Introduction
Population-based colorectal cancer (CRC) screening has been shown to reduce incidence of colon cancer and related mortality [1, 2]. Among patients at average risk, the most favored cancer prevention test is colonoscopy every 10 years, beginning at age 50 (45 for African-Americans) [3]. Screening per 1000 patients using colonoscopy, a gain of 270 life-years and a decrease in 24 deaths from CRC has been estimated [4].

However, despite being the reference standard, colonoscopy is far from a perfect test. Studies using compute tomography colonography have estimated the sensitivity of colonoscopy for detecting advanced adenomas to be 88% [5]. Tandem colonoscopy studies have shown that up to one-quarter of polyps are missed during colonoscopy [6]. Adenoma detection rate (ADR) has been shown to be associated with interval colon cancer and related mortality [7, 8]. ADR ≥ 30% for men and ≥ 20% for women has been recommended as a quality indicator for colonoscopy [9]. Wide variations in ADRs for endoscopists have been reported [10, 11]. Therefore, various methods have been employed in attempts to improve ADR, including brief educational interventions [12], use of distal attachments such as caps [13], third-eye retroscopes, newer-generation wide-angle colonoscopes, cuffs and EndoRings.

Cap-assisted colonoscopy: a meta-analysis of high-quality randomized controlled trials

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ABSTRACT
Background and study aims Standard colonoscopy (SC) is the preferred modality for screening for colon cancer; however, it carries a significant polyp/adenoma miss rate. Cap-assisted colonoscopy (CC) has been shown to improve polyp/adenoma detection rate, decrease cecal intubation time and increase cecal intubation rate when compared to standard colonoscopy (SC). However, data on adenoma detection rate (ADR) are conflicting. The aim of this meta-analysis was to compare the performance of CC with SC for ADR among high-quality randomized controlled trials.

Patients and methods We performed an extensive literature search using MEDLINE, EMBASE, Scopus, Cochrane and Web of Science databases and abstracts published at national meetings. Only comparative studies between CC and SC were included if they reported ADR, adenoma per person (APP), cecal intubation rate, and cecal intubation time. The exclusion criterion for comparing ADR was studies with Jadad score ≤ 2. The odds ratio (OR) was calculated using Mantel-Haenszel method. P test was used to measure heterogeneity among studies.

Results Analysis of high-quality studies (Jadad score ≥ 3, total of 7 studies) showed that use of cap improved the ADR with the results being statistically significant (OR 1.18, 95% CI 1.03 – 1.33) and detection of 0.16 (0.02 – 0.30) additional APP. The cecal intubation rate in the CC group was 96.3% compared to 94.5% with SC (total of 17 studies). Use of cap improved cecal intubation (OR 1.61, 95% CI 1.33 – 1.95) when compared to SC (P value < 0.001). Use of cap decreased cecal intubation time by an average of 0.88 minutes (95% CI 0.37 – 1.39) or 53 seconds.

Conclusions Meta-analysis of high-quality studies showed that CC improved the ADR compared to SC.
Cap-assisted colonoscopy (CC) has been extensively studied as a modality to improve ADR. The cap is a straightforward attachment on the distal end of the endoscope that extends outward beyond the tip of the colonoscope to varying lengths. The cap helps in deflecting and flattening the mucosal folds, and by keeping the mucosa away from the lens prevents a red-out. These maneuvers expose the proximal aspects of colonic folds and thereby help in detecting polyps in these otherwise blind mucosal areas. Use of cap has been shown to decrease cecal intubation time, increase cecal intubation rate and improve polyp detection rate. However, data on ADR are rather conflicting.

The aim of this meta-analysis was to compare the performance of CC with standard colonoscopy (SC) for ADR among high-quality randomized controlled trials (RCT).

Patients and methods

Search strategy

An electronic search was performed in MEDLINE, EMBASE, Google scholar, Cochrane database and Web of science. The search for studies of relevance was performed using the following key words and corresponding Medical Subject Heading/Entree terms when possible: “CAP assisted colonoscopy,” “colonoscopy with distal attachment,” “adenoma detection rate,” “adenoma per person,” “cecal intubation rate,” “cecal intubation time” with varying combinations with and/or. We retrieved 2558 abstracts (Fig. 1). Abstracts published in major international conferences, including Digestive Disease Week, United European gastroenterology Week and Asia Pacific Digestive Week over the past 10 years were manually searched. References from major trials and review articles were manually searched.

From the 2400 records, 2358 records were removed (1473 studies, 927 abstracts) because they were not relevant to the comparison between CC and SC. Of the remaining 42 records, 23 were excluded for the following reasons: duplicity, case report, review article, editorial, abstract only. Of the 19 full-text articles that were accepted, only 7 met the criteria of prospective RCTs, Jadad score ≥ 3 (see Table 1), reported ADR, and these studies were used for ADR and APP (adenomas detected per person) [14 – 20]. Of the 42 records, 17 studies were included for cecal intubation rate and 13 studies were included for cecal intubation time [14 – 30]. Thirteen studies were included that compared cecal intubation time between CC and SC [14 – 30]. For analysis of cecal intubation and cecal intubation time, even studies with Jadad score < 3 were included. ADR alone was the primary aim of the study. We removed the constraints for cecal intubation time or rate as we wanted to be less stringent and more inclusive for these endpoints. While ADR is a cornerstone quality indicator for colonoscopy, the other two are not.

![Fig. 1](image-url) Study flow diagram depicting search strategy, screening and studies of cap-assisted colonoscopy identified for inclusion in the meta-analysis of adenoma detection rate.

![Table 1](image-url) Studies and their respective Jadad scores.

| Study         | Final score |
|---------------|-------------|
| Tada 1997     | Paper 0     |
| Matsushita 1998 | Paper 1      |
| Kondo 2007    | Paper 3 (No ADR/APP reported) |
| Horiuchi 2008 | Paper 3     |
| Shida 2008    | Paper 0     |
| Takano 2008   | Abstract 0  |
| Lee 2009      | Paper 1     |
| Choi 2009     | Paper 0     |
| Harada 2009   | Paper 1     |
| Sato 2009     | Prelim Report 3 (No ADR/APP reported) |
| Takeuchi 2010 | Paper 3     |
| Tee 2010      | Paper 3 (No ADR/APP reported) |
| Dai 2010      | Paper 0     |
| Hewett 2010   | Paper 3     |
| Park 2012     | Paper 3     |
| Rastogi 2012  | Paper 3     |
| De Wijkerslooth 2012 | Paper 4 |
| Frieling 2013 | Paper 3 (No ADR/APP reported) |
| Pohl 2015     | Paper 3     |
Data extraction

Two investigators (VN and MD) independently reviewed the studies and imported the data into a standardized form. In case of lack of consensus, the senior investigator (AR) reviewed the study independently and then made a final decision regarding the data point.

Data extracted were patient demographics, year of publication, study location, number of subjects, size of adenomas, number of adenomas detected, cecal intubation rate, cecal intubation time and study quality. Individual study and patient characteristics are shown in Table 2.

Statistical analysis

Meta-analyses were performed using Mantel-Haenszel method combining the results from different trials comparing CC and SC. Meta-Analysis was performed according to the PRISMA statement. A complete checklist is provided in Table 3 [33]. A random effects model was used for statistical heterogeneity across trials and a fixed effect model was used if no significant heterogeneity was present. Relative risks (RR) with corresponding 95 % CI were calculated. Heterogeneity was calculated using $I^2$ test. Publication bias was assessed using a funnel plot. Statistical analyses were performed using RevMan software (Review Manager version 5.3; The Nordic Cochrane Centre, Copenhagen, Demark, The Cochrane Collaboration 2015).

Results

Adenoma detection rate

An initial pooled analysis of eight RCTs (5681 patients) was performed, which showed a numerically higher ADR in the CC group compared to the SC group, but results were not statistically significant (OR 1.08, 95 % CI 0.97 – 1.21; $I^2$ 56 %) (Fig. 2a). However, when only high-quality RCTs were included (Jadad score ≥ 3) as per the primary aim of this study, there were seven RCTs with a total of 4,681 patients (2,344 patients in the CC group, 2,337 patients in the SC group). We were unable to include some studies with a score of 3 or more, as they lacked information regarding ADR/APP [22, 24, 30]. ADR was significantly higher in the CC group (OR 1.18, 95 % CI 1.03 – 1.33) (Fig. 2b). There was no significant heterogeneity in the ADR analysis ($I^2$ = 0 %). Publication bias for studies included for ADR was assessed using a funnel plot (Fig. 3).

Analysis was also performed using a random effects model. Analysis of the seven high-quality RCTs using the random effects model showed significantly higher ADR in the CC group (OR 1.10, 95 % CI 1.02 – 1.18) (Fig. 2c).

Sensitivity analysis was not performed based on our stringent criteria to include only high-quality studies with Jadad score ≥ 3 which carry a very low risk for bias [34 – 36].

Table 2 Study characteristics.

| Author          | Country | Sample | CC | SC | Age | Male (%) |
|-----------------|---------|--------|----|----|-----|----------|
| Tada et al. [32]| Japan   | 140    | 70 | 70 | 60  | 73       |
| Matsushita et al. [26]| Japan   | 24     | 12 | 12 | 59  | 63       |
| Kondo et al. [24]| Japan   | 456    | 221| 235| 61  | 60       |
| Horiiuchi et al. [16]| Japan   | 835    | 424| 411| 64  | 65       |
| Shida et al. [28]| Japan   | 178    | 82 | 96 | 64  | 51       |
| Takano et al. [29]| Japan   | 2502   | 1287| 1215| NA  | NA       |
| Harada et al. [23]| Japan   | 592    | 289| 303| 63  | 66       |
| Lee et al. [25]  | Hong Kong| 1000   | 499| 501| 53  | 46       |
| Sato et al. [27] | Japan   | 221    | 110| 111| NA  | NA       |
| Dai et al. [31]  | China   | 250    | 121| 129| 51  | 54       |
| Hewett et al. [15]| United States | 100 | 52 | 48 | 62  | 57       |
| Takeuchi et al. [20]| Japan   | 274    | 141| 133| 64  | 70       |
| Tee et al. [30]  | Australia| 400    | 200| 200| 54  | 48       |
| De Wijkerslooth et al. [14]| Netherlands | 1339 | 656| 683| 60  | 51       |
| Choi et al. [21] | Korea   | 228    | 114| 114| NA  | NA       |
| Rastogi et al. [19]| United States | 420 | 210| 210| 61  | 95       |
| Park et al. [17] | Korea   | 600    | 300| 300| 62  | 52       |
| Frieling et al. [22]| Germany | 504    | 252| 252| 60±15.5 | 182     |
| Pohl et al. [18] | United States | 1113 | 562| 551| 62  | 64       |
Table 3  PRISMA checklist.

| TITLE |
|------|
| Title | 1 | Identify the report as a systematic review, meta-analysis, or both. | Mentioned as meta-analysis |

| ABSTRACT |
|---------|
| Structured summary | 2 | Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number: | A detailed abstract with the necessary information has been provided |

| INTRODUCTION |
|-------------|
| Rationale/ | 3 | Describe the rationale for the review in the context of what is already known. | Provided |
| Objectives | 4 | Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS). | Provided |

| METHODS |
|---------|
| Protocol and registration/ | 5 | Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number. | Not applicable with Meta-analysis |
| Eligibility criteria | 6 | Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale. | Provided |
| Information sources | 7 | Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched. | Provided |
| Search | 8 | Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated. | Provided |
| Study selection | 9 | State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis). | Provided |
| Data collection process | 10 | Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators. | Provided |
| Data items | 11 | List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made. | Provided |
| Risk of bias in individual studies | 12 | Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis. | Provided |
| Summary measures | 13 | State the principal summary measures (e.g., risk ratio, difference in means). | Provided |
| Synthesis of results | 14 | Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I²) for each meta-analysis. | Provided |
| Risk of bias across studies | 15 | Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies). | Provided |
| Additional analyses | 16 | Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified. | Provided |

| RESULTS |
|---------|
| Study selection | 17 | Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram. | Provided |
| Study characteristics | 18 | For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations. | Provided |
| Risk of bias within studies | 19 | Present data on risk of bias of each study and, if available, any outcome-level assessment (see Item 12). | Provided |
| Results of individual studies | 20 | For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group and (b) effect estimates and confidence intervals, ideally with a forest plot. | Provided |
### Mean adenomas detected per person

Analysis for APP included six RCTs with 4,368 patients. There were 2,184 patients in each group. Use of cap led to a mean difference of 0.16 (95% CI 0.02–0.30) additional APP (Fig. 4). Significant heterogeneity was found in the studies reporting mean APP ($I^2 = 68\%$).

### Large adenoma detection rate

Analysis for large adenomas (≥10 mm) included four RCTs with 2,468 patients. There were 1,427 patients in the CC group compared to 1,421 patients in the SC group. Use of cap led to a statistically significantly higher rate of detection of large adenomas (OR 1.49, 95% CI 1.03–2.15, $P<0.005$) with heterogeneity of ($I^2 = 44\%$) (Fig. 5).

### Sessile serrated adenoma detection rate

Analysis for sessile serrated adenoma (SSA) included only three RCTs with 2,872 patients. There were 1,427 patients in the CC group compared to 1,445 patients in the SC group. Use of cap did not lead to any significant difference in detection of SSA with (OR 1.12, 95% CI 0.66–1.88) and a significant heterogeneity of ($I^2 = 76\%$) (Fig. 6).

### Cecal intubation rate and time

Pooled analysis of 17 studies that included 5,416 patients in the CC and 5,401 patients in the SC groups were utilized to evaluate the cecal intubation rate (Fig. 7A). The cecal intubation rate in the CC group was 96.3% compared to 94.5% with SC. Use of cap improved cecal intubation (OR 1.61, 95% CI 1.33–1.95) when compared to SC ($P<0.001$). Low heterogeneity was identified among studies ($I^2 = 2\%$).

Thirteen studies were used to analyze the impact of cap on cecal intubation time (Fig. 7B). The CC group included 3,014 patients and the SC group included 3,037 patients. Use of cap decreased the cecal intubation time by an average of 0.88 minutes (95% CI 0.37–1.39) or 53 seconds. However, significant heterogeneity was detected among these studies ($I^2 = 87\%$).

### Discussion

Results of our meta-analysis indicate that use of cap improves detection of adenomas. An improvement in ADR, mean number of adenomas detected per patient and large adenomas was seen with CC. For ADR we included only trials with a Jadad score ≥3 to ensure only high-quality trials. The Jadad score is the most widely used scale to measure the quality of RCTs. Overall, we found seven RCTs with a Jadad score ≥3. This study differs from a previous meta-analysis [13] in that we excluded the study by Lee [25] as it employed suboptimal techniques for randomization. Proper technique includes a statistician or a computer-generated sequence [25]. Furthermore, in that study, the quality of bowel preparation was significantly less satisfactory. They classified the quality of their bowel preparation into three categories: “excellent,” “fair,” and “poor.” In the results, they noted that a higher proportion of patients in the CC group had more satisfactory bowel preparation. According to the authors, the inferior bowel preparation in the CC group could have negatively impacted the ADR. As a matter of fact, this is the only trial where use of CAP has been associated with lower ADR compared to standard colonoscopy. All other trials have shown either no difference or higher ADR with CAP.

ADR is a quality indicator for colonoscopy and has been shown to be associated with improved outcomes related to interval cancer and colorectal cancer-related mortality. While this meta-analysis shows an overall improvement in ADR with CC, individual studies have shown variable results.
which was the largest study evaluating CC in the United States showed that the impact on the individual endoscopist ADR is variable. The range of impact was from

- 20% improvement to 15% decrease in the individual ADR with CC. They also showed that those who preferred

| Study or subgroup | Cap assisted colonoscopy Events Total | Standard colonoscopy Events Total | Odds ratio M-H, fixed, 95% CI | Year |
|-------------------|-------------------------------------|-----------------------------------|-------------------------------|------|
| Horiuchi 2008     | 123 424                             | 99 411                            | 1.29 [0.95, 1.75]             | 2008 |
| Lee 2009          | 152 499                             | 188 501                           | 0.73 [0.56, 0.95]             | 2009 |
| Hewett 2010       | 34 52                               | 33 48                             | 0.86 [0.37, 1.98]             | 2010 |
| Takeuchi 2010     | 84 141                              | 74 133                            | 1.17 [0.73, 1.90]             | 2010 |
| Rastogi 2012      | 144 210                             | 117 210                           | 1.73 [1.16, 2.58]             | 2012 |
| de Wijkerslooth 2012 | 196 656                          | 189 683                           | 1.11 [0.88, 1.41]             | 2012 |
| Park 2012         | 79 300                              | 75 300                            | 1.07 [0.74, 1.55]             | 2012 |
| Pohl 2015         | 235 561                             | 219 552                           | 1.10 [0.86, 1.39]             | 2015 |
| **Total (95% CI)** | **2843 2838**                      |                                   | **1.08 [0.97, 1.21]**         |      |
| **Total events**  | 1047 994                            |                                   |                               |      |

Heterogeneity: Chi² = 15.74, df = 7 (P = 0.03); I² = 56%
Test for overall effect: Z = 1.34 (P = 0.18)

| Study or subgroup | Cap assisted colonoscopy Events Total | Standard colonoscopy Events Total | Odds ratio M-H, fixed, 95% CI | Year |
|-------------------|-------------------------------------|-----------------------------------|-------------------------------|------|
| Horiuchi 2008     | 123 424                             | 99 411                            | 1.29 [0.95, 1.75]             | 2008 |
| Hewett 2010       | 34 52                               | 33 48                             | 0.86 [0.37, 1.98]             | 2010 |
| Takeuchi 2010     | 84 141                              | 74 133                            | 1.17 [0.73, 1.90]             | 2010 |
| Rastogi 2012      | 144 210                             | 117 210                           | 1.73 [1.16, 2.58]             | 2012 |
| de Wijkerslooth 2012 | 196 656                          | 189 683                           | 1.11 [0.88, 1.41]             | 2012 |
| Park 2012         | 79 300                              | 75 300                            | 1.07 [0.74, 1.55]             | 2012 |
| Pohl 2015         | 235 561                             | 219 552                           | 1.10 [0.86, 1.39]             | 2015 |
| **Total (95% CI)** | **2344 2337**                      |                                   | **1.18 [1.04, 1.33]**         |      |
| **Total events**  | 895 806                            |                                   |                               |      |

Heterogeneity: Chi² = 5.30, df = 6 (P = 0.51); I² = 0%
Test for overall effect: Z = 2.59 (P = 0.010)

a Results with all eligible studies.

b Results with only high-quality studies (Jadad score ≥ 3).

c Results with only high-quality studies using random effects.

Fig. 2 Forest plot of pooled estimates of adenoma detection rate using cap-assisted colonoscopy compared to standard colonoscopy. a Results with all eligible studies. b Results with only high-quality studies (Jadad score ≥ 3). c Results with only high-quality studies using random effects.
CAP showed an improvement in ADR. We have also shown an improvement in the average number of adenomas detected per patient.

CC also improved detection of large adenomas, however, a statistically significant improvement in mean number of diminutive adenomas was not found. We suspect this may be due, in part, to the differing sizes of small adenomas reported (5 mm vs. 6 mm). There was no significant improvement in detection of proximal adenomas or SSAs as the RCTs that were performed were not adequately powered to detect any difference in the above outcomes.

Our meta-analysis has some limitations. The study populations in the studies were very diverse with studies being performed in Asia, North America, and Europe. That, however, improves generalizability of the results. Given the obvious lack of blinding of the endoscopists and the nature of such studies evaluating devices to improve ADR, investigator bias is unavoidable. Endoscopist experience in the different studies also varies widely and could not be accounted for with respect to

| Study or subgroup | Cap assisted colonoscopy | Standard colonoscopy | Mean difference | Year |
|-------------------|--------------------------|----------------------|-----------------|------|
|                   | Mean | SD | Total | Mean | SD | Total | Weight | IV, random, 95 % CI |                  |
| Horiuchi 2008     | 0.48 | 0.83 | 424   | 0.37 | 0.83 | 411   | 24.0 % | 0.11 [-0.00, 0.22] | 2008             |
| Tee 2010          | 0.39 | 0.96 | 192   | 0.28 | 0.96 | 195   | 18.3 % | 0.11 [-0.08, 0.30] | 2010             |
| Takeuchi 2010     | 1.72 | 1.82 | 141   | 1.19 | 1.07 | 133   | 9.9 %  | 0.53 [0.18, 0.88]  | 2010             |
| de Wijkerslooth 2012 | 0.52 | 1.05 | 656   | 0.5  | 1.06 | 683   | 23.9 % | 0.02 [-0.09, 0.13] | 2012             |
| Rastogi 2012      | 2.3  | 2.94 | 210   | 1.4  | 2.94 | 210   | 4.9 %  | 0.90 [0.34, 1.46]  | 2012             |
| Pohl 2015         | 0.89 | 1.56 | 561   | 0.82 | 1.52 | 552   | 19.0 % | 0.07 [-0.11, 0.25] | 2015             |
| **Total (95 % CI)** | **2184** | **2184** | **100.0 %** | **0.16 [0.02, 0.30]** |

Test for overall effect: $Z = 2.31 \ (P = 0.02)$

| Study or subgroup | Events | Total | Events | Total | Weight | Risk ratio | M-H, random, 95 % CI | Year |
|-------------------|--------|-------|--------|-------|--------|------------|----------------------|------|
| Horiuchi 2008     | 13     | 424   | 11     | 411   | 16.0 % | 1.15 [0.52, 2.53] | 2008             |
| Hewett 2010       | 4      | 52    | 1      | 48    | 2.8 %  | 3.69 [0.43, 31.89] | 2010             |
| Rastogi 2012      | 76     | 210   | 39     | 210   | 41.2 % | 1.95 [1.39, 2.73] | 2012             |
| Pohl 2015         | 62     | 561   | 52     | 552   | 40.0 % | 1.17 [0.83, 1.66] | 2015             |
| **Total (95 % CI)** | **1247** | **1221** | **100.0 %** | **1.49 [1.03, 2.15]** |

Total events: 155103

Test for overall effect: $Z = 2.12 \ (P = 0.03)$

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**Fig. 3** Funnel plot showing publication bias.

**Fig. 4** Forest plot of pooled estimate of adenoma per person (APP) showing higher detection of average adenoma per person using cap compared to standard colonoscopy.

**Fig. 5** Figure plot of pooled estimate of adenomas > 10 mm, showing significant improved detection with CAP assisted colonoscopy compared to standard colonoscopy.
the impact of CC on ADR. Use of a cap with colonoscopy requires some training, adjustment, and experience. This factor was not adjusted for or studied in the trials, making it difficult to gauge the impact of that on the results.

A cap is a simple, inexpensive and easy-to-use tool to improve the quality of colonoscopy. The cost of the cap, albeit low, appears to be the only negative factor weighing against its use in daily clinical practice. To derive maximum benefit from cap, endoscopists need to gain experience with the device. As the cap projects outside the tip of the colonoscope, it may appear to limit the angle of view. This must be compensated for with adequate deflection of the tip and use of the edge of the cap to flatten the haustral folds to expose their proximal aspects and derive the maximum benefit. Furthermore, the benefit of CC has been shown to significantly extend visualization of the right colon in a colonoscopic training model [37]. Use of cap offers other secondary benefits such as improved cecal intubation rates and stabilization of the tip of the scope during polypectomy.

Conclusion

In conclusion, this meta-analysis showed that there is a marginal and statistically significant benefit to use of a cap during colonoscopy to improve ADR and cecal intubation rate and reduce cecal intubation time. Further research needs to be conducted to determine if there are specific patient subgroups that may benefit more from use of a cap, whether to train endoscopists in use of the device, and identify appropriate training methods.

Competing interest

None

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| Study or subgroup | Cap assisted colonoscopy | Standard colonoscopy | Odds ratio M-H, fixed, 95% Cl Year | Odds ratio M-H, fixed, 95% Cl |
|-------------------|-------------------------|----------------------|-----------------------------------|-----------------------------|
| Matsushita 1998  | 24 24                   | 24 24                | Not estimable                     | 1998                        |
| Kondo 2007        | 213 221                 | 224 235              | 1.31[0.52, 3.31] 2007             |                             |
| Shida 2008        | 80 82                   | 94 96                | 0.85[0.12, 6.18] 2008             |                             |
| Takano 2008       | 1219 1287              | 1125 1215            | 1.43[1.04, 1.99] 2008             |                             |
| Horiiuchi 2008    | 424 424                 | 411 411              | Not estimable                     | 2008                        |
| Sato 2009         | 100 110                 | 102 111              | 0.88[0.34, 2.26] 2009             |                             |
| Harada 2009       | 279 289                 | 288 303              | 1.45[0.64, 3.29] 2009             |                             |
| Choi 2009         | 114 114                 | 114 114              | Not estimable                     | 2009                        |
| Lee 2009          | 480 499                 | 474 501              | 1.44[0.79, 2.62] 2009             |                             |
| Takeuchi 2010     | 132 133                 | 136 141              | 4.85[0.56, 42.10] 2010            |                             |
| Tee 2010          | 192 200                 | 195 200              | 0.62[0.20, 1.91] 2010             |                             |
| Hewett 2010       | 52 52                   | 48 48                | Not estimable                     | 2010                        |
| Rastogi 2012      | 211 212                 | 211 215              | 4.00[0.44, 36.09] 2012            |                             |
| Park 2012         | 242 240                 | 192 200              | 2.35[1.62, 3.40] 2012             |                             |
| de Wijkerslooth 2012 | 649 656            | 671 683              | 1.66[0.65, 4.24] 2012             |                             |
| Frieling 2013     | 252 252                 | 252 252              | Not estimable                     | 2013                        |
| Pohl 2015         | 555 561                 | 542 552              | 1.71[0.62, 4.73] 2015             |                             |

Total (95% CI) 5416 5401 100.0% 1.61[1.33, 1.95]

Test for overall effect: Z = 4.88 (P < 0.00001)

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| Study or subgroup | Cap assisted colonoscopy | Standard colonoscopy | Mean difference IV, random, 95% CI Year | Mean difference IV, random, 95% CI |
|-------------------|-------------------------|----------------------|----------------------------------------|-----------------------------------|
| Tada 1997         | 12.4 6.6 70             | 12.3 5.2 70         | 0.10[-1.87, 2.20] 1997                 |                                   |
| Matsushita 1998   | 4.3 1.5 12              | 5.8 2 12           | 1.50[-2.91, -0.09] 1998                |                                   |
| Horiiuchi 2008    | 7.9 5 424               | 8.6 5.3 411       | -0.70[-1.40, -0.00] 2008               |                                   |
| Harada 2009       | 10.2 12.5 289          | 13.4 15.8 303     | 3.20[-5.49, -0.91] 2009                |                                   |
| Lee 2009          | 6 4 499                | 7.2 4.8 501        | 1.20[-1.75, 0.65] 2009                 |                                   |
| Choi 2009         | 5.19 2.59 114          | 7.33 4.15 114      | 2.14[-3.04, -1.24] 2009               |                                   |
| Dai 2010          | 12.4 6.6 70            | 12.3 5.2 70        | 0.10[-0.87, 2.07] 2010                 |                                   |
| Tee 2010          | 9.94 7.05 200          | 10.34 6.82 200    | -0.40[-1.76, 0.96] 2010                |                                   |
| Hewett 2010       | 3.2 0.2 52             | 3.1 0.2 48        | 0.10[0.02, 0.18] 2010                  |                                   |
| Rastogi 2012      | 3.29 2.55 210          | 3.98 2.56 210     | -0.69[-1.18, -0.20] 2012              |                                   |
| Park 2012         | 5.3 3.3 166            | 5.8 3.7 163        | -0.50[-1.26, 0.26] 2012                |                                   |
| de Wijkerslooth 2012 | 7.7 5 656           | 8.9 6.2 683       | 1.20[-1.80, -0.60] 2012               |                                   |
| Frieling 2013     | 7.7 4.6 252            | 8.7 5 252         | -0.60[-1.84, -0.16] 2013              |                                   |

Total (95% CI) 3014 3037 100.0% -0.88[-1.39, -0.37]

Heterogeneity: Tau² = 0.60; Chi² = 92.50, df = 12 (P < 0.00001); I² = 87%

Test for overall effect: Z = 3.40 (P = 0.0007)

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**Fig. 7** Forest plot of pooled estimates of cecal intubation rate (a) and cecal intubation time (b) showing improved rates and lesser time with cap compared to standard colonoscopy.
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