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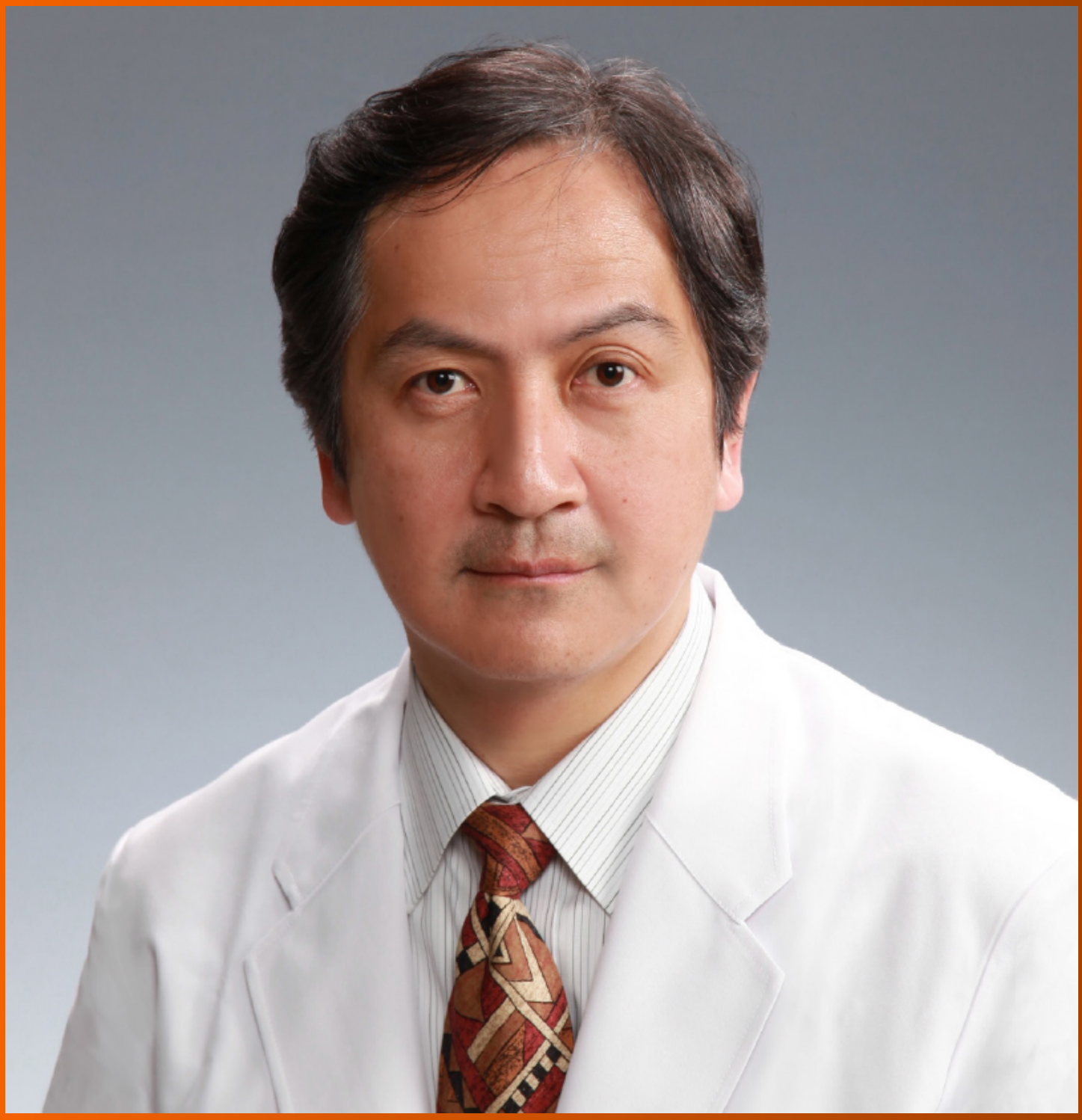

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ABOUT COVER

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ORIGINAL ARTICLE

Observational Study

Prediction of the severity of colorectal lesion by fecal hemoglobin concentration observed during previous test in the French screening program

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Author contributions: The study was conceived and designed by Balamou C and Koïvogui A; the data was acquired and collated by Balamou C, Clerc A, Piccotti C, Deloraine A, and Exbrayat C; the data were analyzed by Balamou C, Koïvogui A, and Rodrigue CM; the study was drafted and revised critically by all authors; All authors gave final approval of the version to be published and have contributed to the study.

Institutional review board statement: This study is co-signed by the heads of the structures involved, as such, no further Institutional Review Board was required.

Informed consent statement: Patients were not required to give informed consent to the study because the analysis used anonymous data that was obtained

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Abstract

BACKGROUND

The rate of positive tests using fecal immunochemical test (FIT) does not decrease with subsequent campaigns, but the positive predictive value of advanced neoplasia significantly decreases in subsequent campaign after a first negative test. A relationship between the fecal hemoglobin concentration (Fhb) and the opportunity to detect a colorectal cancer in subsequent campaign has been shown.

AIM

To predict the severity of colorectal lesions based on Fhb measured during previous colorectal cancer screening campaign.

METHODS

This etiological study included 293750 patients aged 50-74, living in Auvergne-Rhône-Alpes (France). These patients completed at least two FIT [$test_{(-1)}$ and $test_{(0)}$] between June 2015 and December 2019. Delay between $test_{(-1)}$ and $test_{(0)}$ was > 1

after each patient agreed to participate in screening campaigns.

Conflict-of-interest statement: The authors declare that they have no conflict of interest.

Data sharing statement: Data and materials are available when requested by e-mail. However, each request will be processed in accordance with French legislation on the availability of research data.

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year and test$_{(-1)}$ result was negative (< 150 ngHb/mL). The severity of colorectal lesions diagnosed at test$_{(0)}$ was described according to Fhb measured at test$_{(-1)}$ [Fhb$_{(-1)}$]. The relationship between the severity classified in seven ordinal categories and the predictive factors was analyzed in an ordered multivariate polytomous regression model.

RESULTS

The test$_{(0)}$ positive rate was 4.0%, and the colonoscopy completion rate was 97.1% in 11594 patients who showed a positive test$_{(0)}$. The colonoscopy detection rate was 77.7% in those 11254 patients who underwent a colonoscopy. A total of 8748 colorectal lesions were detected (including 2182 low-risk-polyps, 2400 high-risk-polyp, and 502 colorectal cancer). The colonoscopy detection rate varied significantly with Fhb$_{(-1)}$ [0 ngHb/mL: 75.6%, (0-50 ngHb/mL): 77.3%, (50-100 ngHb/mL): 88.7%, (100-150 ngHb/mL): 90.3%; P = 0.001]. People with a Fhb$_{(-1)}$ within (100-150 ngHb/mL) (P = 0.001) were 2.6 (2.2; 3.0) times more likely to have a high severity level compared to those having a Fhb$_{(-1)}$ value of zero. This risk was reduced by 20% in patients aged 55-59 compared to those aged < 55 [adjusted odds ratio: 0.8 (0.6; 1.0)].

CONCLUSION

The study showed that higher Fhb$_{(-1)}$ is correlated to an increased risk of severity of colorectal lesions. This risk of severity increased among first-time participants (age < 55) and the elderly (≥ 70). To avoid the loss of chance in these age groups, the FIT positivity threshold should be reduced to 100 ngHb/mL. The other alternative would be to reduce the time between the two tests in these age groups from the current 2 years to 1 year.

Key Words: Colorectal cancer screening; Fecal immunochemical test; Fecal hemoglobin concentration; Colorectal lesion severity

Core Tip: The study showed that the severity of the colonic lesions increases with a high concentration of fecal hemoglobin measured in previous test. The elderly (≥ 70 years) had a high proportion of positive colonoscopy when the fecal hemoglobin concentration measured in previous campaign was between 100 and 150 ngHb/mL. Younger patients (age < 54) were likely to have a high-severity neoplasia. Given these results, the recommendation to reduce the FIT positivity threshold to 100 ngHb/mL for first-time participants and the elderly (aged ≥ 70) should attract the attention of the decision-making authority.

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INTRODUCTION

Colorectal cancer (CRC) is the third most common cancer worldwide and the second leading cause of cancer-related death[1]. To address these major public health issues, several countries have launched nationwide CRC screening program (CRCSP) in order to reduce the incidence and mortality of CRC.

In 2015, in France, the fecal immunochemical test (FIT) OC-Sensor® was introduced as part of the CRCSP based on its performance to detect advanced adenoma and CRC [2-5]. The positivity threshold has been set at 150 ngHb/mL (30 μgHb/g) of stool. Anyone who tested negative was re-invited for testing 2 years later. Anyone who tested positive was advised to complete a colonoscopy. Several studies showed a

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reduction in the CRC incidence several years after FIT introduction in the CRCSP[6,7].

Some colonic polyps such as adenomatous and serrated polyps exhibit a malignant potential, while others do not (hyperplastic, post-inflammatory, hamartomatous)[8]. Surveillance of polyp characteristic over time should lead to a significant increase in the clinical performance of the detection of polyps with high malignant potential[9]. The variability in growth behavior supports the hypothesis that some polyps continue to grow, other are remaining stable, whereas some polyps regress over time. Some authors have reported that advanced adenoma may have the potential to grow faster than non-advanced adenoma, while most small polyps remain stable or are regress over time[10,11].

It was shown that the rate of positive test results with FIT does not decrease during the subsequent campaigns, but the positive predictive value for advanced neoplasia, especially for CRC, significantly decreased in participants during the subsequent campaign after a first negative test[12,13]. A relationship between the fecal hemoglobin concentration (Fhb) and the risk to detect a CRC or an advanced adenoma has also been shown[14-21], but the severity risk of the colorectal lesions according to the earlier Fhb was poorly described.

Looking for less invasive methods for monitoring patients at moderate risk for CRC, this study aims to predict the severity of colorectal lesions based on the Fhb measured during a previous colorectal cancer screening test.

MATERIALS AND METHODS

Study design and population

This etiological study included 293750 patients living in one of the six French departments (Ain, Ardèche, Drôme, Isère, Savoie, & Haute-Savoie) of the Auvergne-Rhône-Alpes region. These patients were aged between 50 and 74 and had completed at least two FIT screening tests between June 1, 2015 and December 31, 2019. The delay between the last test [$test_{(0)}$] and the penultimate test [$test_{(-1)}$] was > 1 year, with a negative $test_{(-1)}$ result (< 150 ngHb/mL). The diagnosis of a colorectal lesion as well as its severity were described according to the Fhb measured at $test_{(-1)}$ [$Fhb_{(-1)}$].

All study data were extracted on the same date (November 30, 2020) from departmental databases. These databases were regularly enriched by socio-demographic data, diagnosis (colonoscopy, histopathology), and follow-up data provided by partners (Health Insurance Plans, Medical Information Services, Gastroenterologists, Surgeons & GPs).

Population and design

In each selected department, the CRCSP campaigns were organized according to the CRCSP national specifications[22,23]. As a reminder, this nationwide screening program started in 2009, and the CRCSP target was every 2 years in an eligible population, *i.e.* asymptomatic patients aged 50 to 74, with no risk factors other than their age (according to the CRCSP national specification). This program was based on the guaiac fecal occult blood test (gFOBT) or hemoccult© II, which has been replaced by the FIT in 2015. The CRC screening test was a two-step method: The first step consisted in the completion of a FIT, the second-step consisted in the completion of a colonoscopy in case of positive FIT. The positivity threshold of the test was set at 150 ngHb/mL of stool. In case of normal colonoscopy, the patient received an invitation to the CRCSP after 5 years. In case of positive colonoscopy (high risk polyps or cancer) the patient was excluded from the nationwide program.

Operational definition of variables and descriptive analysis

As a study result criterion, $test_{(0)}$ was positive at the threshold of 150 ngHb/mL. The value of the Fhb measured during this $test_{(0)}$ [$Fhb_{(0)}$] was treated as a discrete variable (0 ngHb/mL, 0-50 ngHb/mL, 50–100 ngHb/mL, 100-150 ngHb/mL, 150-300 ngHb/mL, > 300 ngHb/mL). The colonoscopy completion rate was defined by the proportion of patients who had a colonoscopy (complete or incomplete) among those with a positive $test_{(0)}$ result. Colonoscopy was considered positive when a colorectal neoplasia was diagnosed by the gastroenterologist or by a cytopathological examination of the specimens. In the CRCSP, no specific training other than specialized training as an endoscopic physician was required for the practice of colonoscopy by gastroenterologists. The colonoscopy detection rate was defined by the proportion of positive colonoscopies among those performed (complete or incomplete) after a positive test. In the event of a positive result, the diagnostic course was analyzed in terms of types of

diagnosed lesions including: Low risk polyps (LRP), high risk polyps (HRP), unspecified-polyp (UP), and CRC. HRP included: Adenomas ≥ 10 mm (except hyperplastic polyps), serrated adenomas, adenomas with high grade dysplasia, and villous or tubulo-villous adenomas. For these colorectal tumors detected, five localizations were described during colonoscopy: Cecum, right colon (ascending colon and right angle), transverse colon, left colon (left angle and descending colon), and rectosigmoid (rectum and sigmoid colon). The diagnoses associated with CRC and polyps or adenoma were those related to C18–C20 and D12 of the 10th version of the World Health Organization International Classification of Diseases[24]. CRC lesions were described by stage of severity, using the tumor, node, and metastasis (TNM) classification based on tumor size, lymph node involvement, and the possible presence of metastases[25]: CRC Stage-0 ($pTisN_0M_0$), Stage-I ($pT_{1-2}N_0M_0$), Stage-II ($pT_3N_0M_0$ or $pT_4N_0M_0$), Stage-III (pT_1-$T_2N_1M_0$ or $pT_1N_2M_0$ or pT_3-$T_4N_1M_0$ or pT_2-$T_3N_2M_0$ or $pT_4N_2M_0$), and Stage-IV (any T, any N, M_1). The size of the polyp, its dysplasia, its cytopathological aspect, and the TNM classification were used to define a scale of severity of colorectal lesions in 7 ordinal categories: Severity level-0 (LRP), level -1 (HRP), level-2 (Stage-0), level-3 (Stage-I), level-4 (Stage-II), level-5 (Stage-III), and level-6 (Stage-IV). The main studied factors were the value of $Fhb_{(-1)}$ and the variation of the Fhb between $test_{(-1)}$ and $test_{(0)}$. The value of $Fhb_{(-1)}$ expressed in ngHb/mL (0, 0-50, 50-100, 100-150) and its variation in ngHb/mL (≤ 0, 0-50, 50-100, 100-150, 150-300, ≥ 300) were treated as discrete variables. The cofactors studied were: (1) the participation in at least one gFOBT campaign (new participant: -the person under 50-years-old at the time the gFOBT was used in the program-, No-gFOBT: -the person has never completed a gFOBT despite being often invited to the gFOBT campaigns-, Yes-gFOBT: -the person completed at least one gFOBT campaign-); (2) the age at the time of performing $test_{(-1)}$ (50-54, 55-59, 60-64, 65-69, ≥ 70-years-old); (3) the gender (female *vs* male); (4) the delay (mo) between $test_{(-1)}$ and $test_{(0)}$ (≤ 24, 25-30, > 30) and; (5) the number of tests completed before the $test_{(-1)}$ (0, 1, 2, 3, ≥ 4).

Statistical analysis

The main characteristics were described in frequencies for qualitative variables and in mean ± SD for quantitative variables. Proportions were compared using Pearson Chi-2 test or Fisher's exact test when appropriate.

The relationship between the diagnosis of neoplasia (positive colonoscopy *vs* negative colonoscopy) and the predictive factors [$Fhb_{(-1)}$, participation in at least one gFOBT campaign, age at $test_{(-1)}$, gender, delay between $test_{(-1)}$ and $test_{(0)}$, number of tests completed before $test_{(-1)}$] was analyzed in a multivariate logistic regression model, with the estimation of the adjusted odds ratio (OR) and its 95% confidence interval (CI). For the construction of the multivariate model, all the adjustment covariates regardless of the strength of association in univariate analysis were used. In addition, a strong correlation existed between several covariates [age, delay, number of tests completed before $test_{(-1)}$, participation in at least one gFOBT campaign], the model was extended to the terms of interaction between these covariates. Only the significant interaction terms ($P < 0.05$ in univariate analysis) were retained in the final model evaluated by the likelihood ratio test. Positive tests without colonoscopy at the time of the study ($n = 340$) were excluded from this logistic regression analysis.

The relationship between the severity of the lesions (ordinal variable; 0 to 6) and the predictive factors [$Fhb_{(-1)}$, participation in at least one gFOBT campaign, age at $test_{(-1)}$, gender, delay between $test_{(-1)}$ and $test_{(0)}$, number of tests completed before $test_{(-1)}$] was analyzed in an ordered, multivariate polytomous regression model, with the estimation of the risk and its 95%CI. All the adjustment covariates regardless of the strength of association in univariate analysis were used in the multivariate model. In addition, the model was extended to terms of interaction between covariates with a strong correlation (cited above). Only the significant interaction terms ($P < 0.05$ during a univariate analysis) were retained in the final model evaluated by the likelihood ratio test. In this analysis, the unspecified polyps ($n = 3664$) were classified as the polyps not at risk. Similarly, cancers without any precision (unknown/unspecified, $n = 101$) on the TNM classification were classified as tumors *in situ*. As a reminder, negative colonoscopies ($n = 2846$) were excluded from this ordered, univariate, and multivariate polytomous regression. The differences were significant at the 5% level with version 13 of the STATA software (College Station, TX, United States).

Ethical considerations

Before analysis, all data were anonymized. The screening database had a favorable opinion from the institution that oversees the ethics of data collection ("Commission nationale de l'Informatique et des libertés")[26]. According to the current French

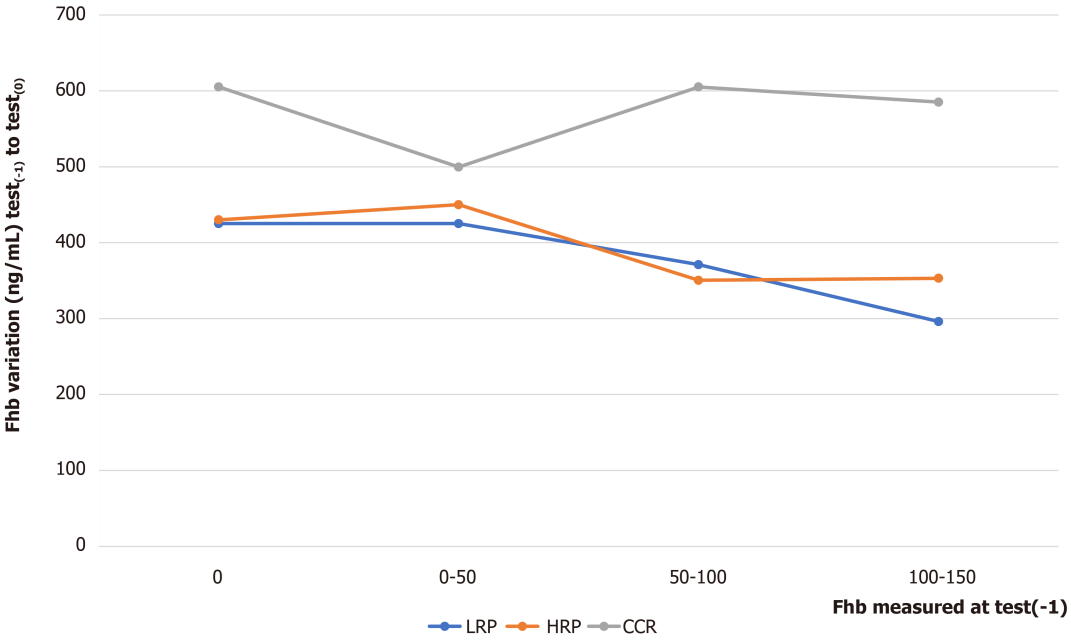

Figure 1 Type of colorectal lesion according to fecal hemoglobin concentration variation (ng/mL) between $test_{(-1)}$ and $test_{(0)}$ and fecal hemoglobin concentration measured at $test_{(-1)}$. Fhb: Fecal hemoglobin; LRP: Low risk polyps; HRP: High risk polyps.

legislation, a study that does not change the care of patients did not require the opinion of the Clinical Research Centers Ethics Committee. This article does not contain any studies with human participants performed by any of the authors. This study does not involve human participants, and an informed consent was therefore not required. This article does not contain any studies with animals performed by any of the authors.

RESULTS

A total of 575587 patients completed at less one FIT between 2015 and 2019. Among them, 281837 (49.0%) people were excluded from this etiological analysis because they had completed only one FIT during the study duration. Finally, our study focused on the 293750 people who completed at least two FIT such as $test_{(-1)}$ and $test_{(0)}$. With a mean age of 61.1 ± 6.7 when completing the $test_{(-1)}$, the positivity rate of the $test_{(0)}$ was 4.0% in these 293750 people. This positivity rate was significantly higher ($P < 0.001$) among patients who have a $Fhb_{(-1)}$ between 100 and 150 ngHb/mL (Table 1).

A total of 282156 people (*i.e.* 96.2% of the sample) had a negative $test_{(0)}$ [$Fhb_{(0)} < 150$ ngHb/mL]. The colonoscopy completion rate was globally estimated at 97.1% in 1594 people who had a positive $test_{(0)}$ [$Fhb_{(0)} \geq 150$ ngHb/mL]. The colonoscopy detection rate was 77.7% among those 11254 people who had a colonoscopy, with a total of 8745 colonic lesions detected (including 2182 LRP, 2400 HRP, 502 CRC). This colonoscopy detection rate varied significantly ($P < 10^{-3}$) with the $Fhb_{(-1)}$ [0: 75.6%, (0-50): 77.3%, (50-100): 88.7%, (100-150): 90.3%; $P < 0.001$) (Table 1).

In total, 27.4% of the lesions detected (*i.e.* 2395 cases) were detected in people who completed a $test_{(0)}$ more than 30 mo after the $test_{(-1)}$. However, these 2395 lesions were mostly polyps compared to the lesions detected in people who completed a $test_{(0)}$ within a reasonable delay between $test_{(0)}$ and $test_{(-1)}$ (delay ≤ 24 m -LRP: 63.8%, HRP: 30.3%, CRC: 5.9%-; delay in 24-30 m -LRP: 64.2%, HRP: 29.3%, CRC: 6.5%-; delay > 30 m -LRP: 74.1%, HRP: 21.9%, CRC: 4.0%-; $P = 0.0001$).

For the same value of the previous Fhb [$Fhb_{(-1)}$], the colonoscopy detection rate was not significantly different between the positive values of $Fhb_{(0)}$ [*i.e.* $Fhb_{(-1)} = 0$ & $Fhb_{(0)} =$ (150-300): rate = 75.5% *vs* $Fhb_{(-1)} = 0$ & $Fhb_{(0)} \geq 300$: rate = 75.7%; $P = 0.8$). However, the colonoscopy detection rate was significantly higher when the $Fhb_{(0)}$ was higher, from 75.6% when $Fhb_{(0)}$ was 0 ngHb/mL to 90.3% at (100-150) ngHb/mL (Table 2).

Regardless of the age group, the colonoscopy detection rate was significantly different between the values of $Fhb_{(-1)}$ [*i.e.* age ≥ 70 years: $Fhb_{(-1)} = 0$: rate = 79.1%, $Fhb_{(-1)} =$ (0-50): Rate = 75.9%, $Fhb_{(-1)} =$ (50-100): Rate = 88.2%, $Fhb_{(-1)} =$ (100-150): Rate = 93.8%;

Table 1 Result of the last test completed, based on the characteristics of the study population

Characteristics	Result of the last test [test$_{(0)}$]														
	Positive test and colonoscopy completion rate			Colonoscopy detection rate		Number of the colorectal lesions									
	Nb. (%T+)	*P* value[1]	Number T+ (% Colo in T+)	Number Colo (% Positive Colo)	*P* value[1]	All lesions	Polyps			CRC					
							LRP	HRP	UP	S-0	S-I	S-II	S-III	S-IV	USC
Overall	293750 (4.0)		11594 (97.1)	11254 (77.7)		8748	2182	2400	3664	133	130	53	64	21	101
Fhb$_{(-1)}$ (ngHb/mL)		$< 10^{-3}$			$< 10^{-3}$										
0	280012 (3.5)		9655 (97.0)	9368 (75.6)		7085	1890	1769	3070	85	99	31	47	15	79
0-50	1680 (10.4)		174 (98.9)	172 (77.3)		133	27	41	56	3	4	1	0	0	1
50–100	8776 (13.0)		1144 (96.9)	1108 (88.7)		983	177	360	370	25	16	12	9	2	12
100-150	3282 (18.9)		621 (97.6)	606 (90.3)		547	88	230	168	20	11	9	8	4	9
gFOBT campaign participation		$< 10^{-3}$			0.03										
Yes-gFOBT	213476 (4.2)		8874 (97.0)	8605 (77.8)		6695	1760	1906	2603	112	109	44	59	17	85
New entrant	40199 (2.9)		1156 (97.5)	1127 (75.1)		846	168	203	456	8	6	0	0	1	4
No-gFOBT	40075 (3.9)		1564 (97.3)	1522 (79.3)		1207	254	291	605	13	15	9	5	3	12
Age (yr) at test$_{(-1)}$		$< 10^{-3}$			$< 10^{-3}$										
50-54	57625 (3.0)		1727 (97.9)	1690 (73.7)		1245	276	348	582	10	14	1	6	1	7
55-59	62489 (3.5)		2166 (97.3)	2107 (75.6)		1592	389	445	687	21	19	4	7	3	17
60-64	64141 (3.9)		2514 (97.4)	2449 (78.4)		1920	509	503	807	28	19	17	15	7	15
65-69	63915 (4.7)		2997 (97.0)	2907 (78.7)		2287	592	647	886	38	54	14	17	5	34
≥ 70	45580 (4.8)		2190 (95.9)	2101 (81.1)		1704	416	457	702	36	24	17	19	5	28
Gender		$< 10^{-3}$			$< 10^{-3}$										
Female	160181 (3.3)		5343 (97.1)	5188 (72.8)		3778	962	937	1663	59	51	15	33	11	47
Male	133569 (4.7)		6251 (97.0)	6066 (81.9)		4970	1220	1,463	2001	74	79	38	31	10	54
Delay (mo) between test$_{(-1)}$ and test$_{(0)}$		$< 10^{-3}$			$< 10^{-3}$										
≤ 24	40422 (5.2)		2111 (94.3)	1991 (72.2)		1437	435	435	482	21	23	12	12	0	17

24-30	163470 (4.0)		6538 (97.7)	6390 (76.9)		4916	1322	1440	1833	99	83	29	39	14	57
> 30	89858 (3.3)		2945 (97.6)	2873 (83.4)		2395	425	525	1349	13	24	12	13	7	27
Nb. of tests completed before test$_{(-1)}$		$< 10^{-3}$			0.01										
0	68839 (3.5)		2421 (97.1)	2351 (76.1)		1790	396	465	855	19	21	9	5	4	16
1	54790 (3.7)		2044 (97.7)	1996 (77.6)		1548	364	432	667	20	26	6	13	6	14
2	55794 (4.0)		2245 (97.1)	2180 (76.6)		1670	434	472	678	25	17	11	12	2	19
3	56716 (4.4)		2514 (97.3)	2445 (77.9)		1905	553	562	649	34	37	13	24	5	28
4	57611 (4.1)		2370 (96.3)	2282 (80.4)		1835	435	469	815	35	29	14	10	4	24

[1]Pearson Chi-2 test or Fisher's exact test. Fhb$_{(0)}$: Fecal hemoglobin measured at test$_{(0)}$ (last screening test); Fhb$_{(-1)}$: Fecal hemoglobin measured at test$_{(-1)}$ (penultimate test); CRC: Colorectal cancer; Colo: Colonoscopy; gFOBT: Guaiac fecal occult blood test; HRP: High risk polyps; LRP: Low risk polyps; UP: Unspecified-polyp; USC: Unspecified stage of colorectal cancer; S-0: Colorectal cancer Stage-0 ($pTisN_0M_0$), S-I: Stage-I ($pT_{1-2}N_0M_0$); S-II: Stage-II ($pT_3N_0M_0$ or $pT_4N_0M_0$); S-III: Stage-III (pT_1-$T_2N_1M_0$ or $pT_1N_2M_0$ or pT_3-$T_4N_1M_0$ or pT_2-$T_3N_2M_0$ or $pT_4N_2M_0$); S-IV: Stage-IV (any T, any N, M_1); T+: Positive test.

P = 0.001). In the age groups of 65-69 years and ≥ 70 years, the proportion of CRC among colorectal lesions was significantly higher when the Fhb$_{(-1)}$ was between 100 and 150 [*i.e.* age in 65-69 years: Fhb$_{(-1)}$ = 0: %CRC = 6.2, Fhb$_{(-1)}$ = (0-50): %CRC = 8.2, Fhb$_{(-1)}$ = (50-100): %CRC = 8.1, Fhb$_{(-1)}$ = (100-150): %CRC = 15.8; P = 0.001) (Table 3).

Overall, the proportion of recto-sigmoid lesions was 57.2% among the 5100 lesions for which the location was provided. The proportion of CRC among these colorectal lesions was significantly higher (P = 0.01) in cecal localization compared to other colonic locations. However, this increase in the proportion of CRC among the cecal lesions was not statistically significant regardless of the stratum combining Fhb$_{(-1)}$ and Fhb$_{(0)}$ (Table 4).

Regardless of the Fhb$_{(-1)}$ modalities [except for modality (0-50)], the variation in Fhb between test$_{(0)}$ and test$_{(-1)}$ was significantly greater when the lesion was CRC colorectal cancer. For this modality (0-50), the number of lesions was relatively lower (CRC = 9, LRP = 27, UP = 56, HRP = 41) (Figure 1).

The multivariate logistic regression included 11254 people who completed a colonoscopy. This analysis shows that people with a Fhb$_{(-1)}$ in (100-150) were 2.9 times more likely to be diagnosed with a colorectal lesion in test$_{(0)}$ compared to those having a Fhb$_{(-1)}$ value of zero (adjusted OR = 2.9; 95%CI: 2.2-3.8). This risk of detecting a neoplastic lesion increased significantly with the age, the gender, the delay between test$_{(-1)}$ and test$_{(0)}$, and the number of tests performed before test$_{(-1)}$ (Table 5).

The ordered polytomous regression included 8748 people having exhaustive information on the colorectal lesion. The analysis showed that people with a Fhb$_{(-1)}$ in (100-150) (P = 0.001) were 2.6 (2.2; 3.0) times more likely to have a high severity level, compared to those having a Fhb$_{(-1)}$ value of zero. The risk to have a high severity level

Table 2 Colonoscopy detection rate, number and severity of colorectal lesions according to the previous rate and the last rate of fecal hemoglobin

$Fhb_{(0)}$ by $Fhb_{(-1)}$			Colonoscopy detection rate		Number of colorectal lesions by Severity									
$Fhb_{(-1)}$ (ngHb/mL)	$Fhb_{(0)}$ (ngHb/mL)	Number (% in subtotal)	Number Colo (%Positive Colo)	*P* value[1]	Nb. of colorectal lesions	Polyps			CRC					
						LRP	HRP	UP	S-0	S-I	S-II	S-III	S-IV	USC
0				0.8										
	0	257589 (92.0)												
	0-50	1805 (0.6)												
	50-100	8275 (3.0)												
	100-149	2688 (1.0)												
	150-300	4903 (1.7)	4778 (75.5)		3609	980	918	1601	35	38	5	6	2	24
	≥ 300	4752 (1.7)	4590 (75.7)		3476	910	851	1469	50	61	26	41	13	55
	Subtotal	280012 (100.0)	9368 (75.6)		7085	1890	1769	3070	85	99	31	47	15	79
0–50				0.3										
	0	1328 (79.1)												
	0-50	30 (1.8)												
	50-100	112 (6.7)												
	100-149	36 (2.1)												
	150-300	86 (5.1)	85 (74.1)		63	17	18	24	1	2	1	0	0	0
	≥ 300	88 (5.2)	87 (80.5)		70	10	23	32	2	2	0	0	0	1
	Subtotal	1680 (100.0)	172 (77.3)		133	27	41	56	3	4	1	0	0	1
50–100				0.7										
	0	6589 (75.1)												
	0-50	106 (1.2)												
	50-100	700 (7.9)												
	100-149	237 (2.7)												
	150-300	540 (6.2)	525 (88.4)		464	97	174	175	7	4	2	2	0	3
	≥ 300	604 (6.9)	583 (89.0)		519	80	186	195	18	12	10	7	2	9
	Subtotal	8776 (100.0)	1108 (88.7)		983	177	360	370	25	16	12	9	2	12

100–149				0.3									
	0	2244 (68.4)											
	0-50	49 (1.5)											
	50-100	259 (7.9)											
	100-149	109 (3.3)											
	150-300	293 (8.9)	286 (88.8)	254	52	103	87	4	2	3	1	0	2
	≥ 300	328 (10.0)	320 (91.6)	293	36	127	81	16	9	6	7	4	7
	Subtotal	3282 (100.0)	606 (90.3)	547	88	230	168	20	11	9	8	4	9

[1]Pearson Chi-2 test or Fisher's exact test. $Fhb_{(0)}$: Fecal hemoglobin measured at $test_{(0)}$ (last screening test); $Fhb_{(-1)}$: Fecal hemoglobin measured at $test_{(-1)}$ (penultimate test); CRC: Colorectal cancer; Colo: Colonoscopy; HRP: High risk polyps; LRP: Low risk polyps; UP: Unspecified-polyp; USC: Unspecified stage of colorectal cancer; S-0: Colorectal cancer Stage-0 ($pTisN_0M_0$), S-I: Stage-I ($pT_{1-2}N_0M_0$); S-II: Stage-II ($pT_3N_0M_0$ or $pT_4N_0M_0$); S-III: Stage-III (pT_1-$T_2N_1M_0$ or $pT_1N_2M_0$ or pT_3-$T_4N_1M_0$ or pT_2-$T_3N_2M_0$ or $pT_4N_2M_0$); S-IV: Stage-IV (any T, any N, M_1).

was higher in male compared to female (P = 0.001). This risk was reduced by 20% in age group 55-59 years compared to age group < 55 years [adjusted OR: 0.8 (0.6; 1.0), P = 0.02] (Table 5).

DISCUSSION

This study showed that the risk of detecting a colorectal lesion during a campaign was proportional to the Fhb observed in the previous test completed. Above all, it highlighted that an increase in the probability of detecting a colorectal neoplasia with a high level of severity was proportional to the Fhb observed in the previous test completed. These probabilities varied with the socio-demographic characteristics, especially with age.

The proportion of positive tests and the colonoscopy detection rate increased proportionally with the $Fhb_{(-1)}$. Furthermore, the detection of colorectal lesions according to the variation in the Fhb between $test_{(-1)}$ and $test_{(0)}$ allows to support an association between the detection of cancerous lesions and the strong Fhb variations between two consecutive tests. These results agree with previous data already described in the literature. Furthermore, the increased risk of detecting a neoplasia during a new screening 2 years after a negative screening test result has already been reported in Ireland[14] and recently in the Ile-de-France region[27]. These authors observed variable proportions of pathologies (advanced adenomas or CRC) during a subsequent campaign and hypothesized that these lesions could have been diagnosed during the previous campaign if the FIT positivity threshold was not relatively high. However, they admitted that lowering the positivity threshold would both allow the

Table 3 Colonoscopy detection rate and proportion of colorectal cancer among colorectal lesions according to the previous rate of fecal hemoglobin and the age at the time of the previous test

$Fhb_{(-1)}$ by age at $test_{(-1)}$		Colonoscopy detection rate and CRC proportion			
		Number Colo (%Positive colo)	*P* value[1]	Number of lesions (%CRC)	*P* value[2]
Age (yr) at $test_{(-1)}$	$Fhb_{(-1)}$ (ngHb/mL)				
Overall		11254 (77.7)		8748 (5.7)	
50-54			$<10^{-3}$		0.7
	0	1471 (71.6)		1053 (3.1)	
	0-50	21 (71.4)		15 (0.0)	
	50-100	130 (90.8)		118 (2.5)	
	100-150	68 (86.8)		59 (5.1)	
	Subtotal	1690 (73.7)		1245 (3.1)	
55-59			$< 10^{-3}$		0.1
	0	1797 (73.7)		1324 (3.9)	
	0-50	31 (67.7)		21 (4.8)	
	50-100	178 (87.1)		155 (7.1)	
	100-150	101 (91.1)		92 (7.6)	
	Subtotal	2107 (75.6)		1592 (4.5)	
60-64			$< 10^{-3}$		0.05
	0	2044 (76.4)		1562 (4.6)	
	0-50	37 (70.3)		26 (7.7)	
	50-100	247 (90.3)		223 (8.1)	
	100-150	121 (90.1)		109 (8.3)	
	Subtotal	2449 (78.4)		1920 (5.3)	
65-69			$< 10^{-3}$		0.001
	0	2373 (76.5)		1815 (6.2)	
	0-50	54 (90.7)		49 (8.2)	
	50-100	308 (88)		271 (8.1)	
	100-150	172 (88.4)		152 (15.8)	
	Subtotal	2907 (78.7)		2287 (7.1)	
≥70			$< 10^{-3}$		0.01
	0	1683 (79.1)		1331 (6.5)	
	0-50	29 (75.9)		22 (9.1)	
	50-100	245 (88.2)		216 (10.2)	
	100-150	144 (93.8)		135 (13.3)	
	Subtotal	2101 (81.1)		1704 (7.6)	

[1]Pearson Chi-2 test.

[2]Fisher's exact test. CRC: Colorectal cancer; Colo: Colonoscopy; $Fhb_{(-1)}$: Fecal hemoglobin measured at $test_{(-1)}$ (penultimate test).

diagnosis of lesions that could be serious only 2 years later and create an unsustainable endoscopy referral burden[14].

The current positivity threshold in the French screening program induces a considerable loss of chance. Indeed, in most countries, the threshold of FIT positivity is chosen in part to adapt to the offer of colonoscopies. The need to readjust this strategy in patients with a Fhb between 100 and 150 ngHb/mL should be assessed[27]. This

Table 4 Number of colorectal lesions and the proportion of colorectal cancer among colorectal lesions by localization, according to the previous rate and the last rate of fecal hemoglobin

$Fhb_{(0)}$ by $Fhb_{(-1)}$		Colorectal lesion number (%Specified localization)	Number of colorectal lesions by localization and proportion of CRC						
			Specified localization: number (% CRC)	Cecum: number (% CRC)	Right colon: number (% CRC)	Transverse colon: number (%CRC)	Left colon: number (%CRC)	Rectosigmoid: number (%CRC)	*P* value[1]
$Fhb_{(-1)}$ (ngHb/mL)	$Fhb_{(0)}$ (ngHb/mL)								
Overall	150-300	4390 (57.0)	2500 (5.4)	195 (6.7)	490 (5.3)	221 (3.2)	252 (3.2)	1342 (6.1)	0.2
	> 300	4358 (59.7)	2600 (13.4)	179 (16.8)	432 (11.8)	176 (11.4)	235 (11.1)	1578 (14.1)	0.3
	Total	8748 (58.3)	5100 (9.5)	374 (11.5)	922 (8.4)	397 (6.8)	487 (7.0)	2920 (10.4)	0.01
0	150-300	3609 (55.7)	2011 (5.3)	154 (7.8)	391 (5.1)	176 (2.8)	200 (3.0)	1090 (5.8)	0.2
	> 300	3476 (58.2)	2022 (12.0)	145 (14.5)	355 (10.1)	139 (8.6)	185 (10.3)	1198 (12.9)	0.3
	Subtotal	7085 (56.9)	4033 (8.6)	299 (11.0)	746 (7.5)	315 (5.4)	385 (6.5)	2288 (9.5)	0.02
0-50	150-300	63 (61.9)	39 (10.3)	2 (0.0)	6 (16.7)	4 (0.0)	8 (12.5)	19 (10.5)	1.0
	> 300	70 (55.7)	39 (12.8)	2 (0.0)	4 (25.0)	2 (0.0)	3 (0.0)	28 (14.3)	0.8
	Subtotal	133 (58.7)	78 (11.5)	4 (0.0)	10 (20)	6 (0.0)	11 (9.1)	47 (12.8)	0.9
50-100	150-300	464 (62.1)	288 (5.6)	24 (0.0)	66 (4.6)	23 (4.4)	23 (0.0)	152 (7.9)	0.5
	> 300	519 (63.0)	327 (17.1)	22 (27.3)	46 (17.4)	21 (23.8)	29 (10.3)	209 (16.3)	0.5
	Subtotal	983 (62.6)	615 (11.7)	46 (13.0)	112 (9.8)	44 (13.6)	52 (5.8)	361 (12.7)	0.6
100-149	150-300	254 (63.8)	162 (6.2)	15 (6.7)	27 (7.4)	18 (5.6)	21 (4.8)	81 (6.2)	1.0
	> 300	293 (72.4)	212 (21.7)	10 (30.0)	27 (22.2)	14 (21.4)	18 (22.2)	143 (21.0)	1.0
	Subtotal	547 (68.4)	374 (15)	25 (16.0)	54 (14.8)	32 (12.5)	39 (12.8)	224 (15.6)	1.0

[1]Pearson Chi-2 test or Fisher's exact test. CRC: Colorectal cancer; $Fhb_{(0)}$: Fecal hemoglobin measured at $test_{(0)}$ (last screening test); $Fhb_{(-1)}$: Fecal hemoglobin measured at $test_{(-1)}$ (penultimate test).

study highlights the need for a strategy taking into account the age of people participating in the screening campaign. The elderly (≥ 70 years) had a high proportion of positive colonoscopy when the Fhb measured in the previous campaign was between 100 and 150 ngHb/mL. Younger people (< 54 years) had a likelihood of having high-severity neoplasia. Given these results, the recommendation to reduce the FIT positivity threshold to 100 ngHb/mL for first-time arrivals and the elderly (≥ 70 years) should attract the attention of the French health authority.

Another alternative would be to reduce the delay between two tests for these first-time participants and the elderly (age ≥ 70 years) from the current 2 years to 1 year. This alternative could have its main justification in the enthusiasm of the elderly towards screening campaigns in France, described in a previous study[28]. The reduction in the time between two tests has the advantage of allowing the recovery of false negative results that a decrease in the positivity threshold cannot recover. Indeed, after finding that the Fhb was less than 4 μgHb/g in 94.0% of false negative individuals, Ibañez-Sanz *et al*[29] concluded that the decrease in the positivity threshold of the FIT does not increase the detection rate of advanced neoplasia but may increase costs and potential adverse effects. Whatever strategy chosen, it should also include the 65-69-age group, which accounts for more than 33.3% of the CRCs detected and presents a significantly increased proportion of CRC when $Fhb_{(-1)}$ was between 100 and 150.

In terms of the location of colorectal lesions, it has been argued that FITs are possibly less effective at detecting lesions located in the proximal colon than distally [30]. Digby *et al*[19] showed that 77.8% of adenomas and 69.2% of cancers were located in the distal colon. The results of this study are consistent with this proximal location. However, in the Ibañez-Sanz study[29], about 60% of the lesions were localized in the proximal colon, while the expected percentage was 30%.

Table 5 Analysis of the relationship between the diagnosis and severity of colorectal lesions and the predictive factors

Predictive factors	Risk analysis of colorectal lesions in a logistic regression model				Risk analysis of the severity of colorectal lesions in an ordered polytomous regression model			
	Univariate		Multivariate		Univariate		Multivariate	
	Unadjusted OR (95%CI)	*P* value[1]	Adjusted OR (95%CI)	*P* value[1]	Unadjusted OR (95%CI)	*P* value[2]	Adjusted OR (95%CI)	*P* value[2]
Fhb_{-1} (ngHb/mL) (Ref.: 0)								
0-50	1.1 (0.8; 1.6)	0.6	1.1 (0.8; 1.6)	0.5	1.4 (1.0; 2.0)	0.1	1.3 (0.9; 1.8)	0.1
50-100	2.5 (2.1; 3.1)	$< 10^{-3}$	2.4 (2.0; 3.0)	$< 10^{-3}$	1.8 (1.6; 2.1)	$< 10^{-3}$	1.8 (1.6; 2.0)	$< 10^{-3}$
100-150	3.0 (2.3; 3.9)	$< 10^{-3}$	2.9 (2.2; 3.8)	$< 10^{-3}$	2.6 (2.2; 3.1)	$< 10^{-3}$	2.6 (2.2; 3.0)	$< 10^{-3}$
gFOBT campaign participation (Ref.: Yes-gFOBT)								
New entrant	0.9 (0.7; 1.0)	0.04	3.3 (2.2; 5.0)	$< 10^{-3}$	0.6 (0.6; 0.8)	$< 10^{-3}$	0.1 (0.1; 0.2)	$< 10^{-3}$
No-gFOBT	1.1 (1.0; 1.2)	0.2	2.8 (1.9; 4.1)	$< 10^{-3}$	0.8 (0.7; 0.9)	$< 10^{-3}$	0.2 (0.1; 0.3)	$< 10^{-3}$
Age (yr) at $test_{(-1)}$ (Ref.: 50-54)								
55-59	1.1 (1.0; 1.3)	0.2	1.3 (1.0; 1.6)	0.04	1.1 (0.9; 1.3)	0.4	0.8 (0.6; 1.0)	0.02
60-64	1.3 (1.1; 1.5)	$< 10^{-3}$	1.4 (1.2; 1.8)	0.001	1.0 (0.9; 1.2)	0.5	0.7 (0.6; 0.9)	0.004
65-69	1.3 (1.1; 1.5)	$< 10^{-3}$	1.4 (1.1; 1.8)	0.002	1.3 (1.1; 1.5)	0.002	0.9 (0.7; 1.1)	0.2
≥ 70	1.5 (1.3; 1.8)	$< 10^{-3}$	1.7 (1.3; 2.1)	$< 10^{-3}$	1.2 (1.0; 1.4)	0.01	0.8 (0.6; 1.0)	0.07
Gender (Ref.: Female)								
Male	1.7 (1.5; 1.9)	$< 10^{-3}$	1.7 (1.5; 1.8)	$< 10^{-3}$	1.2 (1.1; 1.3)	0.002	1.2 (1.1; 1.3)	$< 10^{-3}$
Delay (mo) between $test_{(-1)}$ and $test_0$ (Ref.: < 24)								
24-30	1.3 (1.1; 1.4)	$< 10^{-3}$	1.3 (1.1; 1.5)	$< 10^{-3}$	1.0 (0.9; 1.1)	0.9	1.0 (0.9; 1.1)	0.9
> 30	1.9 (1.7; 2.2)	$< 10^{-3}$	2.1 (1.7; 2.6)	$< 10^{-3}$	0.6 (0.5; 0.7)	$< 10^{-3}$	0.6 (0.5; 0.7)	$< 10^{-3}$
Number of tests completed before $test_{(-1)}$ (Ref.: 0)								
1	1.1 (0.9; 1.2)	0.3	2.7 (1.9; 3.9)	$< 10^{-3}$	1.2 (1.0; 1.4)	0.03	0.3 (0.2; 0.4)	$< 10^{-3}$
2	1.0 (0.9; 1.2)	0.7	2.7 (1.8; 4.1)	$< 10^{-3}$	1.2 (1.0; 1.3)	0.03	0.2 (0.1; 0.3)	$< 10^{-3}$
3	1.1 (1.0; 1.3)	0.1	2.9 (1.9; 4.4)	$< 10^{-3}$	1.4 (1.2; 1.6)	$< 10^{-3}$	0.3 (0.2; 0.4)	$< 10^{-3}$
4	1.3 (1.1; 1.5)	$< 10^{-3}$	3.5 (2.3; 5.2)	$< 10^{-3}$	1.1 (1.0; 1.3)	0.1	0.2 (0.1; 0.3)	$< 10^{-3}$

[1]*P* values were estimated from likelihood ratio tests based on data from 11254 people who completed a colonoscopy.

[2]*P* values were estimated from likelihood ratio tests based on data from 8748 people diagnosed with colorectal lesion after colonoscopy. $Fhb_{(-1)}$: Fecal hemoglobin measured at $test_{(-1)}$ (penultimate test); gFOBT: Guaiac fecal occult blood test; OR: Odds ratio; CI: Confidence interval.

The optimal interval for CRC screening using FIT remains unclear[5]. In terms of the impact of the delay between the tests on the risk of detection of a colorectal lesion, the results of this study are not consistent with Van Roon's analysis, certainly because of the lower test positivity threshold (≥ 50 ng/mL) in their study carried out in a small sample (7501 people)[31]. In addition, this study found an unexpected reverse direction in the analysis of the lesion severity risk according to the delay between $test_{(0)}$ and $test_{(-1)}$. This paradoxical reduction in the risk of severity could be explained by the high proportion of polyps among the lesions detected in patients with an abnormally long delay between $test_{(0)}$ and $test_{(-1)}$. We can also hypothesize that some patients with a time between the two tests greater than 2 years may be symptomatic and therefore will not appear in the screening program as mentioned by Liao *et al*[21].

Limitations of the study

The main limitation of this study is the amount of missing data, especially on the stages of the lesions and their colonic locations. However, this is a consequence inherent to retrospective studies that cannot question the results of this study. In addition, the absence of a cancer registry in the "Auvergne Rhône-Alpes Region" does not allow interval cancers to be included in this study.

CONCLUSION

An increased risk of severity of the colorectal lesion was observed in proportion to the increase in $Fhb_{(-1)}$. This risk of severity varied with the socio-demographic characteristics of the patients, especially among first-time participants. An increased colonoscopy detection rate was observed in the elderly in correlation with the increase in $Fhb_{(-1)}$. According to these results, the FIT positivity threshold should be reduced to 100 ngHb/mL for first-time participants and patients aged ≥ 70. The other alternative should be to reduce the delay between the two tests for these first-time participants and the elderly (age ≥ 70) from the current 2 years to 1 year.

ARTICLE HIGHLIGHTS

Research background

The rate of positive tests using fecal immunochemical test (FIT) does not decrease with subsequent campaigns, but the positive predictive value of advanced neoplasia significantly decreases in subsequent campaign after a first negative test. A relationship between the fecal hemoglobin concentration (Fhb) and the opportunity to detect a colorectal cancer in subsequent campaign has been shown.

Research motivation

In this period of implementation of the optimization strategies of the French program, our motivation was to alert the health authority on the severity of the lesions not diagnosed because of the high positivity threshold of the current screening FIT.

Research objectives

Our objective was to predict the severity of colorectal lesions based on Fhb measured during previous colorectal cancer screening campaign.

Research methods

The etiological study included 293750 patients aged 50-74, living in Auvergne-Rhône-Alpes (France). These patients completed at least two FIT [$test_{(-1)}$ and $test_{(0)}$] between June 2015 and December 2019. Delay between $test_{(-1)}$ and $test_{(0)}$ was > 1 year, and $test_{(-1)}$ result was negative (< 150 ngHb/mL). The severity of colorectal lesions diagnosed at $test_{(0)}$ was described according to Fhb measured at $test_{(-1)}$ [$Fhb_{(-1)}$]. The relationship between the severity classified in seven ordinal categories and the predictive factors was analyzed in an ordered multivariate polytomous regression model.

Research results

The $test_{(0)}$ positive rate was 4.0% and the colonoscopy completion rate was 97.1% in 11594 patients who showed a positive $test_{(0)}$. The colonoscopy detection rate was 77.7% in those 11254 patients who underwent a colonoscopy. In total, 8748 colorectal lesions were detected (including 2182 low-risk-polyps, 2400 high-risk-polyp and 502 colorectal cancer). The colonoscopy detection rate varied significantly with $Fhb_{(-1)}$ [0 ngHb/mL: 75.6%, (0-50): 77.3%, (50-100): 88.7%, (100-150): 90.3%; P = 0.001). People with a $Fhb_{(-1)}$ within (100-150 ngHb/mL) (P = 0.001) were 2.6 (2.2; 3.0) times more likely to have a high severity level compared to those having a $Fhb_{(-1)}$ value of zero. This severity risk was reduced by 20% in patients aged 55-59 compared to those aged < 55 [adjusted odds ratio: 0.8 (0.6; 1.0)].

Research conclusions

The study showed that higher $Fhb_{(-1)}$ is correlated to an increased risk of severity of colorectal lesions. This risk of severity increased among first-time participants (age < 55) and the elderly (≥ 70). To avoid the loss of chance in these age groups, the FIT

positivity threshold should be reduced to 100 ngHb/mL. The other alternative would be to reduce the time between the two tests in these age groups from the current 2 years to 1 year.

Research perspectives

At the end of this study, we aim to conduct an experiment with a screening program considering the age of patients and the previous values of the fecal hemoglobin concentration.

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