Accepted Manuscript online: 2022-05-23 Article published online: 2022-09-14

Adenoma detection rate is enough to assess endoscopist performance: a population-based observational study of FIT-positive colonoscopies

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submitted 9.11.2021
accepted after revision 20.5.2022
published online 23.5.2022

Bibliography
Endosc Int Open 2022; 10: E1208–E1217
DOI 10.1055/a-1859-8277
ISSN 2364-3722

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ABSTRACT

Background and study aims Neoplasia-related indicators, such as adenoma detection rate (ADR), are a priority in the quality improvement process for colonoscopy. Our aim was to assess and compare different detection and characterization indicators in fecal immunochemical test (FIT)-positive colonoscopies, to determine associated factors, and to propose benchmarks.

Patients and methods Retrospective analysis of prospectively collected data from all colonoscopies performed between 2015 and 2019 after a positive quantitative FIT in the population-based colorectal cancer screening program conducted in Alsace, part of the French national program. Detection indicators included ADR, mean number of adenomas per colonoscopy, and proximal serrated lesion (SL) detection rate. Characterization indicators included rate of non-neoplastic polyp (NNP) detection.

Results Overall, 13,067 FIT-positive colonoscopies were evaluated, performed by 80 community gastroenterologists. The overall ADR was 57.6 %, and a 10 µg/g increase in fecal hemoglobin concentration was significantly associated with higher ADR (odds ratio [95 % confidence interval] = 1.02 [1.02–1.03]). Endoscopists whose ADR was ≥ 55 % were high detectors for all neoplasia, including proximal SLs and number of adenomas. The rate of detection of NNPs was 39.5 % in highest detectors (ADR > 70 %), significantly higher than in lower detectors (21.4 %) ($P < 0.001$). There was a strong correlation between detection and characterization indicators, e. g. between rates of detection of proximal SLs and NNPs (Pearson = 0.73; $P < 0.01$).

Conclusions A single indicator, ADR, is enough to assess endoscopist performance for both detection and characterization in routine practice provided the minimum target standard is raised and a maximum standard is added: 55 % and 70 % for FIT-positive colonoscopies, respectively.

Introduction

Most countries undertake colorectal cancer (CRC) screening programs with fecal occult blood test (FOBT), guaiac-based FOBT (gFOBT) or fecal immunochemical test (FIT), flexible sigmoidoscopy or colonoscopy, all effective in reducing CRC incidence and mortality [1]. All these screening methods lead to colonoscopy, allowing detection of early-stage CRCs and removal of neoplastic polyps (NPs). Colonoscopy is an operator-dependent examination: adenoma and polyp detection vary dramatically between endoscopists [2, 3]. High adenoma detection rate (ADR) and high polypectomy rate (PR) are associated with lower risk of post-colonoscopy CRC and fatal post-colonoscopy CRC [4–7]. Measuring endoscopist neoplasia detection performance, therefore is a priority in the quality improvement process for colonoscopy [8, 9]. ADR is the most commonly recommended neoplasia-related quality indicator [8, 9].

There is a large body of literature about ADR in the setting of screening colonoscopies, but literature is scarce in the setting of FIT-positive colonoscopies [10–14]. The US Multi-Society Task Force on CRC recommended that ADR should be greater than 45 % in men and 35 % in women in FIT-positive colonoscopies (weak recommendation; very low quality of evidence) [15]. The European Society of Gastrointestinal Endoscopy (ESGE) recommendations stipulated that "in FIT-positive enriched populations, the minimum standard may need to be higher than 25 %; however, the exact value is yet to be established" [9].

The benefit of removal of NPs is diminished by the removal of non-neoplastic polyps (NNPs), mainly hyperplastic polyps (HPs) that account for around 22.5 % to 30 % of polyps (75 % of sessile serrated polyps that account for 30 % to 40 % of polyps) [16]. Accurate real-time endoscopic characterization of the histology of colorectal polyps would be crucial to determine whether a polyp has to be removed and analyzed or not. Optical technologies, such as narrow-band imaging (NBI), have been developed to help endoscopists differentiate neoplastic from NNPs, so that small NNPs can be discarded after resection or safely left in situ without polypectomy. Their performances have been thoroughly investigated, mainly in expert hands, and are diversely appreciated [17, 18]. Performance levels for community endoscopists have been disappointing [19].

The main aim of this study was to evaluate and compare different neoplasia-related detection and characterization indicators for colonoscopy. Secondary objectives were: (1) to determine associated factors; and (2) to establish minimum and target standards for FIT-positive colonoscopies.

Patients and methods

Screening program

The French organized CRC screening program, implemented from 2003, moved from gFOBT (Hemoccult II) to quantitative FIT (OC-Sensor) in 2015. Its design has been previously described [20]. Residents aged 50 to 74 years are invited by mail every other year to participate. People with serious comorbidities, recent CRC screening or high CRC risk such as family history are excluded. The FIT-positivity threshold is set at 30 µg hemoglobin per gram (µg/g) feces so that the positivity rate would be 4 % to 5 %. People with a positive FIT are referred for colonoscopy.

Colonoscopies

All data concerning FIT-positive colonoscopies performed between 2015 and 2019 from the screening program in Alsace (0.57 million residents aged 50 to 74) were prospectively collected and retrospectively analyzed. All certified endoscopists participated in the program. Colonoscopies were performed by community gastroenterologists, generally with sedation/anesthesia provided by an anesthesiologist. As in most previous studies, all colonoscopies were included, whether complete to the cecum or not, whatever the quality of bowel preparation [2, 3, 7, 10, 13, 21–26]. Likewise, as in most previous studies, colonoscopies displaying invasive CRC were excluded for assessment of neoplasia-related indicators [5, 10, 11, 21, 23–32], as well as those reported by endoscopists who had performed < 30 FIT-positive colonoscopies [2–4, 7, 10].

Pathological classification

Pathological examination of detected polyps was performed as routine procedure by community general pathologists. The result of each colonoscopy was classified according to the lesions with the worst prognosis. Conventional adenoma was defined as any tubulous, tubulo-villous or villous adenoma. Advanced adenoma (AA) was defined as a conventional adenoma measuring ≥ 10 mm or with a villous component > 20 % or with high-grade dysplasia. In most cases, polyp size was ascertained from the pathology report, or failing that, from the endoscopist's evaluation recorded in the colonoscopy report. Serrated lesions (SLs) included sessile serrated lesions (SSLs), traditional serrated adenomas, and HPs. NP was defined as any precancerous lesion, including conventional adenoma, SSL, and traditional serrated adenoma. NNP was defined as any non-precancerous lesion, including HP, normal or inflammatory mucosa, lipoma, and lymph node. Non-adenomatous non-serrated lesions (NANSLs) included all normal or inflammatory mucosa, lipomas, and lymph nodes.

Indicators

ADR, AADR, SSLDR, PDR, NNPDR and non-adenomatous non-serrated lesion detection rate (NANSLDR) were defined, respectively, as the percentages of colonoscopies where at least one conventional adenoma, one AA, one SSL, one polyp, one NNP and one NANSL were found. All SLs were excluded when calculating ADR, AADR and mean number of adenomas (MNAs) [8]. The ProxSLDR was defined as the percentage of colonoscopies where at least one SL of any size was found in the proximal colon (proximally to the descending colon, splenic flexure being included) [33]. The distal HP detection rate (DistHPDR) was defined as the percentage of colonoscopies where at least one HP was found in the rectum or distal colon. MNA was defined as the overall number of conventional adenomas detected divided by the number of colonoscopies performed. The MNAPPC was defined as the number of conventional adenomas detected divided by the number of colonoscopies where at least one adenoma

was detected. Neoplasia-related indicators were classified in two categories: detection (ADR, AADR, PDR, MNA, MNAPPC, SSLDR, ProxSLDR) and characterization indicators (NNPDR, DistHPDR, NANSLDR).

Statistical methods

Descriptive statistics were first computed. Qualitative data were described using numbers by modality and associated percentage, and quantitative data were described by mean, median, range and standard deviation (SD). Stratification by sex was also provided to capture potential differences. A correlation analysis was performed to answer the primary objective. Pearson correlation and determination R2 coefficients were derived across all neoplasia-related quality indicators, as well as associated *P* values. A correlation was deemed high whenever the coefficient was greater than 0.7 (in absolute value). Multivariable logistic regression analyses were conducted to determine factors associated with ADR, ProxSLDR, and NNPDR, respectively. The following factors were selected based on clinical expertise and data availability: sex, age (as a categorical variable), year, screening history, fecal hemoglobin concentration, time to colonoscopy, endoscopist, private or hospital practice, annual volume of FIT-positive colonoscopies, and cecal intubation rate (CIR). Colonoscopy was the statistical unit used for the multivariable analyses. The significance level for all statistical analyses was set at 0.05. Statistical analyses were performed using R software version 3.6.0.

All authors had access to the study data and reviewed and approved the final manuscript. This study was approved by the institutional review board of the hospital of Mulhouse.

Results

The FIT uptake was 44.4 % in 2018 and 2019 and the positivity rate was 3.8 %. Overall, 14,228 individuals had 14,228 FIT-positive colonoscopies performed by 116 endoscopists. Among these individuals, 773 (5.4 %) had colonoscopies displaying a CRC and were excluded, so that the colonoscopies of 13,455 individuals (mean age 62.4 years [SD 7.0; men 59.6 %]) were analyzed. These procedures permitted to remove 23,379 polyps, the characteristics of which are detailed in ▶ **Table 1**. The overall CIR was 97.8 %: ≥ 90 % for 94.0 % of endoscopists and ≥ 95 % for 80.2 %. The number of colonoscopies per endoscopist varied from 1 to 623 (mean 116, SD 126, median 85). A total of 388 colonoscopies reported by 36 endoscopists having performed < 30 colonoscopies during the study period were excluded from further analysis. Consequently, 13,067 colonoscopies were finally evaluated, performed by 80 endoscopists. ▶ **Table 2** describes the detection and characterization indicators and ▶ **Table 3** reports the correlation coefficients and associated *P* values.

▶ **Table 1** Characteristics of all polyps removed within the colorectal cancer screening program with fecal immunochemical test.

Size (mm)	**No.**	**Proportion**
0–5	12,792	54.7 %
6–9	4822	20.6 %
10–19	4545	19.4 %
≥ 20	1220	5.2 %
Pathology	**No.**	**Proportion**
Tubulous adenoma	11,741	50.2 %
Tubulovillous adenoma	4615	19.7 %
Villous adenoma	133	0.6 %
Total conventional adenomas	17,229	73.7 %
Hyperplastic	4023	17.2 %
Sessile serrated polyp without dysplasia	314	1.3 %
Sessile serrated adenoma with dysplasia	403	1.7 %
Traditional serrated adenoma	23	0.1 %
Total serrated lesions	4763	20.4 %
Inflammatory	220	0.9 %
Lymphoid	65	0.3 %
Juvenile	39	0.2 %
Other	641	2.7 %
Total non-adenomatous, non-serrated	965	4.1 %
Unknown	1162	5.0 %
Total	23,379	100.0 %

Detection indicators

The overall ADR was 57.6 %. Of 72 endoscopists having an ADR ≥ 45 %, 5 (6.9 %) had an MNA below 0.8, whereas of 48 endoscopists having an ADR ≥ 55 %, only one (2.1 %) had an MNA below 0.8 (▶ **Fig. 1**). Likewise, 26 (36.1 %) endoscopists having an ADR ≥ 45 % had a ProxSLDR below 4 %, whereas only two (4.2 %) having an ADR ≥ 55 % had a ProxSLDR below 4 % (▶ **Fig. 2**). Overall, 40.0 % of the endoscopists had an ADR < 55 % and 52.5 % an ADR between 55 % and 70 %. Globally, 0.84 × PDR gave an estimate of ADR. However, individually, the ADR/PDR ratio varied from 0.61 to 0.93 depending on the endoscopist (▶ **Fig. 3**).

Characterization indicators

Most NNPs were distal HPs (15.4 % overall) and NANSLs (6.0 % overall). Overall, the positive predictive value (PPV) of optical diagnosis for NPs, that is the mean number of neoplastic polyps divided by the mean number of polyps, was 72.8 %, varying from 37.8 % to 100 % depending on the endoscopist. It was inversely significantly correlated with all other characterization indicators: e. g. DistHPDR ($r = -0.69$; $P \leq 0.01$; coefficient of determination R2 = 0.47) and NNPDR ($r = -0.68$; $P \leq 0.01$; R2 = 0.46). The NNPDR was 39.5 % in endoscopists whose ADR was > 70 %, significantly higher than 21.4 % in those whose ADR was ≤ 70 % ($P < 0.001$). The correlation between characterization (NNPDR) and detection indicators was moderate for ADR ($r = 0.64$; $P < 0.01$; R2 = 0.40) (▶ **Fig. 4**) and strong for ProxSLDR ($r = 0.73$; $P < 0.01$; R2 = 0.54).

▶ **Table 2** Detection and characterization indicators within the fecal immunochemical test screening program (80 endoscopists having performed ≥30 colonoscopies).

Indicator	Men		Women		Overall				
	Mean (SD)	Median (range)	Mean (SD)	Median (range)	Mean (SD)	Median (range)	Benchmark		% High detectors
							Minimum	Desirable	
ADR	63.5% (12.1)	64.5% (25.0–90.5)	46.4% (11.0)	46.9% (21.3–67.6)	56.5% (10.2)	57.8% (27.8–81.0)	45%	55–70%	87.5
AADR	41.0% (10.4)	41.6% (14.3–70.7)	26.6% (9.4)	26.1% (5.0–48.8)	35.1% (8.5)	35.2% (16.2–61.9)	25%	–	88.8
PDR	74.0% (12.8)	75.6% (25.0–95.2)	58.1% (12.5)	59.6% (29.5–90.3)	67.5% (11.8)	68.9% (30.6–89.8)	55%	–	87.5
MNA	1.5 (0.6)	1.4 (0.4–3.0)	0.8 (0.4)	0.8 (0.2–2.1)	1.2 (0.5)	1.2 (0.3–2.7)	0.8	1	85.0
MNAPPC	2.3 (0.6)	2.3 (1.0–4.1)	1.7 (0.4)	1.7 (1.0–3.3)	2.1 (0.5)	2.1 (1.0–3.8)	1.8	–	78.8
SSLDR	3.8% (3.7)	2.9% (0.0–18.2)	3.9% (4.4)	2.9% (0.0–23.1)	3.9% (3.5)	3.1% (0.0–17.4)	–	–	–
ProxSLDR	7.6% (6.0)	6.6% (0.0–22.6)	7.4% (6.3)	6.0% (0.0–29.4)	7.7% (5.5)	6.5% (0.0–25.3)	4%	5%	62.5
NNPDR	27.9% (13.2)	28.0% (0.0–72.5)	19.4% (12.4)	16.3% (0.0–74.2)	24.5% (12.4)	24.3% (0.0–73.2)	30%	25%	75.0
NANSLDR	8.5% (6.0)	7.6% (0.0–25.5)	5.8% (5.1)	4.8% (0.0–23.8)	7.4% (5.2)	6.6% (0.0–23.8)	10%	7%	75.0

AADR, advanced adenoma detection rate ADR; adenoma detection rate MNA, mean number of adenomas per colonoscopy; MNAPPC, mean number of adenomas per positive colonoscopy; NANSLDR, non-adenomatous non-serrated lesion detection rate; NNPDR, non-neoplastic polyp detection rate; PDR, polyp detection rate; ProxSLDR, proximal serrated lesion detection rate; SSLDR, sessile serrated adenoma/polyp detection rate.

Time course of detection and characterization indicators

Whereas the overall ADR was similar between the two FIT rounds (58.0% in the first [2015–17] vs 57.0% in the second [2017–19]; $P=0.2$), the overall ProxSLDR increased significantly from 7.0% to 8.5% ($P=0.002$). Likewise, characterization indicators increased significantly (e.g. NNPDR from 15.4% to 22.9% [$P<0.001$]).

Factors associated with detection and characterization indicators

▶ **Table 4** reports results from multivariable analyses and provides odds ratios (ORs), 95% confidence intervals (95% confidence intervals [CIs]) and associated *P* values for the detection and characterization indicators. The factors significantly associated with ADR were sex, age, screening history, fecal hemoglobin concentration, CIR<90%, and endoscopist. In particular, a 10 µg/g increase in fecal hemoglobin concentration was associated with higher ADR (OR [95% CI]=1.02 [1.02–1.03]). Private or public practice, year of colonoscopy, time to colonoscopy, and FIT-positive colonoscopy volume, however, were not significant (data not shown). Regarding ProxSLDR, a previous colonoscopy screening, CIR<90%, and endoscopist were significant factors. Finally, the factors significantly associated with NNPDR were sex, previous screening colonoscopy, and endoscopist.

Discussion

Main findings

The overall ADR in FIT-positive colonoscopies was 57.6% in this study, higher than ADRs reported in other FIT (43.5% to 51.5%) [10,11,32], gFOBT (35% to 47%) [21,32] and colonoscopy screening programs (20% to 25%) [7,22]. However, dramatic inter-endoscopist variation was observed in our organized screening program in both adenoma detection and characterization. For example, depending on the endoscopist, the ratio to estimate ADR from PDR varied from 0.61 to 0.93 and the NNPDR from 0% to 73.2%. In any case, our findings demonstrated that a single indicator, ADR, was enough to define high-level detectors exhibiting good characterization ability, provided its minimum target standard was raised to 55% and a maximum standard was added at 70%. We further are the first to demonstrate that each 10 µg/g increase in fecal hemoglobin concentration was associated with higher ADR (OR [95% CI]=1.02 [1.02–1.03]). Last, 35.9% of individuals were not being given the best possible chances as their colonoscopies were performed by 48.3% of endoscopists who had low CIRs and/or low ADRs.

▶ **Table 3** Correlation coefficients between the values of detection and characterization indicators (80 endoscopists having performed ≥ 30 colonoscopies).

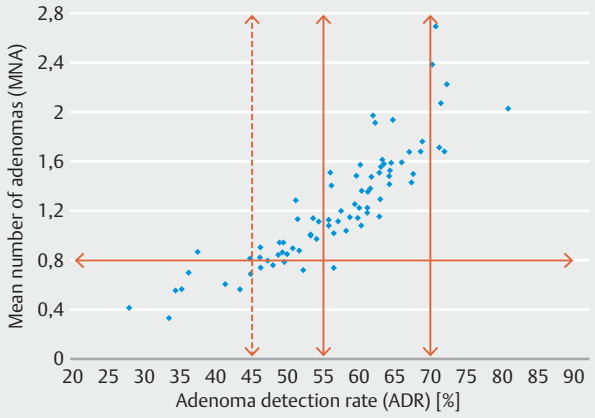
	Pearson (p) – R2							
					NNPDR	**1.00–1.00**		
ADR	1.00–1.00				**DistHPDR**	0.95 (*P*<0.01) −0.91	1.00–1.00	
AADR	0.76 (*P*<0.01) −0.57	1.00–1.00			**NANSLDR**	0.72 (*P*<0.01) −0.52	0.53 (*P*<0.01) −0.28	1.00–1.00
PDR	0.94 (*P*<0.01) −0.88	0.71 (*P*<0.01) −0.51	1.00–1.00			**NNPDR**	**DistHPDR**	**NANSLDR**
MNA	0.87 (*P*<0.01) −0.76	0.61 (*P*<0.01)	0.89 (*P*<0.01) −0.79	1.00–1.00				
MNAPPC	0.69 (*P*<0.01) −0.48	0.46 (*P*<0.01) −0.21	0.75 (*P*<0.01) −0.57	0.94 (*P*<0.01) −0.88	1.00–1.00			
SSLDR	0.53 (*P*<0.01) −0.28	0.39 (*P*<0.01) −0.15	0.55 (*P*<0.01) −0.30	0.62 (*P*<0.01) −0.38	0.49 (*P*<0.01) −0.24	1.00–1.00		
ProxSLDR	0.73 (*P*<0.01) −0.53	0.49 (*P*<0.01) −0.24	0.77 (*P*<0.01) −0.60	0.80 (*P*<0.01) −0.63	0.67 (*P*<0.01) −0.45	0.77 (*P*<0.01) −0.59	1.00–1.00	
	ADR	**AADR**	**PDR**	**MNA**	**MNAPPC**	**SSLDR**	**ProxSLDR**	

AADR, advanced adenoma detection rate; ADR, adenoma detection rate; DistHPDR, distal hyperplastic polyp detection rate; MNA, mean number of adenomas per colonoscopy; MNAPPC, mean number of adenomas per positive colonoscopy; MNP, mean number of polyps per colonoscopy; NANSLDR, non-adenomatous non-serrated lesion detection rate; NNPDR, non-neoplastic polyp detection rate; PDR, polyp detection rate; ProxSLDR, proximal serrated lesion detection rate; SSLDR, sessile serrated adenoma/polyp detection rate.

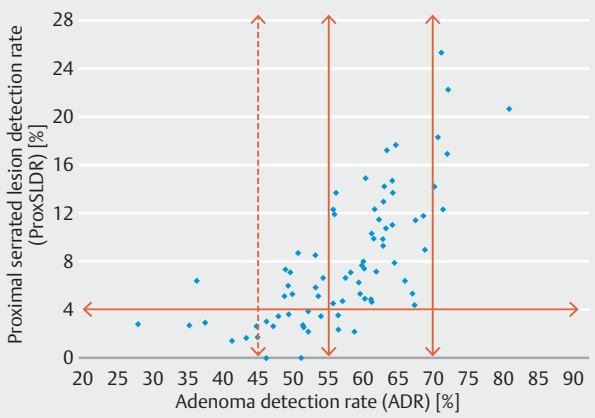
Alternative detection indicators

Overall, our correlations between neoplasia-related quality indicators were comparable to data in the literature. There is no ideal detection indicator, the purpose of which is to assess and compare performances between individual endoscopists, but also between endoscopy centers and CRC screening strategies and programs. The most appropriate indicator is one that is actually measured in routine practice. Therefore, it has to be user-friendly for busy endoscopists, i.e. a unique global indicator that is easy to calculate and correlated with post-colonoscopy CRC risk and death. All detection indicators are equally complicated to calculate, as they all depend on the pathology report, except for PDR and PR that can be automatically derived from administrative data. The correlations are strong between ADR and PDR or PR [2, 34]. Moreover, PR is significantly associated with risk of proximal post-colonoscopy CRC [5]. However, the ratio to estimate ADR from PDR varies from 0.53 to 0.68 depending on studies and gender and varied from 0.61 to 0.93 in our study depending on the endoscopist [34]. These large variations reflect the very different behaviors of endoscopists encountering a polyp, depending on many factors, such as personality, training, time availability, use of electronic chromoendoscopy and/or high-definition endoscopes, and payment system. Therefore, ADR cannot be estimated from PDR or PR using a unique conversion factor for the evaluation of an individual endoscopist. The conversion factor should be first evaluated individually by the endoscopist on a sample of 50 colonoscopies, and then used for the assessment of subsequent colonoscopies [35].

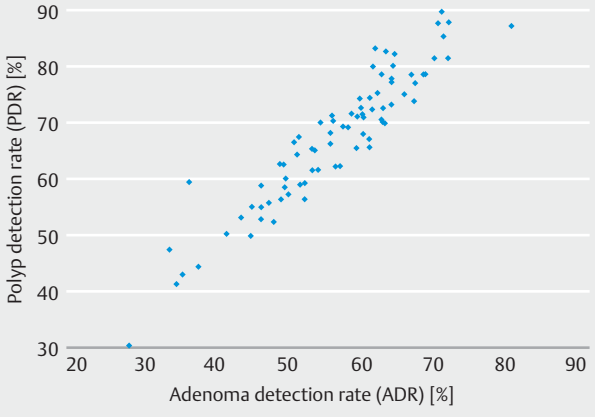
Our results concerning SLs are similar to data in the literature. Our overall SSLDR was 3.9 % (95 % CI 3.6–4.3), significantly higher than reported in another large FIT screening programs, estimated at 1.8 % (95 % CI 1.7–1.9) [24]. Likewise, our overall ProxSPDR was 7.6 % (95 % CI 7.2–8.1), within the range of 3 % to 13 % reported in screening colonoscopies, and increased over time [36]. As others, we found a good correlation between SSLDR, ProxSLDR and ADR and all other detection indicators along with broad inter-endoscopist variations (0 % to 25 %) [24, 25, 36]. We further found a significant ProxSLDR decrease in individuals previously screened by colonoscopy (OR 0.6; 95 % CI 0.4–0.9), whereas there was no significant difference in individuals previously screened by gFOBT and FIT. This observation, along with the fact that there was no significant association between fecal hemoglobin concentration and proxSLDR confirms that FOBT (gFOBT and FIT) is not a good screening tool for proximal SLs.



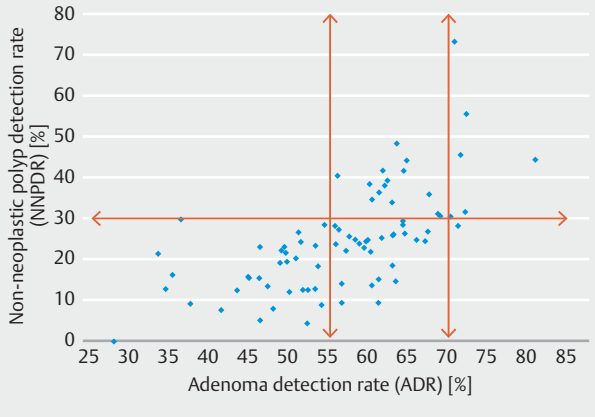
▶ **Fig. 1** Correlation between adenoma detection rate and mean number of adenomas per colonoscopy.



▶ **Fig. 2** Correlation between adenoma and proximal serrated lesions detection rates.



▶ **Fig. 3** Correlation between adenoma and polyp detection rates.



▶ **Fig. 4** Correlation between adenoma and non-neoplastic polyps detection rates.

ADR benchmark

The ASGE/ACG Task Force on Quality in Endoscopy raised the recommended minimum target for ADR to 25 % in 2015 [8]. This target was adopted by the ESGE in 2017 [9] and validated by three studies [4, 6, 7]. For each 1 % increase in ADR, a 3 % reduction in post-colonoscopy CRC incidence and a 5 % reduction in post-colonoscopy CRC mortality were observed [6]. There is no evidence-based benchmark established for FOBT screening. A benchmark ADR of 35 % is recommended for gFOBT screening in the English BCSP as in the previous French program [37]. The US Multi-Society Task Force on CRC recommended a benchmark of 45 % in men and 35 % in women for FIT-positive colonoscopies (positivity threshold 20 µg/g) [15]. Two studies estimated that an ADR of 25 % in screening colonoscopies in average risk individuals corresponded to ADRs of 49 % and 55 % in FIT-positive colonoscopies (positivity threshold 15 µg /g) [12, 13]. The level of evidence, however, is low to moderate. French recommendations adopted a benchmark of 45 % based on our first FIT round. This low cut-off was chosen so that only 12.5 % of endoscopists with very low ADRs – the greatest contributors to failure to prevent CRC – were considered low detectors. It is situated below our overall prevalence of adenomas (57.6 %) and well below our true prevalence (70 % to 80 %) reached by very high detectors. We consider that a minimum of 45 %, under which the risk of post-colonoscopy CRC would be prohibitive, should be a condition for acquiring and maintaining certification. However, we would recommend raising the minimum standard to 55 %. The rationale is based on the dose-dependent approximately linear relationship between ADR and post-colonoscopy CRC risk [6]. We chose 55 % because almost all endoscopists having an ADR ≥ 55 % had an MNA ≥ 0.8 (▶ **Fig. 1**) and a ProxSLDR ≥ 4 % (▶ **Fig. 2**). Thus, a single indicator target, ADR ≥ 55 %, would enable selection of high detectors for both conventional adenomas and proximal SLs, while avoiding the “one and done” pattern. Furthermore, the MNAPPC did not add any complementary information on colonoscopy quality.

▶ **Table 4** Results from multivariable logistic regression to determine associated factors with detection and characterization indicators (13,067 colonoscopies performed by the 80 endoscopists).

	ADR		ProxSLDR		NNPDR	
	Odds ratio [95 % CI]	***P* value**	**Odds ratio [95 % CI]**	***P* value**	**Odds ratio [95 % CI]**	***P* value**
Sex						
▪ Women	Ref		Ref		Ref	
▪ Men	2.1 [1.9–2.3]	0.001	1.0 [0.9–1.2]	0.5	1.6 [1.5–1.8]	0.001
Age						
▪ 50–54 years	Ref		Ref		Ref	
▪ 55–59 years	1.7 [1.5–1.9]	0.001	1.0 [0.8–1.3]	0.9	1.1 [1.0–1.3]	0.08
▪ 60–64 years	2.0 [1.8–2.3]	0.001	1.3 [1.1–1.6]	0.007	1.3 [1.2–1.5]	0.001
▪ 65–69 years	2.3 [2.0–2.5]	0.001	1.2 [1.0–1.5]	0.06	1.2 [1.1–1.4]	0.004
▪ 70–74 years	2.5 [2.2–2.8]	0.001	1.0 [0.8–1.2]	0.7	1.0 [0.9–1.2]	0.6
Screening history						
▪ No screening	Ref		Ref		Ref	
▪ Colonoscopy	0.4 [0.3–0.5]	0.001	0.6 [0.4–0.9]	0.03	0.6 [0.4–0.7]	0.001
▪ gFOBT	0.9 [0.9–1.0]	0.2	1.0 [0.8–1.1]	0.7	0.9 [0.8–1.1]	0.3
▪ FIT	0.8 [0.7–0.9]	0.001	1.0 [0.8–1.2]	0.7	0.9 [0.8–1.1]	0.4
Fecal hemoglobin concentration						
▪ 10 µg/g	1.02 [1.02–1.03]	0.001	1.01 [1.00–1.02]	0.3	1.00 [0.99–1.00]	0.4
CIR						
▪ ≥ 95 %	Ref		Ref		Ref	
▪ 90 %–95 %	0.8 [0.6–1.1]	0.2	0.7 [0.4–1.3]	0.3	0.9 [0.6–1.4]	0.6
▪ 90 %	0.5 [0.3–0.8]	0.004	0.4 [0.1–1.1]	0.07	0.8 [0.4–1.6]	0.6

ADR, adenoma detection rate; CIR, cecal intubation rate; FIT, fecal immunochemical test; gFOBT, guaiac fecal occult blood test; NNPDR, non-neoplastic polyp detection rate; ProxSLDR, proximal serrated lesion detection rate.

In our opinion, adopting the highest detectors' performance level as the aspirational benchmark is not desirable because that level is achieved by detecting and removing all diminutive lesions, both adenomas and NNPs [26, 31]. There is no proof that the risk of post-colonoscopy CRC of very high detectors is significantly lower than that of high detectors. The overall rates of NNPs and diminutive polyps were much lower in our population-based study than in a single high-level detector series (22.9 % vs 35.7 %, and 54.7 % vs 75.0 %, respectively, $P<0.00001$) [26]. However, "high-level detectors can produce a substantial economic burden of polyp resection and pathology charges for lesions with minimal clinical significance" [26]. Likewise, in a small study of FIT-positive colonoscopies, some accredited endoscopists had ADRs as high as 90 % to 95 % [38]. Their NNPDRs and NANSLDRs were not reported but certainly very high. ADR is the ideal tool to encourage endoscopists to improve their adenoma detection performances but should not lead to an endless race. A maximum standard for the target ADR is thus desirable. To determine this maximum, we propose to adopt the true prevalence of "clinically relevant adenomas," and not of "all adenomas," We adopted 70 % because NNPDR and NANSLDR were significantly higher in endoscopists having an ADR > 70 % than in those having an ADR ≤ 70 %. Interestingly, using another method, Rex et al. proposed an aspirational target of 65 % to 70 % for FIT-positive colonoscopies, similar to our 55 % to 70 % proposition [26].

Characterization indicators

The correlation between detection and characterization indicators was moderate (ADR) to strong (ProxSLDR) in our study. Previous small single-center studies observed strong correlations between ADR and NANSLDR or NNPDR [23, 30, 39]. In other words, the more endoscopists detected adenomas and proximal SLs, the lower their PPV for NPs, i. e. the lesser their characterization competency and greater the number of NNPs they removed. There is neither an indicator nor a benchmark recommended to estimate the proportion of NNPs removed during colonoscopy. Such an indicator would represent the

ability of the endoscopist to differentiate NPs that have to be removed from NNPs that should be left in situ and to estimate indirectly the cost-effectiveness of polypectomy. The lower the proportion of NNPs removed, the more cost-effective the procedure. NNPDR and NANSLDR are potential candidates. They vary largely depending on the endoscopist [23, 30, 39]. Literature is scarce in this field. Regardless of the indicator, our proportion of NNPs was lower than previously reported. Our overall NNPDR was 22.9 %, significantly lower than the 28 % to 29 % observed in a single-center study ($P<0.001$) [39]. Likewise, our overall NANSLDR was 6.4 %, significantly lower than the 9 % to 10 % observed in two small single-center studies ($P<0.001$) [23, 30]. Technological progresses, such as high-definition, electronic chromoendoscopy (e. g. NBI) or artificial intelligence, should allow increased characterization ability. Some authors, using new technologies, are able to discriminate NPs from NNPs in > 90 % of cases [17, 40]. Such high accuracy is however controversial and, in any case, community endoscopists are far from these performances [17, 19]. Moreover, NNPDR and NANSLDR increased over time in our study, probably the perverse effect of the adenoma detection race, endoscopists being encouraged to improve their ADRs and thus being prompted to detect and remove as many polyps as possible. Feedback and training are thus desirable to increase characterization performances and diminish unnecessary risks and costs. For research purposes, NANSLDR being too restrictive, we would recommend measuring NNPDR and propose a maximum standard of 30 % corresponding to the third quartile in our study (and an aspirational maximum standard of 25 % corresponding to the second quartile).

Strengths and limitations of the study

This was a large population- and community-based real-world study, which is its main strength. Other strengths include prospectively collected data and a high-quality database, as evidenced by our 5 % rate of unknown polyp histology. Our study is, to our knowledge, the first to analyze the association between neoplasia-related indicators and fecal hemoglobin concentration and screening history. Our study is not without limitations. The main is the low-to-moderate level of evidence of the minimum standard we proposed for ADR. Strong evidence could be derived from studies evaluating post-colonoscopy CRC risk and its association with ADR within CRC screening programs with FIT, but results will not be available for several years. Another limitation is that our standards are not generalizable as they are specific for our population and FIT positivity threshold (30 µg/g). In any case, a universal ADR standard cannot be established as ADR depends on colorectal neoplasia incidence which varies according to several factors such as age, sex, country, ethnicity, screening history, FIT positivity threshold [8, 9]. Moreover, our FIT-positive population was not screening naïve as a gFOBT CRC screening program had been running for 8 to 12 years before. Standards should be lessened for lower positivity thresholds and raised in naïve populations. Last, some factors influencing neoplasia yield were not included in our analysis. For instance, certain patient-related factors such as body mass index, smoking habits or quality of bowel preparation, endoscopist-related factors such as withdrawal time and technique, practice duration, endoscope-related factors such as instrument generation, and endoscopy center-related factors such as the existence of screening-dedicated sessions were not examined. This should however not modify our findings because the principal demographic features predictive of neoplasia at colonoscopy are age and gender, which were analyzed, and to a lesser extent family history of colorectal neoplasia, which was excluded from our screening program.

Future research

Future research should be directed at measuring the correlation between ADR and the risk of post-colonoscopy CRC in FIT screening programs. The low ADRs observed in a number of endoscopists is an issue in organized CRC screening programs supposed to offer to the screened population an equally high-quality service. Reduction of the percentage of low detectors should be a priority for quality improvement programs, as they are the main cause of post-colonoscopy CRCs. Several studies have demonstrated that it is possible to improve performance through well-designed training programs [41]. Endoscopists whose ADRs are < 55 % should improve their detection ability. Those whose ADRs exceed 55 % should improve their characterization ability to leave in situ NNPs and improve the benefit/risk and cost-effectiveness balances of their procedures. A good endoscopist should have both good visual skills, i. e. detection (for both conventional adenomas and significant SLs) and characterization abilities, and manual skills, such as high CIR and good polypectomy competency. We proposed elsewhere a new indicator to evaluate the latter [42].

Conclusions

As a whole, our study is the first to propose: 1) an ADR benchmark for FIT-positive colonoscopies grounded in population- and community-based real-world data; and 2) the concept of a maximum standard for this indicator. It suggests the absence of added value of other indicators, such as ProxSLDR, MNA and MNAPPC, and reinforces the role of ADR as a key performance indicator. It further demonstrates the correlation between characterization and detection indicators. Most importantly, it suggests that ADR, as a single indicator, is enough to assess endoscopist performance for both detection and characterization, provided two conditions are met: 1) the desirable minimum target standard is raised to a higher level than previously recommended; and 2) a maximum standard is added. In the French organized CRC screening program with FIT (30 µg/g positivity cut-off), the desirable target standard should be established between 55 % and 70 % (65 % to 80 % in men, 45 % to 60 % in women) to maximize the benefit/risk balance of the program.

Acknowledgments

In memoriam Dr. Isabelle Gendre (1964–2022). The authors thank all the gastroenterologists, pathologists and general practitioners who participated in the CRC screening program organized in Alsace. This study was performed as part of a quality assurance program within the French national CRC screening program without dedicated funding. The sources of funding of the national program include the French statutory health insurance scheme (Assurance Maladie), the French Ministry of Health and some regional Administrations. They had no role in study design, data collection, analysis, and interpretation, or writing the report.

Preprint server

medRxiv 2020.08.31.20185124; doi: https://doi.org/10.1101/2020.08.31.20185124

Data sharing statement: All deidentified participant data are available upon reasonable request from contactalsacecolon@-depistagecancer-ge.fr

Competing interests

Pr Gabriel Rahmi reports personal fees from Medtronic, Fujifilm, and grants from Norgine.

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