

# Quality indicators in colonoscopy: the chasm between ideal and reality

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Continuous measurement of quality indicators (QIs) should be a routine part of colonoscopy, as a wide variation still exists in the performance and quality levels of colonoscopy in Korea. Among the many QIs of colonoscopy, the adenoma detection rate, average withdrawal time, bowel preparation adequacy, and cecal intubation rate should be monitored in daily clinical practice to improve the quality of the procedure. The adenoma detection rate is the best indicator of the quality of colonoscopy; however, it has many limitations for universal use in daily practice. With the development of natural language processing, the adenoma detection rate is expected to become more effective and useful. It is important that colonoscopists do not strictly and mechanically maintain an average withdrawal time of 6 minutes but instead perform careful colonoscopy to maximally expose the colonic mucosa with a withdrawal time of at least 6 minutes. To achieve adequate bowel preparation, documentation of bowel preparation with the Boston Bowel Preparation Scale (BBPS) should be a routine part of colonoscopy. When colonoscopists routinely followed the bowel preparation protocols,  $\geq 85\%$  of outpatient screening colonoscopies had a BBPS score of  $\geq 6$ . In addition, the cecal intubation rate should be  $\geq 95\%$  of all screening colonoscopies. The first step in improving colonoscopy quality in Korea is to apply these key performance measurements in clinical practice.

**Keywords:** Adenoma detection rate; Colonoscopy; Quality; Screening

## INTRODUCTION

The overall prevalence of colorectal cancer (CRC) is lower in Asian than in Western countries; however, Asia has the highest number of prevalent cases, with relevant health-related implications.<sup>1</sup> Colonoscopy, the gold standard method for CRC screening, can reduce the CRC incidence by 76%–90% and the CRC mortality by 53%.<sup>2,3</sup> However, colonoscopy is an imperfect method and has variable quality, with miss rates of 17%–28%

for polyps of any size, 2.1%–12% for large polyps, and 5%–11% for advanced adenoma in previous studies.<sup>4-7</sup> In addition, the detection rates of adenomas<sup>8</sup> and sessile serrated lesions<sup>9</sup> vary among colonoscopists. Therefore, efforts to maximize the quality of colonoscopy are essential. Improving the quality and performance of the procedure is a goal of every colonoscopist; however, the measurement and application of the quality indicators (QIs) of colonoscopy in daily clinical practice is a challenge for many practitioners. In addition, colonoscopists in both community and academic hospitals have to bear the burden of a large volume of cases, resulting in a chasm between the ideal and the reality with respect to compliance with the QIs of colonoscopy.

In this article, we aimed to provide practical advice for colonoscopists in optimizing the QIs of colonoscopy, with a focus on the four major indicators: adenoma detection rate (ADR), average withdrawal time (AWT), bowel preparation adequacy, and cecal intubation rate (CIR).

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## ADENOMA DETECTION RATE

The ADR can be defined as the number of patients with one or more adenomas divided by the total number of patients who underwent a screening colonoscopy.<sup>10</sup> The American Society for Gastrointestinal Endoscopy (ASGE)/American College of Gastroenterology (ACG) Task Force on Quality in Endoscopy recommends ADR targets for screening colonoscopy of at least 30% for men and 20% for women (25% for all patients) aged  $\geq 50$  years.<sup>10</sup> In a recent review by the American Gastroenterological Association (AGA), the recommended ADR was 30%, with a recommended aspirational target of 35%.<sup>11</sup> However, this expert review was not a formal systematic review and had no formal rating of the quality of evidence or the strength of recommendation. ADR is the best QI because there is a marked variation in the ADR among colonoscopists,<sup>12</sup> which is the rationale for the creation of ADR targets. A Polish study on screening colonoscopy reported that the endoscopist's ADR was significantly associated with the risk of interval CRC ( $p=0.008$ ).<sup>13</sup> Compared with an ADR of  $\geq 20.0\%$ , the hazard ratios for ADRs of  $<11.0\%$ ,  $11.0\%–14.9\%$ , and  $15.0\%–19.9\%$  were 10.94, 10.75, and 12.50, respectively. This study showed that the risk of interval CRC was significantly higher among patients who underwent colonoscopies performed by endoscopists with an ADR of  $<20\%$  than among those examined by endoscopists with an ADR of  $\geq 20\%$ . However, this finding was limited by the fact that the protection against interval CRC continued to improve when the ADR increased to  $>20\%$ . Corley et al.<sup>14</sup> reported the risk of interval CRC according to the quintiles of ADR from 7.35% to 52.51% based on 314,872 colonoscopies performed by 136 gastroenterologists. Patients of gastroenterologists with ADRs in the highest quintile, as compared with patients of gastroenterologists with ADRs in the lowest quintile, had an adjusted hazard ratio of 0.52 for any interval CRC, 0.43 for advanced-stage interval CRC, and 0.38 for fatal interval CRC. Therefore, the ADRs of all colonoscopists should be measured, and those with an overall ADR of  $<25\%$  in screening colonoscopy need to improve their performance.

ADR is the best QI for mucosal inspection and the single most important QI for screening colonoscopy.<sup>10</sup> However, the measurement of ADR is labor intensive and cumbersome. Therefore, it is difficult to apply this method in daily clinical practice. In addition, the adenoma miss rates still varied among high-ADR colonoscopists in a study in which 200 colonosco-

pists performed back-to-back colonoscopies,<sup>15</sup> which raised the question of whether the ADR is indeed the best QI. Many limitations of the ADR may also prevent its universal use in daily practice. First, as ADR measurement requires a manual review of pathology data, colonoscopists cannot know their ADR immediately after the procedure. Therefore, the polyp detection rate (PDR) has been suggested as an alternative QI because it does not require pathological data. In a total of 1,921 colonoscopies, the PDR and ADR correlated well in segments proximal to the splenic flexure but not in the left colon.<sup>16</sup> Therefore, the PDR may be used as a surrogate for the ADR in the right colon. However, checking colonoscopy images one by one is challenging for colonoscopists. If the ADR can be calculated and automatically monitored with natural language processing, which is a method used to extract the ADR from unstructured or free-text data using computer-based artificial intelligence,<sup>17–19</sup> ADR measurement may substantially improve the effectiveness of screening colonoscopy. Second, the use of the ADR as a QI may lead to a “one-and-done” approach to colonoscopy, in which colonoscopists might pay less attention to carefully examining the remaining colonic mucosa after identifying the first adenoma. Therefore, the adenoma per colonoscopy (APC) rate has been suggested as a promising alternative to the ADR,<sup>20</sup> as it reflects careful examination of the whole colon. However, the APC rate also has a limitation in that it is more cumbersome to measure than the ADR. Third, there are no guidelines for the minimum number of colonoscopies required to ensure reliable ADR estimates. When calculating 95% confidence intervals for theoretical ADRs of 15%–40% with varying sample sizes, large numbers of colonoscopies (e.g., 500 cases) are needed to provide narrow confidence intervals for typical ADR estimates.<sup>21</sup> Finally, the target ADR may be adjusted according to the indications of colonoscopy or age group. In a consensus statement by the US Multi-Society Task Force on CRC, the recommended targets for ADR were at least 45% for men and 35% for women aged  $\geq 50$  years in colonoscopy after a positive fecal immunochemical test.<sup>22</sup> For adults aged  $<50$  years, our study group recommended an adjusted ADR target of 20% rather than 25% in screening colonoscopy.<sup>23</sup>

To date, the ADR is the best QI for screening colonoscopy; however, there is a chasm between the ideal and the reality with respect to its universal use in daily practice. If natural language processing can fill this chasm in the near future, the ADR is expected to become a more effective and useful QI for screening colonoscopy.

## AVERAGE WITHDRAWAL TIME

Barclay et al.<sup>24</sup> showed that an AWT of  $\geq 6$  minutes increased the detection rate of significant neoplastic lesions in normal screening colonoscopy. Colonoscopists with AWTs of  $\geq 6$  minutes had a higher detection rate of neoplasia (28.3% vs. 11.8%,  $p < 0.001$ ) and advanced neoplasia (6.4% vs. 2.6%,  $p = 0.005$ ) than those with AWTs of  $< 6$  minutes. In four representative studies comparing the AWT and ADR, the ADR proportionally increased as the AWT increased from 6 to 12 minutes.<sup>25</sup> In an analysis of the Minnesota Cancer Surveillance System based on 76,810 screening colonoscopies, a shorter annual AWT during screening colonoscopies was independently associated with a lower ADR and an increased risk of interval CRC.<sup>26</sup> Careful colonoscopic examination is time consuming, but may result in an increased detection rate of significant neoplastic lesions. It is not difficult to measure the AWT in daily practice because most colonoscopic equipment support the monitoring of the examination time. Therefore, the AWT can only be a secondary QI to the ADR.<sup>27</sup> How can the AWT be increased in daily practice? The AWT may increase when colonoscopists are aware of being monitored. In a Swiss study, the AWT in unmonitored colonoscopists was shorter than the recommended AWT and increased with an awareness of monitoring (from 21% to 36%).<sup>28</sup>

The AWT may be limited because it is only useful for monitoring the performance of colonoscopists with low ADRs.<sup>27</sup> In addition, the AWT is not a useful QI when performing colonoscopy in patients with a history of surgical resection, biopsies, or polypectomies and in those with inadequate bowel preparation. In the ASGE/ACG guidelines, the recommended target AWT is 6 minutes<sup>10</sup>; however, whether 6 minutes is the actual optimal target level of AWT in screening colonoscopy remains unclear. In the AGA review, the minimum AWT target was also 6 minutes, although an aspirational target of 9 minutes was recommended.<sup>11</sup> The European Society of Gastrointestinal Endoscopy (ESGE) guidelines also recommend 6 minutes as the minimum standard and 10 minutes as the target standard.<sup>29</sup> In the New Hampshire Colonoscopy Registry, the ADR and the detection rate of significant serrated polyps increased with each additional minute beyond an AWT of 6 minutes.<sup>30</sup> However, in this study, an AWT of 9 minutes showed the maximum benefit for the ADR and the detection rate of serrated polyps. In the Norwegian Gastronet Quality Assurance program based on 4,429 colonoscopies performed by 67 colonoscopists, the detection rate of polyps  $\geq 5$  mm was not significantly different

between colonoscopists with AWT  $\geq 6$  minutes and those with AWT  $< 6$  minutes.<sup>31</sup> In this study, an AWT of 6 minutes was not a strong predictor of the likelihood of finding a polyp during colonoscopy. In a recent Korean study, the ADR was significantly higher when the segmental withdrawal time was  $\geq 2$  minutes in the right-sided colon,  $\geq 4$  minutes in the proximal colon, and  $\geq 3$  minutes in the left-sided colon than when the segmental withdrawal times were shorter.<sup>32</sup> This study suggests that the segmental withdrawal time is more important than the total withdrawal time.

A gap still exists between the ideal and the reality in terms of the AWT in daily practice. In clinical practice, how time is utilized by colonoscopists matters more than the AWT target of 6 minutes itself. It is important that colonoscopists do not mechanically maintain an AWT of 6 minutes but instead perform careful colonoscopy to maximally expose the colonic mucosa, which may naturally require more time.

## BOWEL PREPARATION ADEQUACY

Inadequate bowel preparation may result in missed neoplastic lesions, incomplete colonoscopic examinations, and incomplete resection. In particular, nonpolypoid lesions are more likely to be missed than polypoid lesions when the bowel preparation is inadequate, especially in the right-sided colon.<sup>33</sup> In a Spanish study, 36.3% of 132 cases of interval CRC were associated with inadequate bowel preparation, which suggests that high-quality bowel preparation can prevent interval CRC.<sup>34</sup> The ASGE/ACG guidelines recommend documentation of bowel preparation quality in  $> 98\%$  and achieving adequate bowel preparation in  $\geq 85\%$  of all outpatient screening colonoscopies.<sup>10</sup> However, recently, the target level for adequate bowel preparation has been increased.<sup>11,29</sup> The updated AGA guidelines recommend achieving adequate bowel preparation in  $\geq 90\%$  (aspirational target  $\geq 95\%$ ) of screening colonoscopies.<sup>11</sup> Similarly, the ESGE guidelines recommend  $\geq 90\%$  as the minimum standard and  $\geq 95\%$  as the target standard.<sup>29</sup> Although adequate bowel preparation has not been clearly defined, bowel preparation can be considered adequate when polyps  $> 5$  mm in size are easily detected during colonoscopy.<sup>35</sup> In daily practice, the quality of bowel preparation has been classified as excellent, good, fair, or poor; however, these terms do not have standardized definitions<sup>36</sup> and have interobserver variations. For an objective documentation of bowel preparation, the Boston Bowel Preparation Scale (BBPS) can be used.<sup>37</sup> In the BBPS, each of the three segments of the co-

lon (right, transverse, and left) is scored from 0 to 3 after cleaning maneuvers such as washing and suctioning of retained fluid and stool.<sup>32</sup> The scores for the three segments are then summed to obtain a total score of 0–9, in which 0 means an unprepared bowel and 9 means an entirely clean bowel. An instructional video demonstrating how to use the BBPS is available online at <http://www.bmc.org/gastroenterology/research.htm>.<sup>37</sup> In a systematic review and meta-analysis of studies on the impact of bowel preparation quality on the ADR, intermediate/fair preparation quality may be followed up at standard guideline-recommended surveillance intervals without substantially affecting quality as measured by the ADR.<sup>38</sup> Therefore, excellent, good, or fair quality may be considered adequate preparation, whereas poor quality indicates inadequate preparation. In terms of the BBPS, a score of  $\geq 6$  is considered to indicate adequate preparation, and early repeat colonoscopy is recommended in patients with a BBPS score of 0 or 1 in any colon segment.<sup>39,40</sup> When the quality of bowel preparation is inadequate according to these definitions, colonoscopy must be repeated at shorter than the recommended intervals.<sup>10</sup>

Colonoscopists should assess the bowel preparation protocols when the frequency of inadequate bowel preparation is  $>15\%$ . Two important factors for improving the quality of bowel preparation are the timing of colonoscopy and the split-dosing regimen. The most important determinant of bowel preparation quality is the timing of colonoscopy (e.g., the interval between the end of preparation ingestion and the start of colonoscopy).<sup>41</sup> Patients should ingest the second half of the split dose 4–5 hours before the scheduled colonoscopy start time and finish the ingestion 2 hours before the procedure time.<sup>9</sup> All patients should be educated on the split-dosing regimen for bowel preparation. Recently, low-volume preparation agents have been commonly used<sup>42,43</sup>; therefore, sufficient education on low-fiber diets is becoming more important than before, when high-volume preparation agents were commonly used. European guidelines recommend a low-fiber diet on the day before colonoscopy but do not have any recommendations about the use of a low-fiber diet for  $>24$  hours before the procedure.<sup>44</sup>

A large gap still exists between the target bowel preparation quality and the actual colonoscopy performance, as the reported rate of inadequate bowel preparation was 28.1% and a split-dose regimen was prescribed to only 55.4% of patients in actual practice.<sup>45</sup> This gap may be narrowed when documentation of bowel preparation with BBPS becomes a routine part of colonoscopy. In addition,  $\geq 85\%$  of outpatient screening colonos-

copies had a BBPS score of  $\geq 6$  when colonoscopists routinely followed the bowel preparation protocols, including the appropriate timing of colonoscopy, use of the split-dosing regimen, and provision of a low-fiber diet education to patients.

## CECAL INTUBATION RATE

Cecal intubation is defined as the successful insertion of the colonoscope tip up to the proximal part of the ileocecal valve and visualization of the entire cecal caput.<sup>10</sup> Cecal intubation can be confirmed using landmarks, including the appendiceal orifice with triradiate folds and the ileocecal valve. If the operator is not certain of cecal intubation, identification of the ileocecal valve and intubation of the terminal ileum may be necessary. When cecal landmarks are not clearly identified and colonoscopists take a photograph of the area believed to be the cecum from a distance, other colonic segments may be mistaken for the cecum. The ASGE/ACG guidelines recommend a target CIR of  $\geq 95\%$  during screening colonoscopy.<sup>10</sup> However, in the National Health Service Bowel Cancer Screening Program, the CIR varied from 76.2% to 100% and was highly consistent with the ADR.<sup>46</sup> According to the Ontario Cancer Registry, patients who underwent colonoscopy performed by a colonoscopist with a high CIR were less likely to develop interval CRC.<sup>47</sup> When 95 cases of cecal intubation failure were analyzed, the identified causes were redundant colon (56.8%), difficult sigmoid colon (34.7%), and sedation difficulty (8.4%).<sup>48</sup>

In a recent study from primary health-care institutions in Korea, the proportion of incomplete examinations attributed to poor bowel preparation or difficulty in cecal intubation was only 4.9%.<sup>49</sup> In addition, most hospital-based studies on screening colonoscopy in Korea reported a high CIR of nearly 100%.<sup>50</sup> As the primary health-care institutions are sufficiently achieving the target CIR ( $\geq 95\%$ ), the CIR may have little room for improvement in Korea. In this regard, the CIR may not be a good QI for screening colonoscopy in Korea, as most colonoscopists already have a high CIR.

## CONCLUSIONS

In Korea, an ongoing pilot study is evaluating the efficacy and safety of population-based colonoscopy screening for CRC; however, a wide variation still exists in the performance level and the QIs of screening colonoscopy.<sup>51</sup> As demonstrated in the NordICC study,<sup>52</sup> suboptimal colonoscopy quality is a major

pitfall in population-based colonoscopy screening. To improve the performance of population-based colonoscopy screening, continuous measurement of QIs should be included in routine practice.<sup>53</sup>

Among the many QIs of colonoscopy, the ADR, AWT, bowel preparation adequacy, and CIR should be prioritized and monitored in daily practice. The first step in improving colonoscopy quality in Korea is to apply these key performance measurements in clinical practice. At the same time, we anticipate future work to clarify the optimal colonoscopy QIs in Korea.

### Conflicts of Interest

The authors have no conflicts of interest.

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### Author Contributions

Conceptualization: JMC; Investigation: SBP; Supervision: JMC; Writing—original draft: SBP; Writing—review & editing: JMC.

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### REFERENCES

1. Wong MC, Ding H, Wang J, et al. Prevalence and risk factors of colorectal cancer in Asia. *Intest Res* 2019;17:317–329.
2. Winawer SJ, Zauber AG, Ho MN, et al. Prevention of colorectal cancer by colonoscopic polypectomy. The National Polyp Study Workgroup. *N Engl J Med* 1993;329:1977–1981.
3. Zauber AG, Winawer SJ, O'Brien MJ, et al. Colonoscopic polypectomy and long-term prevention of colorectal-cancer deaths. *N Engl J Med* 2012;366:687–696.
4. van Rijn JC, Reitsma JB, Stoker J, et al. Polyp miss rate determined by tandem colonoscopy: a systematic review. *Am J Gastroenterol* 2006;101:343–350.
5. Pickhardt PJ, Nugent PA, Mysliwiec PA, et al. Location of adenomas missed by optical colonoscopy. *Ann Intern Med* 2004;141:352–359.
6. Heresbach D, Barrioz T, Lapalus MG, et al. Miss rate for colorectal neoplastic polyps: a prospective multicenter study of back-to-back video colonoscopies. *Endoscopy* 2008;40:284–290.
7. Ahn SB, Han DS, Bae JH, et al. The miss rate for colorectal adenoma determined by quality-adjusted, back-to-back colonoscopies. *Gut Liver* 2012;6:64–70.
8. Chen SC, Rex DK. Endoscopist can be more powerful than age and male gender in predicting adenoma detection at colonoscopy. *Am J Gastroenterol* 2007;102:856–861.
9. Hetzel JT, Huang CS, Coukos JA, et al. Variation in the detection of serrated polyps in an average risk colorectal cancer screening cohort. *Am J Gastroenterol* 2010;105:2656–2664.
10. Rex DK, Schoenfeld PS, Cohen J, et al. Quality indicators for colonoscopy. *Am J Gastroenterol* 2015;110:72–90.
11. Keswani RN, Crockett SD, Calderwood AH. AGA clinical practice update on strategies to improve quality of screening and surveillance colonoscopy: expert review. *Gastroenterology* 2021;161:701–711.
12. Sanaka MR, Gohel T, Podugu A, et al. Adenoma and sessile serrated polyp detection rates: variation by patient sex and colonic segment but not specialty of the endoscopist. *Dis Colon Rectum* 2014;57:1113–1119.
13. Kaminski MF, Regula J, Kraszewska E, et al. Quality indicators for colonoscopy and the risk of interval cancer. *N Engl J Med* 2010;362:1795–1803.
14. Corley DA, Jensen CD, Marks AR, et al. Adenoma detection rate and risk of colorectal cancer and death. *N Engl J Med* 2014;370:1298–1306.
15. Aniwaniwan S, Orkoonasawat P, Viriyautsahakul V, et al. The secondary quality indicator to improve prediction of adenoma miss rate apart from adenoma detection rate. *Am J Gastroenterol* 2016;111:723–729.
16. Boroff ES, Gurudu SR, Hentz JG, et al. Polyp and adenoma detection rates in the proximal and distal colon. *Am J Gastroenterol* 2013;108:993–999.
17. Imler TD, Morea J, Kahi C, et al. Multi-center colonoscopy quality measurement utilizing natural language processing. *Am J Gastroenterol* 2015;110:543–552.
18. Mehrotra A, Dellon ES, Schoen RE, et al. Applying a natural language processing tool to electronic health records to assess performance on colonoscopy quality measures. *Gastrointest Endosc* 2012;75:1233–1239.
19. Raju GS, Lum PJ, Slack RS, et al. Natural language processing as an alternative to manual reporting of colonoscopy quality metrics. *Gastrointest Endosc* 2015;82:512–519.
20. Park SK, Kim HY, Lee CK, et al. Comparison of adenoma detection rate and adenoma per colonoscopy as a quality indicator of colonoscopy. *Scand J Gastroenterol* 2016;51:886–890.
21. Do A, Weinberg J, Kakkar A, et al. Reliability of adenoma detection



- rate is based on procedural volume. *Gastrointest Endosc* 2013;77:376–380.
22. Robertson DJ, Lee JK, Boland CR, et al. Recommendations on fecal immunochemical testing to screen for colorectal neoplasia: a consensus statement by the US Multi-Society Task Force on colorectal cancer. *Gastrointest Endosc* 2017;85:2–21.
  23. Yoon JY, Cha JM, Shin JE, et al. An adjusted level of adenoma detection rate is necessary for adults below 50 years old. *J Clin Gastroenterol* 2018;52:703–708.
  24. Barclay RL, Vicari JJ, Doughty AS, et al. Colonoscopic withdrawal times and adenoma detection during screening colonoscopy. *N Engl J Med* 2006;355:2533–2541.
  25. Chaptini L, Laine L. Can I improve my adenoma detection rate? *J Clin Gastroenterol* 2015;49:270–281.
  26. Shaukat A, Rector TS, Church TR, et al. Longer withdrawal time is associated with a reduced incidence of interval cancer after screening colonoscopy. *Gastroenterology* 2015;149:952–957.
  27. Barclay RL, Vicari JJ, Greenlaw RL. Effect of a time-dependent colonoscopic withdrawal protocol on adenoma detection during screening colonoscopy. *Clin Gastroenterol Hepatol* 2008;6:1091–1098.
  28. Vavricka SR, Sulz MC, Degen L, et al. Monitoring colonoscopy withdrawal time significantly improves the adenoma detection rate and the performance of endoscopists. *Endoscopy* 2016;48:256–262.
  29. Kaminski MF, Thomas-Gibson S, Bugajski M, et al. Performance measures for lower gastrointestinal endoscopy: a European Society of Gastrointestinal Endoscopy (ESGE) quality improvement initiative. *United European Gastroenterol J* 2017;5:309–334.
  30. Butterly L, Robinson CM, Anderson JC, et al. Serrated and adenomatous polyp detection increases with longer withdrawal time: results from the New Hampshire Colonoscopy Registry. *Am J Gastroenterol* 2014;109:417–426.
  31. Moritz V, Bretthauer M, Ruud HK, et al. Withdrawal time as a quality indicator for colonoscopy: a nationwide analysis. *Endoscopy* 2012;44:476–481.
  32. Jung Y, Joo YE, Kim HG, et al. Relationship between the endoscopic withdrawal time and adenoma/polyp detection rate in individual colonic segments: a KASID multicenter study. *Gastrointest Endosc* 2019;89:523–530.
  33. Bianco MA, Cipolletta L, Rotondano G, et al. Prevalence of non-polypoid colorectal neoplasia: an Italian multicenter observational study. *Endoscopy* 2010;42:279–285.
  34. Munoz Garcia-Borrueal M, Hervas Molina AJ, Rodriguez Peralvarez ML, et al. Post-colonoscopy colorectal cancer: characteristics and predictive factors. *Med Clin (Barc)* 2018;150:1–7.
  35. Rex DK, Bond JH, Winawer S, et al. Quality in the technical performance of colonoscopy and the continuous quality improvement process for colonoscopy: recommendations of the U.S. Multi-Society Task Force on Colorectal Cancer. *Am J Gastroenterol* 2002;97:1296–1308.
  36. Larsen M, Hills N, Terdiman J. The impact of the quality of colon preparation on follow-up colonoscopy recommendations. *Am J Gastroenterol* 2011;106:2058–2062.
  37. Calderwood AH, Jacobson BC. Comprehensive validation of the Boston Bowel Preparation Scale. *Gastrointest Endosc* 2010;72:686–692.
  38. Clark BT, Rustagi T, Laine L. What level of bowel prep quality requires early repeat colonoscopy: systematic review and meta-analysis of the impact of preparation quality on adenoma detection rate. *Am J Gastroenterol* 2014;109:1714–1723.
  39. Johnson DA, Barkun AN, Cohen LB, et al. Optimizing adequacy of bowel cleansing for colonoscopy: recommendations from the U.S. multi-society task force on colorectal cancer. *Gastrointest Endosc* 2014;80:543–562.
  40. Clark BT, Protiva P, Nagar A, et al. Quantification of adequate bowel preparation for screening or surveillance colonoscopy in men. *Gastroenterology* 2016;150:396–405.
  41. Kilgore TW, Abdinoor AA, Szary NM, et al. Bowel preparation with split-dose polyethylene glycol before colonoscopy: a meta-analysis of randomized controlled trials. *Gastrointest Endosc* 2011;73:1240–1245.
  42. Kim J, Kim HG, Kim KO, et al. Clinical comparison of low-volume agents (oral sulfate solution and sodium picosulfate with magnesium citrate) for bowel preparation: the EASE study. *Intest Res* 2019;17:413–418.
  43. Shin SH, Kwon KA. Oral sulfate solution is as effective as 2 L polyethylene glycol plus ascorbic acid. *Clin Endosc* 2020;53:503–504.
  44. Hassan C, Bretthauer M, Kaminski MF, et al. Bowel preparation for colonoscopy: European Society of Gastrointestinal Endoscopy (ESGE) guideline. *Endoscopy* 2013;45:142–150.
  45. Woo DH, Kim KO, Jeong DE, et al. Prospective analysis of factors associated with inadequate bowel preparation for colonoscopy in actual clinical practice. *Intest Res* 2018;16:293–298.
  46. Lee TJ, Rutter MD, Blanks RG, et al. Colonoscopy quality measures: experience from the NHS Bowel Cancer Screening Programme. *Gut* 2012;61:1050–1057.
  47. Baxter NN, Sutradhar R, Forbes SS, et al. Analysis of administrative data finds endoscopist quality measures associated with postcolonoscopy colorectal cancer. *Gastroenterology* 2011;140:65–72.
  48. Rex DK, Chen SC, Overhiser AJ. Colonoscopy technique in consecu-

- tive patients referred for prior incomplete colonoscopy. *Clin Gastroenterol Hepatol* 2007;5:879–883.
49. Park SH, Hong KI, Park HC, et al. Colon polyp detection in primary health care institutions of Korea: detection rate and issues with following the guidelines. *Korean J Gastroenterol* 2021;78:328–336.
  50. Kim DH, Lee SY, Choi KS, et al. The usefulness of colonoscopy as a screening test for detecting colorectal polyps. *Hepatogastroenterology* 2007;54:2240–2242.
  51. Choi JH, Cha JM, Yoon JY, et al. The current capacity and quality of colonoscopy in Korea. *Intest Res* 2019;17:119–126.
  52. Bretthauer M, Kaminski MF, Loberg M, et al. Population-based colonoscopy screening for colorectal cancer: a randomized clinical trial. *JAMA Intern Med* 2016;176:894–902.
  53. Yoon JY, Cha JM, Jeon YT, et al. Quality is the key for emerging issues of population-based colonoscopy screening. *Intest Res* 2018;16:48–54.