2.1 Introduction

Colorectal cancer (CRC) is the second most prevalent cause of human cancer-related deaths in Europe [1], and the third in the United States [2]. To date, colonoscopy represents the optimal procedure for CRC screening, since it provides the opportunity of detection and subsequent removal of adenomatous polyps, thus, reducing the incidence and mortality of CRC [3, 4]. However, colonoscopy suffers from several imperfections. Back to back colonoscopy studies have shown that up to 25% of adenomas are missed during colonoscopy, resulting in high interval cancer incidence [5, 6].

In light of these observations, a high-quality examination that will ensure the detection and removal of all precancerous lesions is warranted, and so several quality assessment indicators have been developed, such as the worldwide-accepted adenoma detection rate (ADR), and continuous quality improvement programs have been implemented [7]. ADR is defined as the proportion of average-risk patients undergoing first-time screening colonoscopy in which at least one adenoma is found. It has been demonstrated that ADR correlates directly with interval cancer (CRC after negative colonoscopy), as an ADR that exceeds 25% is significantly associated with a reduction in interval CRC [8]. Moreover, ADR has been inversely associated with the risk of advanced-stage interval cancer and fatal interval cancer [9]. Current ASGE guidelines propose that in patients undergoing screening colonoscopy, an ADR of ≥30% in men and of ≥20% in women should be achieved, at least [10].
In this chapter, we will highlight various procedural and technical-dependent factors that contribute to ADR improvement.

### 2.2 Procedure-Related Factors

The evidences listed below are summarized in Table 2.1.

**Table 2.1** Studies evaluating the impact of pre- and intra-procedural issues on adenoma detection rate

<table>
<thead>
<tr>
<th>Author (year) [ref]</th>
<th>Method</th>
<th>Study design</th>
<th>N</th>
<th>ADR</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oh (2015) [11]</td>
<td>Overall bowel preparation quality</td>
<td>Single-center retrospective study</td>
<td>6097</td>
<td>OR: 0.55 (95% CI 0.41–0.75) for poor/fair preparation</td>
<td>Study design</td>
</tr>
<tr>
<td>Gurudu (2012) [15]</td>
<td>Same-day vs. split-dose preparation</td>
<td>Single-center retrospective study</td>
<td>3560 vs. 1615</td>
<td>26.7 vs. 31.8%</td>
<td>Study design Different endoscopists per period</td>
</tr>
<tr>
<td>Clark (2014) [16]</td>
<td>Overall bowel preparation quality</td>
<td>Meta-analysis</td>
<td>31,047 vs. 4058</td>
<td>OR: 1.30 (95% CI 1.19–1.42) favoring adequate vs. inadequate preparation</td>
<td>Different bowel preparation quality scales used</td>
</tr>
<tr>
<td>Adler (2012) [17]</td>
<td>Overall bowel preparation quality</td>
<td>Multicenter prospective cohort study from private practice</td>
<td>12,134</td>
<td>OR: 0.64 (95% CI 0.47–0.87) for poor preparation and OR: 0.22 (95% CI 0.05–0.92) for insufficient preparation</td>
<td>Relatively small number of participating colonoscopists</td>
</tr>
<tr>
<td>Tholey (2015) [18]</td>
<td>Overall bowel preparation quality</td>
<td>Single-center retrospective cross-sectional study</td>
<td>5113</td>
<td>OR: 0.97 (95% CI 0.85–1.11) for excellent preparation</td>
<td>Study design</td>
</tr>
<tr>
<td>Clark (2016) [19]</td>
<td>Overall bowel preparation quality</td>
<td>Single-center prospective study</td>
<td>749</td>
<td>OR: 0.37 (95% CI 0.15–0.87) favoring high-quality preparation in detecting sessile adenomas</td>
<td>Male population exclusively</td>
</tr>
</tbody>
</table>
### Table 2.1 (continued)

<table>
<thead>
<tr>
<th>Author (year) [ref]</th>
<th>Method</th>
<th>Study design</th>
<th>N</th>
<th>ADR</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calderwood (2015) [20]</td>
<td>Overall bowel preparation quality</td>
<td>Two-center retrospective cross-sectional study</td>
<td>Center A: 3713</td>
<td>OR: 1.3 (95% CI 1.1–1.6) for good preparation</td>
<td>Retrospective study</td>
</tr>
<tr>
<td>Barclay (2006) [21]</td>
<td>Withdrawal time</td>
<td>Prospective cohort study</td>
<td>2053</td>
<td>28.3 vs. 11.8% (mean WT: ≥6 min vs. &lt;6 min)</td>
<td>Study design</td>
</tr>
<tr>
<td>Jover (2013) [22]</td>
<td>Withdrawal time</td>
<td>Multicenter prospective observational study</td>
<td>4539</td>
<td>OR: 1.51 (95% CI 1.17–1.96) for mean WT &gt;8 min</td>
<td>Study design</td>
</tr>
<tr>
<td>Butterly (2014) [23]</td>
<td>Withdrawal time</td>
<td>Retrospective study</td>
<td>7996</td>
<td>OR: 1.50 (95% CI 1.21–1.85) for WT = 9 min</td>
<td>Study design. Withdrawal time recorded by performer</td>
</tr>
<tr>
<td>Lee (2013) [24]</td>
<td>Withdrawal time</td>
<td>Retrospective study</td>
<td>31,088</td>
<td>42.5 vs. 47.1% (mean WT &lt; 7 vs. ≥11 min)</td>
<td>Study design. Only FOB-positive participants</td>
</tr>
<tr>
<td>Vavricka (2016) [25]</td>
<td>Withdrawal time</td>
<td>Single-center prospective study</td>
<td>355 vs. 203</td>
<td>21.4 vs. 36% for monitored-unaware vs. monitored-aware performers</td>
<td>Short-term study</td>
</tr>
<tr>
<td>Kushnir (2015) [29]</td>
<td>Second RC inspection (second pass vs. retroflexion)</td>
<td>Two-center prospective randomized parallel controlled study</td>
<td>400 vs. 455</td>
<td>46 vs. 47%, both methods led to incremental ADR</td>
<td>Academicals medical centers</td>
</tr>
<tr>
<td>Lee (2016) [30]</td>
<td>Retroflexion following two forward-viewing RC examination</td>
<td>Single-center prospective cohort study</td>
<td>1020</td>
<td>25.5% after two FV examinations vs. 27.5% third pass with RV</td>
<td>Non-randomized</td>
</tr>
<tr>
<td>Triantafyllou (2016) [31]</td>
<td>Retroflexion following forward-viewing RC examination</td>
<td>Single-center prospective cohort study</td>
<td>674</td>
<td>6.6% ADR increase</td>
<td>Non-randomized</td>
</tr>
<tr>
<td>Ramirez (2011) [34]</td>
<td>Water-aided colonoscopy</td>
<td>Single-center randomized prospective study</td>
<td>177 vs. 191</td>
<td>57.1% WAC vs. 46.1% AI</td>
<td>Single unblinded endoscopist</td>
</tr>
<tr>
<td>Author (year) [ref]</td>
<td>Method</td>
<td>Study design</td>
<td>N</td>
<td>ADR Limitations</td>
<td></td>
</tr>
<tr>
<td>---------------------</td>
<td>--------</td>
<td>--------------</td>
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<td>-----------------</td>
<td></td>
</tr>
<tr>
<td>Hsieh (2014) [36]</td>
<td>Water-aided colonoscopy</td>
<td>Single-center prospective randomized study</td>
<td>90 vs. 90 vs. 90</td>
<td>Overall ADR: 45.6% WI vs. 56.7% WE vs. 43.3% AIC&lt;br&gt;RC ADR: 14.4% WI vs. 26.7% WE vs. 11.1% AIC&lt;br&gt;Single unblinded endoscopist</td>
<td></td>
</tr>
<tr>
<td>Cadoni (2014) [37]</td>
<td>Water-aided colonoscopy</td>
<td>Two-center prospective randomized study</td>
<td>338 vs. 334</td>
<td>25.8% WAC vs. 19.1% AI&lt;br&gt;Low ADR</td>
<td></td>
</tr>
<tr>
<td>Hsieh (2016) [38]</td>
<td>Water-aided colonoscopy</td>
<td>Two-center prospective randomized study</td>
<td>217 vs. 217 vs. 217</td>
<td>Overall ADR: 40.6% WI vs. 49.8% WE vs. 37.8 AI&lt;br&gt;RC ADR: 17.5% WI vs. 21.7% WE vs. 15.3% AI&lt;br&gt;Long WE insertion time</td>
<td></td>
</tr>
<tr>
<td>Xu (2016) [39]</td>
<td>Nurse participation</td>
<td>RCTs meta-analysis</td>
<td>1672 (3 studies)</td>
<td>45.7% nurse participating vs. 39.3% colonoscopist alone&lt;br&gt;Small number of RCTs included</td>
<td></td>
</tr>
<tr>
<td>Chalifoux (2014) [40]</td>
<td>Trainee participation</td>
<td>Single-center retrospective study</td>
<td>2250 (SD: 1080 HD: 1170)</td>
<td>SD group: 47% without trainee vs. 50% with trainee&lt;br&gt;HD group: 51% without trainee vs. 63% with trainee&lt;br&gt;Single-center study, lack of WT documentation</td>
<td></td>
</tr>
<tr>
<td>Buchner (2011) [41]</td>
<td>Trainee participation</td>
<td>Single-center retrospective study</td>
<td>2430</td>
<td>Overall ADR: 26% without trainee vs. 30% with trainee&lt;br&gt;Diminutive ADR: 17% without trainee vs. 25% with trainee&lt;br&gt;Lack of data regarding bowel preparation</td>
<td></td>
</tr>
<tr>
<td>Gianotti (2016) [42]</td>
<td>Fellow participation</td>
<td>Single-center retrospective study</td>
<td>919 vs. 1806</td>
<td>25% without fellow vs. 36% with fellow with experience of &gt;140 colonoscopies&lt;br&gt;Low ADR of the attending only colonoscopy</td>
<td></td>
</tr>
</tbody>
</table>

ADR adenoma detection rate, WT withdrawal time, FOB fecal occult blood, RC right colon, FV forward-view, RV retroflexion-view, WAC water-aided colonoscopy, AI air insufflation, WE water exchange, WI water immersion, AIC air insufflation control, RC ADR right colon ADR, WAC ADR water-aided colonoscopy ADR, AIC ADR air insufflation control ADR.
2.2.1 Bowel Preparation

While bowel preparation prior to colonoscopy is described by many patients as the most difficult and unpleasant part of the procedure, inadequate bowel preparation has been linked to low ADR [11]. Bowel reparation is considered adequate when the endoscopist is allowed to detect lesions greater than 5 mm in size in every colon segment [12]. Recent guidelines by the European Society of Gastrointestinal Endoscopy [13] and the American Society for Gastrointestinal Endoscopy [14], regarding bowel preparation before colonoscopy, provide useful guidance on this matter. First, split-dose preparation is strongly recommended, as it has been associated with ADR improvement [15]. The second dose of purgatives should be administrated between 3 and 8 h prior the procedure according to ASGE and 4 h according to ESGE. Same-day preparation should be encouraged only for colonoscopies scheduled in the afternoon. Second, a low-residue diet is preferable the day before the examination. Third, oral and written instructions regarding preparation should be provided to each patient, emphasizing on the necessity of adequate bowel preparation. Finally, while 4 L polyethylene glycol (PEG) is considered superior against all other bowel preparation compounds, the optimal choice of formulation should be individualized. It seems logical that improving the bowel cleansing will yield higher ADRs. There is compelling evidence supporting this association [16, 17]. However, it is uncertain if there is any significant improvement in ADR as the degree of bowel cleanliness improves from good to excellent. A few studies have found that high-quality bowel preparation is associated with a superior detection of advanced adenomas and sessile serrated polyps [18, 19]. On the contrary, results from a retrospective study reported only marginal decrease in ADR at the highest levels of bowel cleansing [20]. Authors suggested that an excellent preparation may provide a false sense of overconfidence to endoscopists and led to less meticulous inspection of the colonic mucosa.

2.2.2 Withdrawal Time

Various studies have detected that longer time of withdrawal is associated with higher ADR [21, 22]. Current guidelines recommend that 6 min is the minimum length of time that allows adequate observation of the colonic mucosa during the instrument withdrawal [10], while a longer withdrawal time of 9 min further increases ADR [23]. On the other hand, a withdrawal time prolonged beyond 10 min is associated with a minimal increase in ADR [24].

It is important to state that endoscopists who take longer to withdraw the endoscope do not necessarily have a high-quality colonoscopic withdrawal technique. The withdrawal time should be spent carefully to improve the visualization of the colonic mucosa. Examination of the proximal sides of flexures and folds, thorough washing of the mucosa and suction of debris, alert visualization, and adequate distention of colon are of paramount importance. Additionally, systematic monitoring of the withdrawal time may improve ADR as it has been shown that ADR increases significantly when endoscopists are aware of being supervised during the examination [25].
2.2.3 Second Right Colon Inspection

Incontrovertible evidence point out that colonoscopy is less effective in preventing right-sided colon cancer [26]. Several reasons could be held accountable. First, right-sided polyps are mostly serrated lesions and adenomas with flat morphology and thus more difficult to detect. In addition, polyps are frequently located on the proximal aspects of haustral folds and the area around the hepatic flexure. These sites often remain hidden from standard forward-viewing colonoscopes. Therefore, it is essential to improve the performance of colonoscopy in the proximal colon. A simple and inexpensive method of improving the diagnostic yield of the procedure is the second inspection of the right colon, either by implementation of the retroflexion maneuver [27] or by a second forward-view examination [28]. Results from a prospective study reported that using either one of the aforementioned techniques has incremental benefit on ADR [29], while another study demonstrated that retroflexion in the proximal colon achieves higher ADR, even after two consecutive forward-view examinations [30]. On the contrary, a prospective cohort study that included 674 procedures did not demonstrate any significant benefit regarding right colon adenoma detection by the implementation of the retroflexion maneuver [31].

2.2.4 Water-Aided Colonoscopy

Water infusion methods including the water immersion (WI) and the water exchange (WE) have been proposed to decrease discomfort and minimize sedation use during colonoscopy [32]. Both methods infuse water to distend colon during insertion. In WI, infused water is adjunct to air insufflation, and it is removed predominantly during withdrawal of the scope. In WE, added water is immediately removed during insertion and combined with exclusion of air insufflation and suction of residual air.

Apart from that, water-aided colonoscopy has demonstrated further advantages. Several studies including systematic reviews have compared the water infusion methods with standard air insufflation, evaluating among others screening efficacy [33–35]. Water-aided colonoscopy was associated with a higher ADR, particularly in the right colon [34, 36, 37]. These results can be explained by the observation that intermittent water infusion may clean the mucosa better and thus allow the endoscopist to devote a greater proportion of the withdrawal time to inspection. Furthermore, polyps are prone to better visualization in a water-filled colon because of being less flattened, combined with the magnifying effect of water.

Finally, a head-to-head prospective randomized study with ADR as primary outcome found that WE compared with air insufflation significantly increased ADR (49.8 vs. 37.8%, \( p = 0.016 \)), while there was no difference between WE and WI [38]. Authors suggested that the role of WE method in CRC prevention should be further assessed. However, ADR improvement can be attributed to the longer WE insertion time, thus longer inspection time.
2.2.5 Second Investigator

The presence of an endoscopy nurse or trainee during colonoscopy can improve ADR. Several explanations have been proposed for this association. Even when a lesion is within the field of view, the endoscopist may miss it. This may be due to fail to detect change in the visual field as long as the change occurs during an eye movement or interruptions of visual scanning. Addition of a second observer may improve the attentiveness of the endoscopist, due to a form of competition between the two observers.

A meta-analysis of three randomized controlled trials evaluating nurse participation in colonoscopy observation showed a significant higher ADR in the nurse presence group than endoscopist alone (45.7 vs. 39.3%) [39]. Results in trainees’ participation studies are similar. In a retrospective study, trainee participation during screening colonoscopies, performed with standard or high-definition colonoscopes significantly improved ADR but only when colonoscopies were performed with high-definition scopes [40]. In a similar manner, results from a retrospective study showed that trainee participation improves only detection of diminutive adenomas (<5 mm) [41]. Of note, ADR of fellows who had performed >140 colonoscopies under attending supervision has been found to exceed that of the attenders (36 vs. 25%, \( p < 0.0001 \)) [42]. In conclusion, it is difficult to evade the conclusion that routine observation of colonoscopy withdrawal by a second investigator can improve ADR.

2.3 Technological-Related Factors

2.3.1 Accessory Devices

During the last decade, several endoscopic innovations aiming to enhance visualization behind colonic folds and curves have been developed. We will describe the main accessory devices that either flatten colonic folds or enable a direct view behind them. The current evidence is summarized in Table 2.2.

2.3.1.1 Cap-Assisted Colonoscopy

A transparent plastic cap is attached to the distal tip of the colonoscope in cap-assisted colonoscopy (CAC), depressing the haustral folds and improving mucosal exposure. Moreover, the cap retains the tip of the scope a sufficient distance away from the mucosa allowing the endoscopist to preserve a continuous visual area around the colonic bends. The diameter of the cap depends on the size of the scope, while cap protrusion varies from 2 to 10 mm with 4-mm-long cap used in most studies. In recent years, cap utilization has become popular among endoscopists, especially trainees, as this technique decreases patient discomfort and cecal intubation time [43], while it increases cecal intubation rate [44].

However, there are conflicting data regarding the impact of cap utilization in ADR. There is some evidence that cap-fitted colonoscopy is more effective than standard colonoscopy (SC) in terms of ADR (69 vs. 56%, \( p = 0.009 \)) [45], especially
## Table 2.2  Studies evaluating the impact of add-on devices and new endoscopes on adenoma detection rate

<table>
<thead>
<tr>
<th>Author (year) [ref]</th>
<th>Technology</th>
<th>Study design</th>
<th>N</th>
<th>ADR (%)</th>
<th>AMR (%)</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rastogi (2012) [45]</td>
<td>CAC vs. SC</td>
<td>Single-center prospective randomized parallel design</td>
<td>210 vs. 210</td>
<td>69 vs. 56</td>
<td>NA</td>
<td>Investigator bias in favor of CAC</td>
</tr>
<tr>
<td>Kim (2015) [46]</td>
<td>CAC vs. SC</td>
<td>Single-center retrospective parallel design</td>
<td>515 vs. 508</td>
<td>35.7 vs. 28.3</td>
<td>NA</td>
<td>Longer withdrawal time in CAC group</td>
</tr>
<tr>
<td>Pohl (2015) [47]</td>
<td>CAC vs. SC</td>
<td>Two-center randomized parallel design</td>
<td>561 vs. 552</td>
<td>42 vs. 40</td>
<td>NA</td>
<td>Limited prior experience with cap</td>
</tr>
<tr>
<td>Lee (2009) [48]</td>
<td>CAC vs. SC</td>
<td>Two-center prospective randomized parallel design</td>
<td>499 vs. 501</td>
<td>30.5 vs. 37.5</td>
<td>NA</td>
<td>Inadequate sample</td>
</tr>
<tr>
<td>Ng (2012) [49]</td>
<td>CAC vs. SC</td>
<td>Meta-analysis</td>
<td>726 vs. 707 (six studies)</td>
<td>46.8 vs. 45.3</td>
<td>NA</td>
<td>Absence of polyp histology in most studies</td>
</tr>
<tr>
<td>Lenze (2014) [51]</td>
<td>Endocuff</td>
<td>Single-center retrospective</td>
<td>50</td>
<td>34</td>
<td>NA</td>
<td>No comparator</td>
</tr>
<tr>
<td>Biecker (2015) [52]</td>
<td>Endocuff vs. SC</td>
<td>Two-center prospective randomized parallel design</td>
<td>245 vs. 253</td>
<td>36 vs. 28</td>
<td>NA</td>
<td>Small sample. Withdrawal times not measured</td>
</tr>
<tr>
<td>Floer (2014) [53]</td>
<td>Endocuff vs. SC</td>
<td>Multicenter prospective randomized parallel design</td>
<td>249 vs. 242</td>
<td>35.4 vs. 20.7</td>
<td>NA</td>
<td>Small sample</td>
</tr>
<tr>
<td>Van Doorn (2015) [54]</td>
<td>Endocuff vs. SC</td>
<td>Two-center prospective randomized parallel design</td>
<td>504 vs. 529</td>
<td>54 vs. 53</td>
<td>NA</td>
<td>Inadequate sample. Study restricted on experts</td>
</tr>
<tr>
<td>Chin (2016) [55]</td>
<td>Endocuff vs. SC</td>
<td>Multicenter prospective randomized tandem study</td>
<td>4387 (eight studies)</td>
<td>50.4 vs. 43.3</td>
<td>NA</td>
<td>Tandem studies not included</td>
</tr>
<tr>
<td>Triantafyllou (2016) [56]</td>
<td>Endocuff vs. SC</td>
<td>Multicenter prospective randomized tandem study</td>
<td>100 vs. 100</td>
<td>NA</td>
<td>14.7 vs. 37.6</td>
<td>ADR not measured</td>
</tr>
<tr>
<td>Dik (2015) [58]</td>
<td>EndoRings vs. SC</td>
<td>Multicenter prospective randomized tandem study</td>
<td>57 vs. 59</td>
<td>49.1 vs. 28.8</td>
<td>10.4 vs. 48.3</td>
<td>Inadequate sample to measure ADR</td>
</tr>
<tr>
<td>Granleek (2014) [59]</td>
<td>G-EYE</td>
<td>Single-center prospective cohort</td>
<td>47</td>
<td>44.7</td>
<td>NA</td>
<td>No comparator</td>
</tr>
</tbody>
</table>
in the right colon (29 vs. 16.9%, \( p < 0.001 \)) [46]. On the other hand, a large randomized study comparing CAC to standard colonoscopy failed to find any difference in ADR between the two procedures (42 vs. 40%, \( p = 0.452 \)) [47]. Furthermore, a study reported that the ADR in CAC group was significantly lower than that in the standard group (30.5 vs 37.5%, \( p = 0.02 \)), thus questioning its efficacy [48].

To overcome these conflicting results, a meta-analysis of 16 randomized clinical trials including 8991 patients aiming to evaluate the efficacy of CAC compared to that of standard colonoscopy in polyp detection and cecal intubation time was conducted [49]. Among the 16 studies, only six reported on ADR as an outcome. Authors concluded that there was no significant difference in terms of ADR between CAC and SC (46.8 vs. 45.3%) although a higher proportion of patients with polyp(s) were detected in the CAC group. In subgroup analysis, a short cap (\( \leq 4 \text{ mm} \)) significantly increased polyp detection, whereas a long cap (\( \geq 7 \text{ mm} \)) significantly reduced cecal intubation time, as well as, total colonoscopy time.
In conclusion, although cap utilization may be beneficial for young endoscopists, cap-assisted colonoscopy has a marginal benefit only in polyp detection rate.

### 2.3.1.2 Endocuff

In 2011, a new endoscopic device aiming to improve ADR and control of the tip of the colonoscope was introduced. The Endocuff (EC; Arc Medical Design Ltd., Leeds, England) is a 2-cm-long cap designed to be attached to the tip of colonoscope. It features two circular rows of soft and flexible arms that remain flattened during insertion and protrude out on withdrawal, straightening the mucosal folds.

More thoroughly, during forward motion, the elastic slim projections of the cuff are hinged at their bases to not interfere with colonic mucosa. However, ileal intubation may be more difficult. During withdrawal, the wings project out due to contact with the colonic mucosa, stabilizing the position of the endoscope in the center of the lumen and spreading out the colonic folds. Therefore, the proximal side of the folds is exposed, and previously hidden polyps may now be detected (Fig. 2.1).

EC was initially used as a stabilizing tool for complex polyp resection in the sigmoid colon [50]. In 2014, the first study evaluating EC-assisted colonoscopy was published [51]. The ADR was 34% and reached 41% in the subgroup of screening colonoscopy, while 42% of the adenomas were located in the right colon. Since then, various studies have been conducted comparing EC-assisted versus standard colonoscopy. Two of them associated the use of EC with a higher ADR [52, 53], while no difference between the two groups regarding the ADR was reported in one

![Fig. 2.1](image-url) Endocuff (Arc Medical Design Ltd., Leeds, UK) (a, b); mounted on the colonoscope (c); during scope withdrawal the device flattens the colonic folds and its projections may become visible (d)
large randomized controlled trial [54]. Finally, a meta-analysis including eight studies which reported ADR as an outcome and 4387 patients has shown superiority of EC-assisted colonoscopy in relation to ADR [55]. A recently presented multicenter tandem study showed for the first time that EC use was related with lower rates of missed adenomas compared to SC (14.7 vs. 37.6%, \( p = 0.0004 \)) [56].

The most commonly reported complication of the EC use is minor mucosal lac-
erations without any clinical impact. The new version of EC, Endocuff Vision, has one single row of more rounded and longer projections, thus minimizing the mucosal injury and delivering a better tip control. A prospective, multicenter, randomized controlled trial is currently comparing Endocuff Vision-assisted versus standard colonoscopy in terms of ADR [57].

### 2.3.1.3 EndoRings

The EndoRings device (EndoAid Ltd., Caesarea, Israel) is another easy-to-use endoscopic add-on attachment with design and use similar to EC, except that it consists of two circular rows of flexible rings. It is mounted on the tip of a colonoscope and, during withdrawal, mechanically stretches the colonic folds and provides centering and control of the endoscope (Fig. 2.2). A multicenter, randomized, tandem colonoscopy study demonstrated that EndoRings-assisted colonoscopy has significantly lower polyp and adenoma miss rate than standard colonoscopy [58]. Also, ADR of the first-pass colonoscopy was higher with EndoRings than without it (49.1 vs. 28.8%, \( p = 0.025 \)).

### 2.3.1.4 Balloon-Assisted Colonoscopy

A novel balloon-colonoscope system (NaviAid G-EYE; Smart Medical Systems, Ra’anana, Israel) has been recently introduced. The G-EYE system consists of a standard colonoscope of any brand and model and a reusable and inflatable balloon that is permanently integrated 1–2 cm behind its distal end. The balloon is inflated through a dedicated inflation system (NaviAid SPARK©) that enables, beyond anchoring pressure, three additional intermediate pressure levels and can reach a maximal diameter of 60 mm, when fully inflated. Balloon inflation and deflation is

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**Fig. 2.2** EndoRings (EndoAid Ltd., Caesarea, Israel) mounted on the scope flattens the colonic folds during withdrawal, thus exposing more mucosal area to be examined. Image provided courtesy of EndoAid Ltd., Caesarea, Israel
controlled by a foot pedal. When deflated, the diameter of the scope is about 0.1 mm larger than the conventional colonoscope (Fig. 2.3).

During colonoscopy, the scope advances with the balloon deflated. When cecum is reached and examined, the balloon is partially inflated and the balloon colonoscope is withdrawn by the endoscopist like a standard procedure. Withdrawal of the partially inflated balloon flattens the haustral folds, keeps the scope at the center of the lumen, and inhibits bowel slippage during withdrawal. This fold-flattening effect facilitates visualization of the colonic mucosa behind the folds, to increase polyp detection. Moreover, anchoring pressure is enabled when longer stabilization of the colonoscope is needed (e.g., during therapeutic interventions).

A prospective, pilot study tested the safety and feasibility of the G-EYE balloon colonoscope in 50 patients [59]. Authors reported that balloon-assisted colonoscopy had an ADR of 44.7%, and the results of this study were very promising. Consequently, a multicenter, randomized controlled trial with tandem design demonstrated that balloon-assisted colonoscopy was superior to standard colonoscopy regarding adenoma detection (40.4 vs. 25.9%), especially in the ascending colon (40.5 vs. 23.8%) [60]. Authors concluded that this fold-flattening device, due to its increased diagnostic yield, has the potential to reduce interval CRC and, therefore, to fit in the screening programs of endoscopic units.

### 2.3.1.5 Third-Eye Panoramic

The Third-Eye Panoramic device (TEP; Avantis Medical System, Sunnyvale, USA) is a novel resposable device that enables direct visualization behind colonic folds and flexures. TEP consists of a plastic cap with two video cameras, illuminated by LEDs and directed sideways from its right and left sides, and a flexible plastic catheter containing a video transmission wire. The cap is attached to the tip of any standard colonoscope and holds in place the catheter, which runs alongside the shaft of the endoscope. The proximal end of the catheter plugs into the video processor unit of the colonoscope, and the two lateral images of the TEP are displayed on each side of

![Fig. 2.3 The NaviAid G-EYE (Smart Medical Systems, Ra’anana, Israel). Image provided courtesy of the company](image-url)
the scope’s forward image, creating a panoramic video image of more than 300°. This wide-angle view allows inspection of the colonic mucosa behind folds and flexures.

A feasibility study [61] reported on the safe and effective use of TEP in 33 patients. TER enabled the visualization of polyps and diverticula which were not initially seen with the scope’s forward view. The overall ADR was 44%, but further studies comparing the TEP-assisted to standard colonoscopy, as well as other devices designed to improve ADR, are required.

2.3.2 Wide-Angle Viewing Colonoscopes

Currently, one wide-angle view, the FUSE (EndoChoice, Alpharetta, GA, USA) platform is marketed, while another prototype is close to reach the endoscopy market. The evidence on the performance of these instruments is also summarized in Table 2.2.

2.3.2.1 Full-Spectrum Endoscopy System

Full-Spectrum Endoscopy (FUSE; EndoChoice, Alpharetta, GA, USA) platform consists of a video colonoscope and a main control unit. This novel endoscope has a high-resolution 330° field of view with maintenance of all standard colonoscope capabilities. The full-spectrum view is achieved by using three imagers and light-emitting diode groups positioned at the front and both sides of the forward tip of the scope. Obtained images are displayed on three side-by-side contiguous monitors, thereby creating the 330° field of view and improving visualization of the mucosa behind colonic folds (Fig. 2.4).

![Field view comparison between the standard colonoscope and the full-spectrum endoscopy (EndoChoice, Alpharetta, GA, USA). The panoramic 330° of view gives the opportunity to identify lesions with the lateral lenses during withdrawal. Image provided courtesy of the company](image-url)
Following a successful feasibility study in human subjects [62], an international, multicenter, randomized, tandem study compared the adenoma miss rates of FUSE colonoscopy with those of standard colonoscopy [63]. Per-lesion analysis in 185 patients showed that adenoma miss rate with FUSE colonoscopy was significantly lower than that with standard procedure (7 vs. 41%, \( p < 0.001 \)). Moreover, FUSE detected significantly more adenomas than SC (69% additional adenomas), and most adenomas missed by SC and subsequently detected by FUSE were located in the right colon. In terms of ADR, there was no statistically difference between the two groups due to the small sample size. A recently published study, with similar design to the aforementioned trial, reported a considerably lower overall (10.9 vs. 33.7%, \( p < 0.001 \)) and proximal adenoma miss rate (13.9 vs. 42.2%, \( p = 0.006 \)) with FUSE [64]. It should be mentioned that standard colonoscopy was performed with the addition of right colon reexamination with scope retroflexion.

On the other hand, a large parallel design randomized study enrolling 658 patients undergoing colonoscopy with positive fecal immunochemical test (FIT) demonstrated that FUSE colonoscopy does not increase ADR [65]. More detailed, FIT-positive patients were randomized to undergo either FUSE colonoscopy or SC. No difference in ADR and advanced ADR was detected between the two groups (FUSE 43.6% and 19.5% vs. SC 45.5% and 23.9%, respectively). The inconsistency between the results of this study and the aforementioned tandem studies could be explained by the study design. Parallel group design may be preferable for clinical practice as it compares ADR, but it requires a much larger sample size to achieve adequate statistical power than that of the aforementioned trial [66].

### 2.3.2.2 Extra-Wide-Angle-View Colonoscope

Extra-wide-angle view colonoscope (Olympus, Tokyo, Japan) is a novel colonoscope with a 13.9-mm tip diameter and a 144–232°-angle backward-lateral view lens in addition to a standard 140°-angle forward-view lens, accompanied by a 180-series processor. The lateral-backward viewing lens is projected in a convex way from the tip of the scope. Images from both lenses are simultaneously presented as a single image on a video monitor. Thus, an extensive surface of colonic mucosa is inspected allowing a more meticulous colon examination.

In a single-arm feasibility study assessing the efficacy and safety of this prototype colonoscope [67], all adenomatous lesions found in the sigmoid colon were first detected by the lateral-backward viewing lens. However, further studies appropriately designed to evaluate the utilization of this novel scope are needed.

### 2.4 Summary

Colonoscopy is the gold standard for colorectal cancer screening, although a substantial proportion of adenomas are missed during the procedure. ADR is the primary quality indicator to measure effective colonoscopy, and there is an inverse association between interval CRC and ADR. In addition to inborn incommensurable endoscopy skill, various methods have been featured to optimize ADR. Adequate
bowl preparation, sufficient withdrawal time exceeding the 6 min, and second visualization of the right colon are among others easy-to-follow procedural factors that have demonstrated ADR improvement. During the last years, several endoscopic technologies have been developed to optimize visualization of the colonic mucosa. Although most of them have demonstrated impressive results regarding polyp detection, their impact in clinical practice is still questionable. Beyond additional costs and training requirements, all these modalities have not proved a significant impact on CRC prevention yet, since the advantage of detecting additional lesions is restricted to small, non-advanced adenomas, so far.

Conflict of Interest Statement  The authors declare no conflict of interest related to this publication.

References


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