore, 2020		Italy

Senore, 2020		Italy
Balamou, 2021		France
Meester, 2022		Netherlands
Breekveldt, 2023		Netherlands
Deding, 2023		Denmark
Digby, 2023		Scotland
Ribe, 2023		Norway
Yen et al, 2024		Taiwan

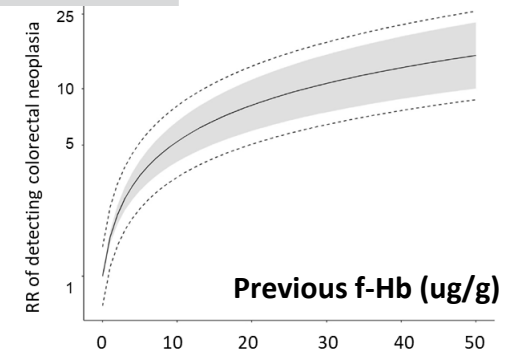
Prior f-Hb concentration	Pooled RR (95% CI)				
	Any colorectal neoplasia (all 13 studies)	Advanced neoplasia	CRC	Advanced adenoma	Advanced adenoma + early-stage CRC
0	1.0	1.0	1.0	1.0	1.0
5	3.4 (2.8–4.1)	4.3 (3.5–5.3)	3.8 (3.0–4.8)	4.5 (3.3–6.1)	4.4 (2.9–6.8)
10	5.2 (4.0–6.6)	7.0 (5.3–9.3)	6.1 (4.4–8.2)	7.5 (5.0–11.2)	7.3 (4.1–13.0)
15	6.7 (5.0–8.9)	9.5 (6.8–13.1)	8.0 (5.6–11.5)	10.3 (6.5–16.4)	11.0 (5.2–19.4)
20	8.1 (5.9–11.1)	11.8 (8.3–16.9)	9.8 (6.6–14.6)	12.9 (7.7–21.6)	12.5 (6.1–26.0)
40	12.8 (8.7–18.8)	20.3 (13.2–31.4)	16.2 (10.1–26.2)	22.7 (12.1–42.4)	21.9 (9.0–53.1)

Gastroenterology 2025;168:587–597

PREVENTION AND EARLY DETECTION

Fecal Hemoglobin Levels in Prior Negative Screening and Detection of Colorectal Neoplasia: A Dose-Response Meta-Analysis

Danica M. N. van den Berg,¹ Rosita van den Puttelaar,¹ Lucie de Jonge,¹ Iris Lansdorp-Vogelaar,¹ and Esther Toes-Zoutendijk¹



Precision inter-screening intervals by clinical scenario



FIT IC



FIT-Negative

6

3

2

N/A

N/A

N/A

N/A

PCCRC



Normal Colonoscopy
(High ADR)

N/A

N/A

N/A

10

10

10

6



Normal Colonoscopy
(Low ADR)

N/A

N/A

N/A

10

10

6

2

Non-complier



Colonoscopy
non-complier

N/A

N/A

N/A

10

6

4

<1

Surveillance



Low-risk
Adenoma

N/A

N/A

N/A

10

9

7

6



High-risk
Adenoma

N/A

N/A

N/A

3

3

3

2



FHbC Tiers

($\mu\text{g/g}$)

<10

10-14

15-19

20-49

50-99

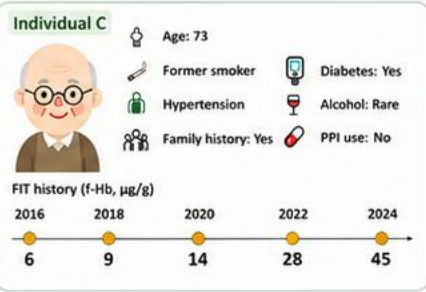
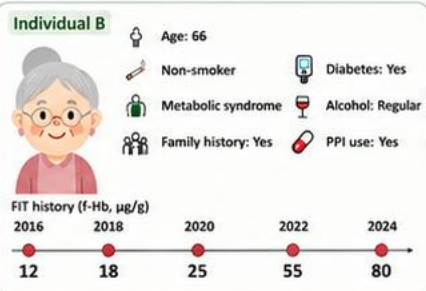
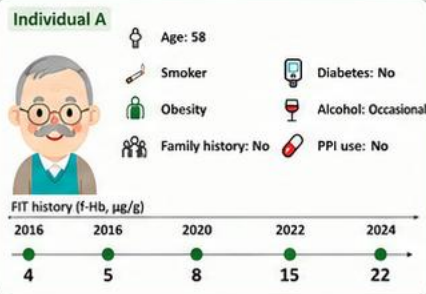
100-149

≥ 150

Reinforcement Learning for Adaptive CRC Screening

1. Physical Data Layer

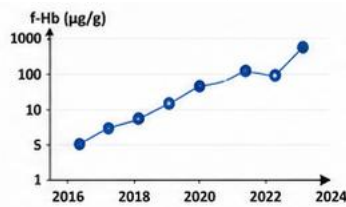
Individuals with personal features & longitudinal FIT history



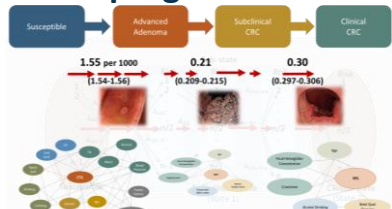
2. Computational Layer

Digital Twin: personalized risk modelling (Dynamic FIT + Features)

Dynamic f-Hb trajectory

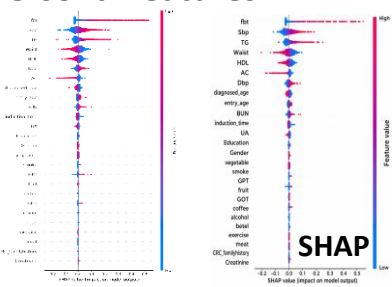


Disease progression



Deep Learning Bayesian Network

Personal features



3. Decision-supported Layer

(eg. Inter-screening Interval & Emerging detection modality)

Dynamic f-Hb concentration ($\mu\text{g/g}$)

	<10	10-14	15-19	20-49	50-99	100-149	≥ 150
Extremely High Risk	Surveillance (<1 year)	1 year	1 year	1 year	1 year	<1 year	<1 year
High Risk	2 years	2 years	1-2 years	1-2 years	1 year	1 year	<1 year
Moderate Risk	3 years	3 years	2-3 years	2 years	1-2 years	1-2 years	1 year
Low Risk	6 years	6 years	3-6 years	3 years	2-3 years	2 years	1-2 years
Extremely Low Risk	6 years	6 years	6 years	6 years	3-6 years	3 years	2-3 years

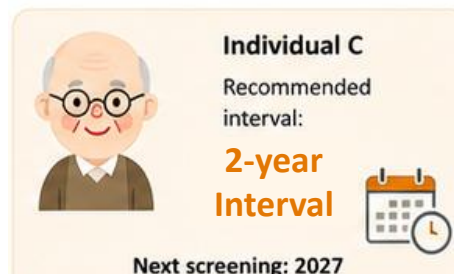
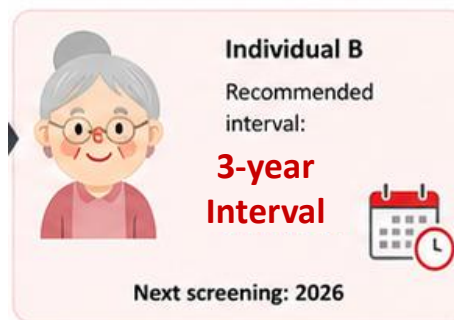
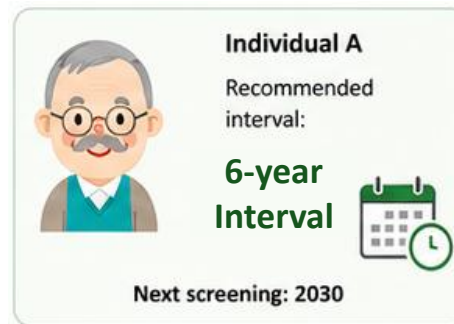
Longer interval (lower risk)

Shorter interval (higher risk)

Notes:

- Risk score is derived from the Bayesian Network (personal features).
- f-Hb trajectory is dynamically updated over time.
- Map is learned from the Digital Twin (multistate model).
- Interval recommendations balance benefit, harm, and resource use.

4. Personalized Service Layer



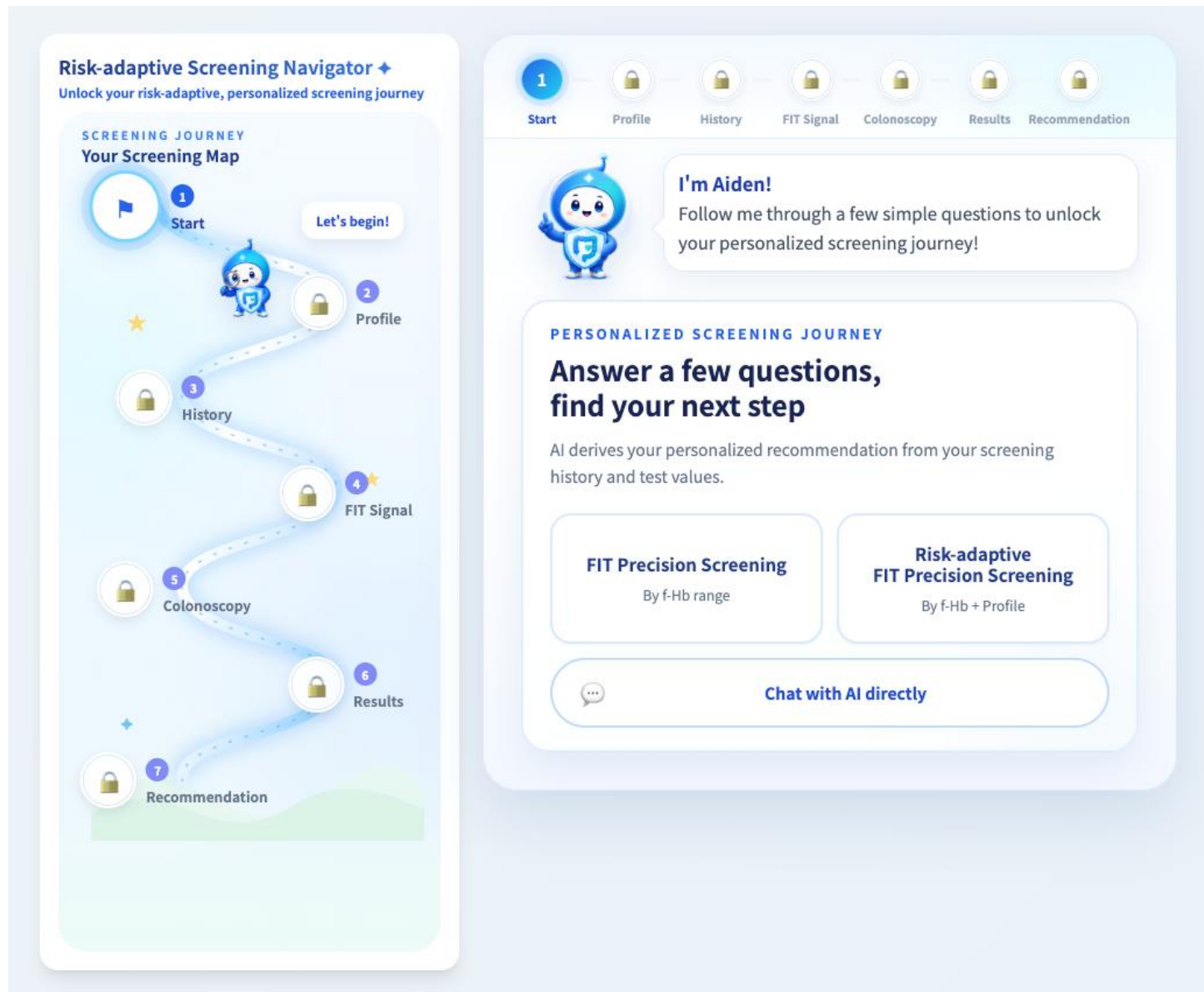
Reinforcement Learning



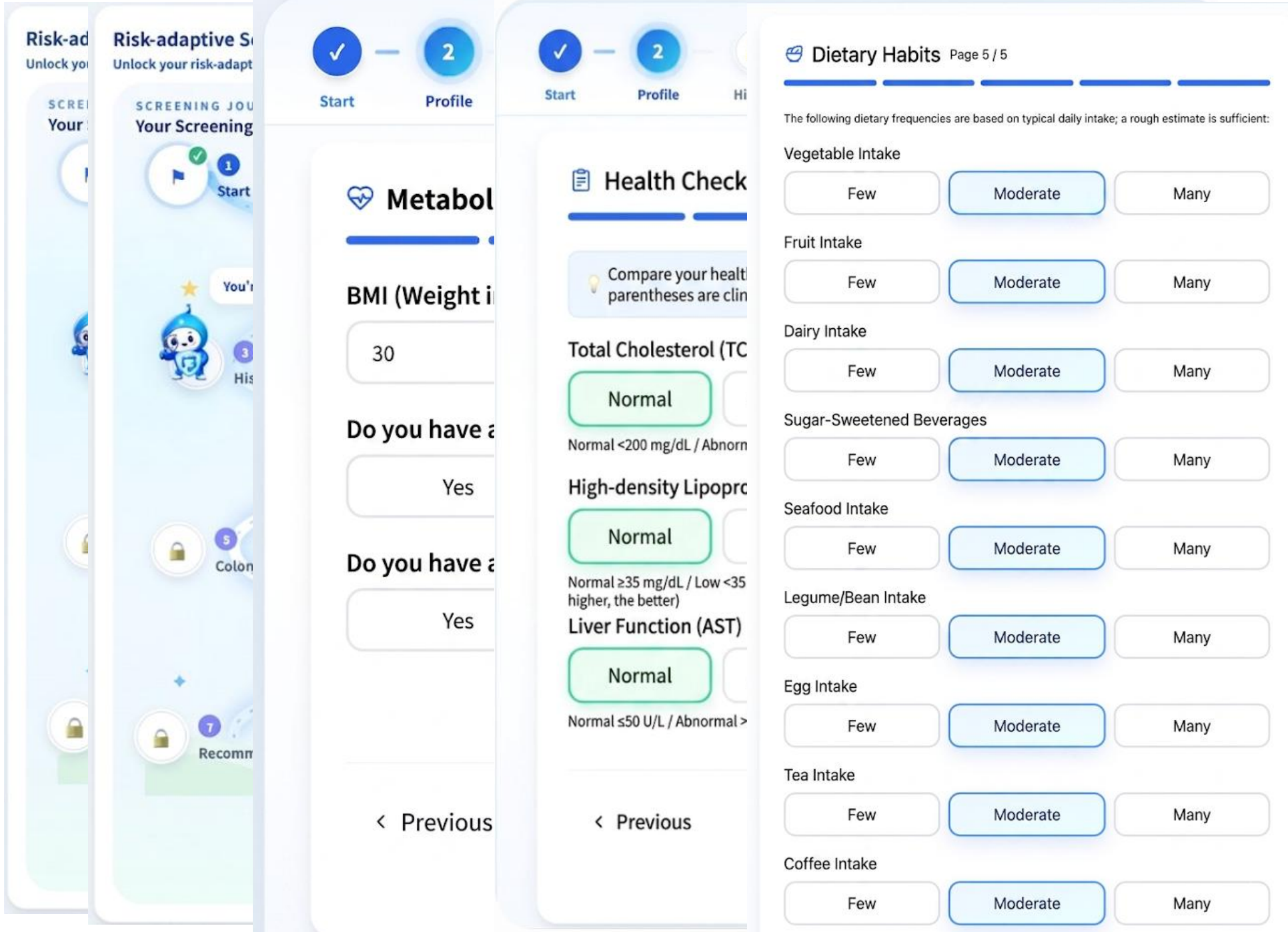
5. Intervention Layer

Primary Prevention and Surveillance & Early awareness of CRC

Risk-adaptive FIT Screening



Negative FIT,
Low f-Hb:
A Longer,
Personalized
Interval



Dietary Habits Page 5 / 5

The following dietary frequencies are based on typical daily intake; a rough estimate is sufficient:

Vegetable Intake

Few	Moderate	Many
-----	----------	------

Fruit Intake

Few	Moderate	Many
-----	----------	------

Dairy Intake

Few	Moderate	Many
-----	----------	------

Sugar-Sweetened Beverages

Few	Moderate	Many
-----	----------	------

Seafood Intake

Few	Moderate	Many
-----	----------	------

Legume/Bean Intake

Few	Moderate	Many
-----	----------	------

Egg Intake

Few	Moderate	Many
-----	----------	------

Tea Intake

Few	Moderate	Many
-----	----------	------

Coffee Intake

Few	Moderate	Many
-----	----------	------

Negative FIT, Low f-Hb: A Longer, Personalized Interval

Step 3 • FIT Signal

What was your most recent FIT result?

Understanding your situation helps us give more precise advice

✓

Negative
Normal value, no referral

>

!

Positive
Referred for colonoscopy

>

#

I have a value to enter

>

µg Hb/g

OC-Sensor

HM-Jack

f-Hb value input

8 µg Hb/g

0

20

50

150

200+

This value is in the negative range

< Back

Next >

✓ **Personalized Recommendation**

Recommended next **FIT Test** interval:

6 years

Next FIT Test: in about 6 years

Personalized risk assessment

Moderate

Your personalized

Population average

6 yr

6 yr

AI Explanation

Hello! It looks like you've received your personalized recommendation for colorectal cancer screening, and I'm here to help you understand what it means for you. Your fecal hemoglobin (f-Hb) level is 8.0 µg/g, which is considered negative and falls within a safe range. The personalized screening interval suggested for you is six years, which aligns with the average recommendation for people with the same f-Hb levels. This means that while your personal risk is categorized as moderate, it's reassuring that you don't need more frequent screenings than usual.

This recommendation is not just based on your f-Hb result but also considers various factors unique to you, such as your age, lifestyle, and family history. The fact that your recommended interval matches the average indicates that your overall risk is comfortably moderate. Your small adenoma risk is estimated to be about 0.29%, which is slightly higher than the average of 0.24% for people in your f-Hb range. However, this is still within a range that allows for a standard six-year interval before your next fecal immunochemical test (FIT).

Practically speaking, you should feel confident following this recommendation. Since your interval is the same as the average, there's no need for extra caution beyond what's advised. This means you can stick with the six-year interval and enjoy peace of mind knowing that your screening schedule is tailored to fit your individual risk profile. If you have any **concerns** or changes in your health, don't hesitate to discuss them with your healthcare provider, but for now, you can feel assured with this thoughtful and precise approach to your health.

Positive FIT, High f-Hb: Closer, Personalized Surveillance

μg Hb/g OC-Sensor HM-Jack

f-Hb value input

170 μg Hb/g

0 20 50 150 200+

Positive — colonoscopy referral recommended

◀ Back

Next ▶

Step 5 • Result Analysis (cont.) ⚡

Adenoma details?

◇ Understanding your situation helps us give more precise advice

If unsure, that's fine — AI uses the most conservative judgment.



≥10mm / Villous / ≥3 polyps

Any one qualifies as high-risk



<10mm, non-villous, and <3 polyps

Low-risk adenoma



Not sure

Conservative judgment (high-risk)



◀ Back



AI Screening Assistant

High-risk Adenoma Surveillance



Personalized Surveillance Recommendation

Recommended next **Colonoscopy** interval:

2 years

🕒 Next Colonoscopy: in about 2 years

🔍 AI Explanation

Your next colonoscopy is scheduled for 2 years from now. This interval is based on the need for surveillance following the removal of a high-risk adenoma. Regular surveillance is essential to monitor and ensure any potential issues are caught early, significantly reducing the risk of colorectal cancer. Keep up with these screenings, as they are vital for your long-term health.

Challenges and Future Directions

- **Public acceptability** remains unclear:

Clear, personalized communication supports informed decisions (e.g., longer screening intervals for low-risk populations).

Toes-Zoutendijk E, et al. Prev Med Rep. 2023.

- **Notification of FHbC** to screening participants

- **Effectiveness and cost-effectiveness** remain unclear:

Precision strategies enhance outcomes; cost-effectiveness is still under evaluation.

Conclusions

- FHbC is a **CHEAP** and **USEFUL** biomarker for risk stratification in the FIT screening program
- FHbC can power **risk-adaptive FIT screening** — from screening to surveillance

Thanks for your attention

