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Meta-Analysis

# Effect of fellow involvement on colonoscopy outcomes: A systematic review and meta-analysis

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ABSTRACT

*Background and aims:* The effect of fellow involvement on colonoscopy outcomes is controversial. Thus, we evaluated this effect on adenoma detection rate (ADR) and on other colonoscopy quality indicators.
*Methods:* MEDLINE and Cochrane central register of controlled trials were searched up to September 2018 for studies evaluating fellow-involved colonoscopies *vs.* attending physicians-only examinations in terms of colonoscopy outcomes. Primary outcome was ADR, while advanced ADR (AADR), mean number of adenomas per colonoscopy (MAC), cecum intubation rate (CIR) and adverse events rate comprised the secondary outcomes. The effect size on study outcomes was calculated using random-effects model and it is presented as Odds Ratio (OR) or Mean Difference (MD) with 95% confidence interval (CI).
*Results:* Nineteen observational studies involving 34,059 patients (fellow-involved 16,875, attending physician-only 17,184) were included. Compared to the attending physician-only group, fellow involvement marginally increased ADR [OR (95%CI) = 1.12 (1.00–1.26); p = 0.06, $I^2$ = 76%]. Attending physicians with low-to-moderate ADR (<35%) benefited most from fellow's participation [OR (95%CI): 1.26 (1.13–1.40) *vs.* 1.12 (1.00–1.26); p = 0.03 when ADR < 35% and OR (95%CI): 1.29 (1.13–1.46) *vs.* 0.95 (0.78–1.16); p = 0.01 when ADR < 30%, respectively]. Moreover, fellow-involved group had higher MAC compared to attending-only group [MD (95%CI) = 0.12 (0.04–0.20); p = 0.002, $I^2$ = 53%]. No benefit from fellow involvement was detected either for AADR, CIR or adverse events rate.
*Conclusions:* Fellow involvement during colonoscopy is associated with more adenomas detected per procedure and with higher ADR when the attending physician-only group ADR is less than 35%.


## 1. Introduction

Colonoscopy is the reference standard for colorectal cancer (CRC) screening, since it enables detection and subsequent removal of its major precursor lesions, namely adenomas [1]. However, colonoscopy is not fully protective as a certain proportion of adenomas may remain undetected, contributing to the development of interval CRC [2]. Adenoma detection rate (ADR) – the percentage of screening or diagnostic colonoscopies in patients aged 50 years or older with at least one adenoma [3] – has been inversely associated with the risk of developing interval CRC [4,5]. Hence, ADR has emerged as a surrogate for meticulous inspection of the colonic mucosa [3]. Beyond adequate bowel preparation and minimum withdrawal time of six minutes, novel endoscopic techniques – *i.e.* retroflexion in the right colon, sophisticated instruments innovations and simple accessory devices fitted on the tip of the scope – have been devised aiming to improve ADR [6–8]. Nonetheless, their exact role in everyday clinical practice remains to be elucidated, since robust data regarding their efficacy are lacking while the additional cost of their use represents a considerable burden. On the other hand, optimizing existing resources like adding a "second observer" during colonoscopy has been proposed as an efficient and cost effective approach to increase ADR [9]. We aimed to perform a meta-analysis of the current literature in order to appraise the evidence for the role of fellows on colonoscopy outcomes.

## 2. Materials and methods

### 2.1. Protocol registration

This systematic review was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) recommendations [10] (available in Appendix A) and the

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pre-specified protocol was registered in the PROSPERO database under the registration number CRD42018110110.

### 2.2. Eligibility criteria

Eligibility criteria were *a priori* defined according to the PICO statement as following; P: patients undergoing colonoscopy for any indication; I: examinations performed by fellows under supervision of attending physicians; C: comparison of fellow-involved *vs.* attending physicians-only colonoscopies; O: colonoscopy outcomes (as listed below in the *Outcome measures* section). Any type of trial published as full-text was included. Pediatric studies, editorials, case reports or case series, systematic reviews, data from conference abstracts, studies not published in English and duplicate publications were excluded.

### 2.3. Identification and selection of studies

A comprehensive computer-aided literature search was conducted on September 26th 2018 across MEDLINE and Cochrane Central Register of Clinical Trials databases. The search was performed using the following terms: "fellow*", "trainee*" and "adenoma*", both as medical subject headings (MeSH) and free-text terms and restricted only to studies published in the English language. Bibliographies of the relevant articles identified by the initial search were also hand searched to identify additional citations. Two independently working investigators (G.T, P.G.) performed the search and eligibility assessment using pre-designed forms, with all disagreements resolved by consensus decision. First, titles and abstracts of all results were reviewed followed by assessment of the full-text content of eligible studies. We also attempted to contact authors of studies with missing or incomplete data to include in them our analysis. Full details of the search strategy are presented in Appendix B.

### 2.4. Data extraction and quality assessment

Two investigators (G.T, P.G.) extracted the data from identified papers independently, using a Microsoft Excel spreadsheet (Microsoft Corp, Redmond, WA, USA). For each study we extracted the following data: year of publication, first author name, country of origin, study design, number of centers, total number of participants, number of participating endoscopists (fellows and attending physicians), indication for colonoscopy, type of colonoscope used [high definition (HD), standard definition (SD)], number of patients with at least one adenoma in each group, number of patients with at least one advanced adenoma in each group, mean adenoma per colonoscopy, cecum intubation rate and adverse events rate.

### 2.5. Study methodological quality

The quality of each study was evaluated independently by two authors (G.T, P.G.) using the Newcastle–Ottawa Scale (NOS) [11], which takes into consideration patient selection, comparability of intervention, control group, and outcome assessment. Regarding comparability, we evaluated each study according to whether authors checked for differences between study's group regarding either patient's (gender, age) or examination's characteristics (indication, bowel preparation).

### 2.6. Outcome measures

The primary endpoint of our study was to examine the effect of fellow participation during colonoscopy on ADR. Secondary endpoints comprised the effect of fellow involvement on the rate of examinations with at least one advanced (≥10 mm, villous component, and/or high-grade dysplasia) adenoma (AADR), mean number of adenomas per colonoscopy (MAC), cecum intubation rate (CIR) as defined in each study and adverse events rate (AE).

### 2.7. Data synthesis and statistical analysis

Regarding the primary endpoint as well as AADR, CIR and AEs, results are expressed as pooled odds ratio (OR) with a 95% confidence interval (CI). For MAC, inverse variance was used and mean difference (MD) 95%CI was calculated. All outcomes were meta-analyzed using random-effects model (DerSimonian and Laird method). The threshold for statistical significance was set to $p < 0.05$. Review Manager 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) and StatsDirect 3 (StatsDirect Ltd, Sale, Cheshire, England) software packages were used to perform the meta-analysis and generate forest and funnel plots of pooled ORs for all outcomes.

### 2.8. Heterogeneity assessment sensitivity analyses and subgroup analyses

The $I^2$ statistic >50% (or a P value < 0.1) was used to indicate statistically significant heterogeneity. In that case, sensitivity analysis was performed (a) by excluding one study at a time as proposed by the Cochrane collaboration, (b) indication of examinations (screening colonoscopies *vs.* examinations of various indications); (c) rate of fellows' participation in the cohort (<50% *vs.* ≥ 50%) performed for the primary outcome only; (d) attending physicians' ADR (<25%, <30%, <35%, <40% and ≥40%, when ADR < 35% operators were deemed as low-to-moderate and when ADR > 45% as high [12] and (e) use of SD *vs.* HD in order to identify factors contributing to the detected heterogeneity. The aforementioned analyses were also performed as predefined subgroup analyses.

### 2.9. Publication bias assessment

Publication bias was assessed by application of Egger's test [13], if studies' number was ≥10 [14], or by visually inspecting funnel plots – constructed by plotting the log odds ratios (ORs) *vs.* precision of individual studies per outcome – for symmetry if study number was less than ten.

## 3. Results

### 3.1. Study selection

We identified 176 citations of which, after title and abstract review 63 deemed potentially relevant and were assessed further for eligibility (Fig. 1). Among these, 44 were excluded for various reasons leaving 19 studies to be included in the meta-analysis [15–33].

### 3.2. Characteristics of studies included

Table 1 summarizes the main characteristics of the included studies. Overall, 34,059 participants were enrolled in the included studies. Of them, 14 were retrospective [15,18–21,23,25–30,32,33], 4 prospective, but non-randomized [16,17,24,31] and one included a prospective non-randomized and a retrospective arm [22]. Regarding their origin 11 studies were conducted in North America (U.S.A. and Canada) [15,18–20,23,27–32], 1 in Argentina [25], 4 in Europe [16,17,22,33] and 3 in Asia [21,24,26]. In 12 studies [15–17,19,22,25,26,28,29,31–33] participants underwent colonoscopy for various indications (screening, surveillance and diagnostic) and in 7 studies [18,20,21,23,24,27,30]

**Table 1**
Characteristics of included studies.

| Author (Year) | Origin | Design | Period | Participants, n | Male, n (%) | Age Mean ± SD, yrs (Fellow group) | Age Mean ± SD, yrs (Attending group) | Fellows, n | Attending endoscopists, n | Fellow-involved colonoscopies, n (%) | Colonoscopy indications | Screening examinations, n (%) | Scopes used[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rogart (2008) [15] | USA | Retrospective, single-center | 08.2006–07.2007 | 309 | 187 (60.5) | 56.9 ± 11 | 55.6 ± 9.9 | NR | 4 | 183 (59.2) | Screening, surveillance, diagnostic | 230 (74.4) | HD |
| Eckardt (2009) [16] | Germany | Prospective, single-center | NR | 368 | 92 (25) | 56 ± 10 | 56 ± 9 | 7 | 3 | 181 (49.2) | Screening, surveillance, diagnostic | 321 (87.2) | HD |
| Koornsta (2009) [17] | The Netherlands | Prospective, single-center non-randomized | NR | 300 | 200 (66.7) | 54 (range 17–86) | 53 (range 18–87) | 1 | 1 | 150 (50) | Screening, surveillance, diagnostic | 88 (29.3) | SD |
| Peters (2010) [18] | USA | Retrospective, single-center | 04.2005–04.2007 | 3594 | 1626 (45.2) | 59.6 ± 7.5 | 58.3 ± 7.1 | NR | NR | 699 (19.4) | Screening | 3594 (100) | NR |
| Buchner (2011) [19] | USA | Retrospective, single-center | 09.2006–12.2007 | 2430 | 1306 (53.7) | 62 ± 12 | 63 ± 13 | 6 | 18 | 318 (13.1) | Screening, surveillance, diagnostic | 1095 (45) | HD and SD |
| Friedman (2011) [20] | USA | Retrospective, single-center | NR | 1190 | NR | NR | NR | NR | 8 | 219 (18.4) | Screening | 1190 (100) | NR |
| Nishiziwa (2011) [21] | Japan | Retrospective, single-center | 01.2006–12.2010 | 853 | 436 (51.1) | 64.8 ± 13.9 | 64.6 ± 13.1 | 10 | 7 | 342 (40.1) | Screening FOBT(+) | 853 (100) | NR |
| De Jonge (2012) [22] | The Netherlands | Retrospective and prospective cohorts included, multicenter | 03.2009–03.2010 | 4112 | 2264 (47.2) | 59.36 (15.9)[b] | | NR | NR | 744 (18.1) | Screening, surveillance, diagnostic | 414 (8.8) | NR |
| Chalifoux (2014) [23] | USA | Retrospective, single-center | 01.2005–12.2006 and 01.2008–09.2010 | 2011 | 1950 (97) | 60.1 ± 7.9 | 60.9 ± 8.8 | NR | 4 | 1341 (66.7) | Screening | 2011 (100) | First period: SD Second period: HD |
| Kim YD (2014) [24] | South Korea | Prospective, single-center non-randomized | 06.2010–11.2011 | 967 | 582 (60.2) | 49.2 ± 10.3 | 50.8 ± 12.9 | 7 | 4 | 633 (65.5) | Screening | 967 (100) | HD |
| Lasa (2014) [25] | Argentina | Retrospective, single-center | 07.2012–07.2013 | 685 | NR | NR | NR | 3 | 4 | 318 (46.4) | Screening, surveillance, diagnostic | NR | NR |
| Kim DJ (2015) [26] | South Korea | Retrospective, single-center | 05.2011–12.2012 | 508 | 269 (53) | 54.44 ± 10.74[b] | | 8 | 3 | 408 (80.3) | Screening, surveillance, diagnostic | NR | HD |
| Giannoti (2016) [27] | USA | Retrospective, single-center | 2009–2014 | 2940 | 1494 (50.8) | 57 (51–64) | 56 (51–63) | 10 | 4 | 2021 (68.7) | Screening | 2940 (100) | HD |
| Pace (2016) [28] | Canada | Retrospective, single-center | 01.2012–06.2012 | 867 | 386 (44.5) | 58.7 ± 12 | 59.6 ± 13 | 3 | 7 | 673 (77.6) | Screening, surveillance, diagnostic | NR | HD |
| Elhanafi (2017) [29] | USA | Retrospective, single-center | 11.2010–04.2012 and 09.2013-02.2014 | 658 | NR | NR | NR | NR | NR | 269 (40.9) | Screening, surveillance, diagnostic | NR | NR |
| Qayed (2017) [30] | USA | Retrospective, single-center | 07.2009–06.2015 | 7503 | 2770 (36.9) | 58.3 ± 7.1 | 57.9 ± 7.1 | 34 | 10 | 5039 (67.2) | Screening | 7503 (100) | NR |
| Shah Ghassemzadeh (2017) [31] | USA | Prospective, single-center, non-randomized | NA | 499 | 447 (89.6) | 63.6 ± 11.8 | 62.7 ± 11.2 | NR | NR | 82 (16.4) | Screening, surveillance, diagnostic | NR | NR |
| Bitar (2018) [32] | USA | Retrospective, single-center | 06.2012–12.2014 | 2024 | 191 (94.4) | 60.6 ± 10.8 | 60.8 ± 9.2 | 15 | 8 | 1657 (83) | Screening, surveillance, diagnostic | 250 (12.3) | HD |
| Gkolfakis (2018) [33] | Greece | Retrospective, single-center | 01.2014–12.2015 | 2241 | 1138 (50.8) | 61.3 ± 12.4 | 62.6 ± 13.1 | 6 | 4 | 1580 (70.5) | Screening, surveillance, diagnostic | 685 (30.6) | SD |

Yrs: years; SD: standard deviation; NR: not reported.

[a] In *scopes used* column: SD: standard definition; HD: high definition.

[b] In these studies mean age refers to all patients enrolled, no data per group (fellow-involved *vs.* attending-only) are available.

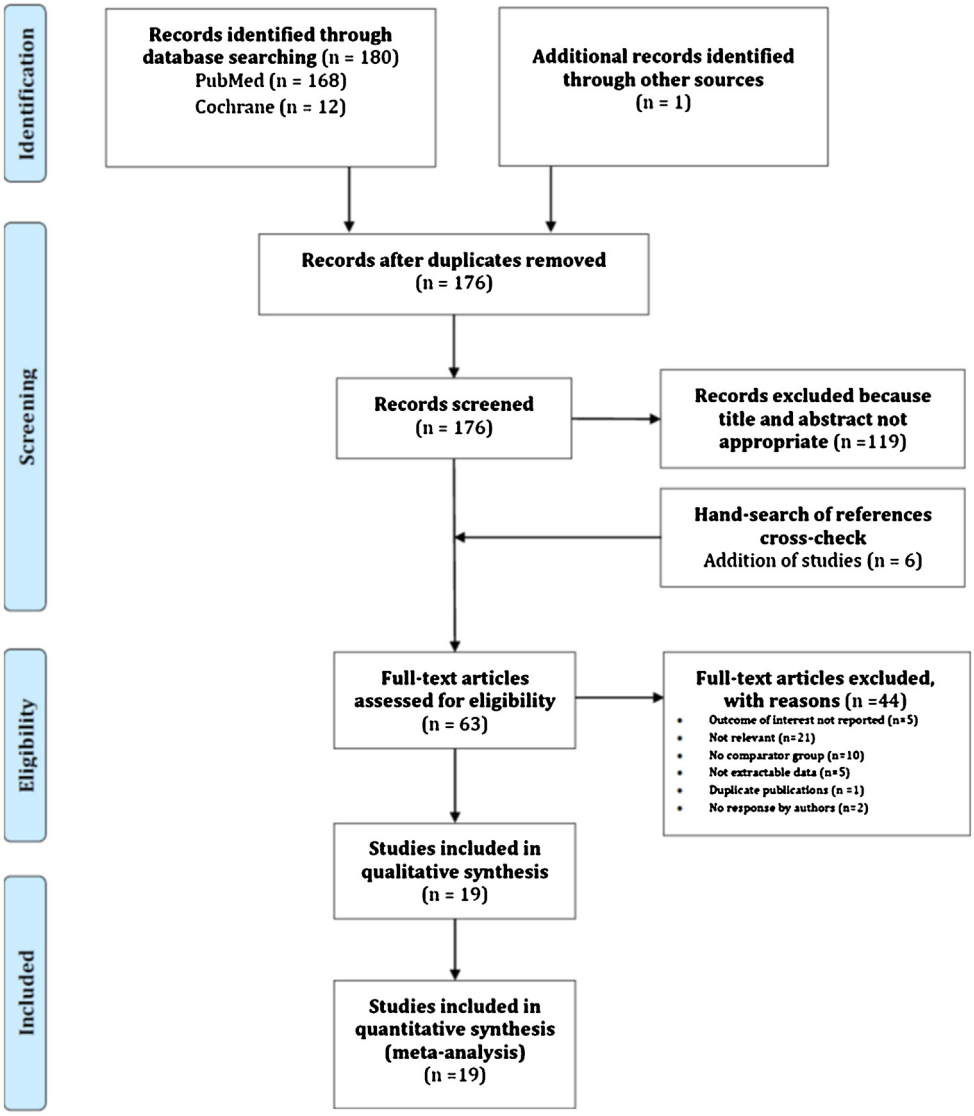


**Fig. 1.** Flowchart of literature search and study selection.

only screening examinations were included. Fifteen studies [15–17,19,19,20,21,23–28,30,32,33] reported the number of participating endoscopists, ranging from 1 to 34 and from 1 to 18 for fellows and attending physicians, respectively. Fellows participated in 13.1%–83% of the examinations.

### 3.3. Methodological quality and risk of bias

Quality assessment of each individual study according to Newcastle-Ottawa Scale is summarized in Appendix C Table 1. Despite all studies being observational and most of them of retrospective design, they maintained a quality level >7. Study center specifications were not available for one [20] and enrollment took place in a Veterans Affairs Hospital center [32] in another one, making the representativeness of these cohorts at the general population questionable. We evaluated comparability of cohorts according to authors control for patient (age, gender) and procedure-related (indication and/or quality of bowel preparation) characteristics. In three studies [21,25,33] comparability could not be assessed because the aforementioned control was either partial or absent.

### 3.4. Primary endpoint — adenoma detection rate

All studies [15–33] provided data on ADR. However, since one study [23] included two cohorts of patients – each one in a different period of time with utilization of different generation's scopes – 20 sets of data were available for our meta-analysis. Overall, at least one adenoma was detected in 6015 out of 16,875 examinations in the fellow-involved group compared to 5039 adenomas found in 17,184 examinations of the attending physician-only group; the difference did not reach statistical significance [OR (95%CI): 1.12 (1.00–1.26); $p = 0.06$; $I^2 = 76\%$; $P < 0.001$; Fig. 2A]. During the multiple-step sensitivity analysis (Appendix C Table 2) heterogeneity was eliminated ($I^2 = 0\%$; $P < 0.62$) when studies using standard definition scopes were included without changing the effect size [OR (95%CI): 1.12 (0.98–1.28)].

Appendix C Table 3 depicts the results of the subgroup analyses. No difference was detected according to indication (screening *vs.* various indications) and the per fellow's rate of participation (<50% *vs.* ≥ 50%) analyses. However, subgroup analysis according to attending physician's ADR showed that fellow's participation was associated with statistically significant higher odds of detection of at least one adenoma (ADR) when the attending physician-only

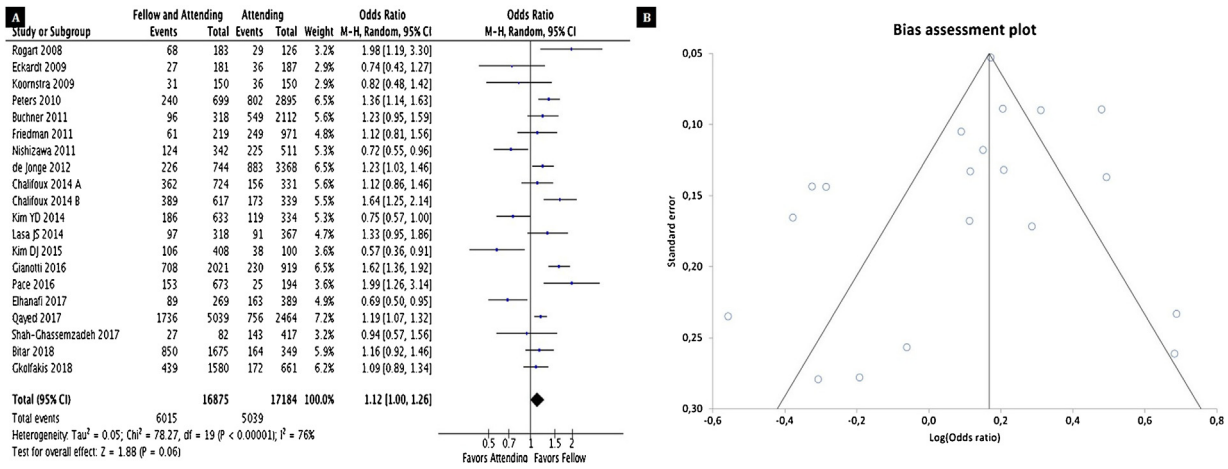


**Fig. 2.** Forest (A) and funnel (B) plot for studies assessing the effect of fellow involvement on ADR.

group ADR was less than 35% [OR (95%CI): 1.26 (1.13–1.40) *vs.* 1.12 (1.00–1.26); p = 0.03]. The effect of fellow's participation was even more evident for attending physician's ADR of less than 30% [OR (95%CI): 1.29 (1.13–1.46) *vs.* 0.95 (0.78–1.16); p = 0.01]. Finally, no publication bias was detected [Egger test: bias (95%CI): −1.31 (−3.44 to 0.83); p = 0.22; Fig. 2B].

### 3.5. Secondary endpoints

#### 3.5.1. Advanced adenoma detection rate

In terms of AADR, 14 sets of data were available for 13 studies [15,16,18–21,23–25,27,29,30,32]. A similar number of colonoscopies with at least one advanced adenoma was detected in the fellow-involved (1157/13238 examinations) and the attending only group (1050/12294 examinations); OR (95%CI): 0.95(0.83–1.08); p = 0.43; (Appendix D Fig. 1A). Neither significant heterogeneity ($I^2$ = 29%; P = 0.15) nor publication bias [Egger test: bias (95%CI): −0.74 (−2.29 to 0.82); p = 0.33; Appendix D Fig. 1B] were detected.

#### 3.5.2. Mean number adenomas per colonoscopy

Six studies [15,19,23,27,30,33] with 7 sets of data provided adequate information in order to calculate the MAC. The mean number of detected adenomas per colonoscopy was higher in the fellow-involved compared to the attending physician-only group [MD (95%CI): 0.12(0.04–0.20); p = 0.02; $I^2$ = 53%; P = 0.05; Appendix D Fig. 2A]. The sensitivity analysis (Appendix C Table 2) revealed that the exclusion of two retrospective studies [27,33] led to disappearance of the initial moderate heterogeneity ($I^2 \leq 36\%$; $P \geq 0.16$) without affecting the meta-analytic outcome. Moreover, heterogeneity was not any more evident when only studies with various indications [15,19,33] were taken into account ($I^2 \leq 42\%$; P = 0.18); however, statistical significance of outcome was lost [MD (95%CI): 0.09 (−0.10 to 0.28); p = 33]. Lack of heterogeneity was also noted for studies with attending physician-group ADR < 25% [15,27] or ≥40% [23] ($I^2$ = 0%; P = 0.66 and $I^2$ = 0%; P = 0.49, respectively). In both cases the meta-analytic outcome was not affected [MD (95%CI): 0.21 (0.11–0.30); p < 0.001 and 0.22 (0.06–0.38); p = 0.008, respectively]. Finally, homogeneity was achieved when included studies were evaluated separately according to endoscopes' generation. Studies with exclusively HD [15,23,27] instruments maintained the meta-analytic outcome compared to studies using either SD or both SD and HD scopes [19,23,33] [MD (95%CI): 0.22 (0.13–0.30); p < 0.001; $I^2$ = 0%; P = 0.82 compared to 0.02 (−0.06 to 0.11); p = 0.60; $I^2$ = 0%; P = 0.67, respectively]. We did not detect any publication bias (Appendix D Fig. 2B).

#### 3.5.3. Cecum intubation rate

CIR was assessed in 7 studies [15,17,22,25,28,31,33], while in 12 [16,18–21,23,24,26,27,29,30,32] studies either no data were provided or only completed colonoscopies were taken into consideration. No significant difference was evident between the two groups: in the fellow-involved group, cecum was reached in 3482/3730 examinations compared to 4960/5283 in the attending physician-only group [OR (95%CI): 0.84(0.53–1.33); p = 0.45; $I^2$ = 66%; P = 0.007; Appendix D Figure 3A]. The sensitivity analysis revealed a study [17] responsible for the moderate heterogeneity; repetition of the analysis after its exclusion did not modify the meta-analytic outcome [OR (95%CI): 1.01 (0.82–1.26); p = 0.90; $I^2$ = 0%; P = 0.61; Appendix C Table 2]. No publication bias was evident (Appendix D Figure 3B).

#### 3.5.4. Adverse events rate

Five studies [15,17,26,31,33] provided details about the reported adverse events per study group. Three adverse events were noted in each group; [3/2403 (1 case of a post- polypectomy perforation, but the polypectomy had been performed by the attending gastroenterologist and 2 cases of post-polypectomy bleeding) for the fellow-involved group and 3/1454 (all were post-polypectomy bleeding cases) for the attending physician-only group examinations, respectively; OR (95%CI): 1.60 (0.27–9.41); p = 0.60; $I^2$ = 0%; P = 0.79; Appendix D Figure 4A]. There was no evidence of publication bias (Appendix D Figure 4B).

## 4. Discussion

This systematic review and meta-analysis demonstrates that fellow involvement may provide a beneficial effect on colonoscopy performance in terms of ADR and MAC. Adenomas were detected in numerically more examinations with marginal ADR increase in favor of trainee's involvement. Of interest, the beneficial effect on ADR from fellow participation was most notable in the attending physician-only group with low-to-moderate ADR. Moreover, the mean number of adenomas per colonoscopy was higher in the fellow-involved group while adverse events rate was similar between the two groups.

Several lines of evidence suggest that participation of a "second observer" *i.e.* endoscopy nurse or trainee during colonoscopy may improve ADR. Indeed, a recent meta-analysis of randomized controlled trials showed a marginally higher ADR with the nurse

present compared to the attending physician-only group (45.7% *vs.* 39.3%; RR: 1.16; 95% CI: 1.04–1.30) [34]. On the other hand, the "fellow effect" remains rather ambiguous: Early studies reported higher ADR when a fellow participated in the procedure [15,18], whereas data published later on failed to confirm this finding [21,35]. In 2013, Oh et al. [35] conducted a meta-analysis of 14 relevant studies. They concluded that fellow-involved group had similar ADR compared to that of the attending physician-only group (31.5% *vs.* 30.4%, p = 0.76). This review is now five years old and a large number of trials (n = 12) has been published subsequently [22–33]. Moreover, their results were susceptible to major criticism as polyp detection rate (PDR) rather than ADR was the primary outcome, the degree of fellow involvement was not reported, three out of fourteen studies reported only PDR, while the only randomized study evaluated the cap-assisted colonoscopy [36,37].

It may be still not possible to draw clear inferences from data regarding the impact of fellow involvement on colonoscopy outcomes. Overall, one could characterize fellow involvement as "quality-neutral", as it is associated with at least equal ADR. Nonetheless, this can still have significant implications for everyday clinical practice engaging patient safety, quality of healthcare services and medical education. From the patients' point of view, colonoscopy by a supervised fellow should not be disregarded for delivering low-quality services or increased exposure to procedure related adverse events. Moreover, colonoscopy quality indicators like ADR and CIR do not differ when fellows are present compared to the attending physician-only group; hence, underlining provision of high quality health services. From the fellowship education perspective, the fact that ADR was equivalent between the two groups, reflects effective attending supervision and at the same time fulfils trainee's ultimate goal within the context of a training program: to perform colonoscopy safely, effectively, and comfortably. This is corroborated by the fact that high ADR supervisors are more likely to have trainees who detect adenomas [38]. On the other hand, Bitar et al. [32] in their study showed that ADR may not finally be a surrogate marker that requisite skills have been acquired, whereas other efficiency metrics as their proposed adenoma management efficiency index (mean withdrawal time divided by the number of adenomas resected) may be. Until an official colonoscopy skills assessment tool develops, ADR monitoring within fellow training programs could be implemented as a useful metric, enabling objective assessment of fellow proficiency. Finally, attending's expertise inversely correlates with the benefit from fellow involvement regarding ADR (beneficial for operators with ADR < 35% *vs.* no effect in those with ADR > 40%). In that case, the rationale that "two pairs of eyes are better than one" is confirmed. Although no solid explanation is available, we postulate that this may be due to increased withdrawal time by fellows that does not match attending physician's levels even by the end of fellowship period [32], gradual improvement in endoscopic competency from onset of training to final stage, associated with decreased adenoma miss rate [39] or lack of proficiency by the attending resulting in a less thorough colon examination [40]. Furthermore, this finding can be explained by the high ADR for both groups, leaving little room for improvements. Our conclusion is slightly different from those previously published in a meta-analysis evaluating nurse participation in colonoscopy [34]. However, results of that study may be hampered by the small number of trials included (n = 3), high risk of bias among them and inconsistencies regarding the phase of mucosa inspection (insertion, withdrawal or both). Overall, our study contributes to previously published data [35], highlighting the valuable role that fellows may have in assisting "low" detectors to deliver colonoscopy of higher quality. In any case, attending physicians have a twofold duty: to provide optimal medical care to their patients and teach their fellows by real-time guidance.

A number of strengths related to this study could be cited. We used rigorous methodology when conducting this systematic review and meta-analysis. We acted based on a predefined registered protocol, reported our full search strategy, fulfilled a recursive bibliographic search, carried out the assessment of eligibility and data extraction independently and pooled data using a random effects model to allow a more conservative estimation of the effect. Moreover, this updated meta-analysis identified twelve additional studies enrolling cumulatively almost 13,000 colonoscopies since the previous iteration five years ago; to the best of our knowledge, this is the also first study to evaluate four different colonoscopy key performance measures that can also be applied as quality metrics to complement ADR [3]. Finally, we performed detailed subgroup analyses according to indications of examinations, rate of fellows' participation and different levels of attending physician's ADR to examine whether or not any benefit existed of fellow involvement in "low-moderate" or "high" detector cases.

Still, there are limitations of this meta-analysis that merit discussion. The principal limitation lies in the heterogeneity encountered, calling for careful interpretation of the results. Despite our efforts to ameliorate it by performing multiple sensitivity analyses, this heterogeneity is a result from the nature of the studies available for synthesis as most of them were single-center retrospective studies, enrolling populations with diverge colonoscopy indications and without proper design or enough power to address the precision of effect estimates. Second, analysis per year of fellowship as well as comparison in terms of withdrawal time or total procedure time between the two groups was not applicable due to lack of data. Final, meta-analysis of retrospective cohort studies is *de facto* prone to confounding and selection bias.

In summary, in the absence of studies randomizing patients to a fellow plus attending physician *vs.* an attending physician only, our analysis suggests that fellow involvement may pose certain positive effects on adenoma detection rate during colonoscopy. Aside of the beneficial impact on established colonoscopy metrics, patient safety, quality of healthcare services delivered and medical education could also profit from fellow participation.

## Competing interests

None declared.

## Acknowledgements

None.

## Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.dld.2019.05.012.

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