



OPEN ACCESS

# Expert opinions and scientific evidence for colonoscopy key performance indicators

Colin J Rees,<sup>1</sup> Roisin Bevan,<sup>2</sup> Katharina Zimmermann-Fraedrich,<sup>3</sup> Matthew D Rutter,<sup>2</sup> Douglas Rex,<sup>4</sup> Evelien Dekker,<sup>5</sup> Thierry Ponchon,<sup>6</sup> Michael Bretthauer,<sup>7</sup> Jaroslaw Regula,<sup>8</sup> Brian Saunders,<sup>9</sup> Cesare Hassan,<sup>10</sup> Michael J Bourke,<sup>11</sup> Thomas Rösch<sup>3</sup>

► Additional material is published online only. To view please visit the journal online (<http://dx.doi.org/10.1136/gutjnl-2016-312043>).

For numbered affiliations see end of article.

## Correspondence to

Professor Colin J Rees, Department of Gastroenterology, South Tyneside District Hospital, South Shields NE34 0PL, UK; [colin.rees@stft.nhs.uk](mailto:colin.rees@stft.nhs.uk)

Received 12 April 2016

Revised 8 September 2016

Accepted 11 September 2016

Published Online First

8 October 2016

## ABSTRACT

Colonoscopy is a widely performed procedure with procedural volumes increasing annually throughout the world. Many procedures are now performed as part of colorectal cancer screening programmes. Colonoscopy should be of high quality and measures of this quality should be evidence based. New UK key performance indicators and quality assurance standards have been developed by a working group with consensus agreement on each standard reached. This paper reviews the scientific basis for each of the quality measures published in the UK standards.

## INTRODUCTION

Colonoscopy is a widely performed procedure for patients with lower GI symptoms and is an integral part of all colorectal cancer (CRC) screening programmes, either primarily or secondarily following positive stool tests or other colonic imaging. There is evidence from randomised trials that faecal occult blood tests (guaiac faecal occult blood testing (FOBT)) and sigmoidoscopy<sup>1–4</sup> reduce CRC mortality in screening, but there is currently no evidence from randomised trials for screening colonoscopy.<sup>5–7</sup> Results from trials are expected in the 2020s.

It is fundamentally important that colonoscopy procedures are of the highest possible quality and that measures of quality are based upon evidence. Widely used quality measures include caecal intubation and adenoma detection rates (ADR) and these should be evaluated alongside other measures of quality. New UK key performance indicators (KPI) and quality assurance (QA) standards for colonoscopy have been developed by the British Society of Gastroenterology (BSG), the Joint Advisory Group for GI Endoscopy and the Association of Coloproctology of Great Britain and Ireland and are published in this edition of *Gut*.<sup>8</sup> The evidence presented in this review paper is taken from the development of these guidelines and from data review performed for the recently published German guidelines on quality standards in GI endoscopy.<sup>9</sup> While colonoscopy is crucial in the detection and prevention of CRC, this will only be the case if procedures are performed to high standards. In the UK, a 2012 national audit<sup>10</sup> demonstrated a significant improvement in colonoscopy completion rates when compared with a previous 1999 audit, it also showed that wide variation still existed between centres and endoscopists.<sup>10 11</sup>

While colonoscopy can detect CRC and prevent it by removal of adenomas,<sup>12</sup> it can also lead to serious complications and quality measures should ensure that these are minimised.<sup>13–16</sup> Additionally, poor quality colonoscopy is associated with increased rates of interval cancers.<sup>17 18</sup> A major challenge is to deliver high quality colonoscopy in the setting of ever-increasing demand and activity. England has seen a 20% increase in colonoscopy activity over the last 5 years with 360 000 procedures performed annually.<sup>19</sup> In the USA, 14 million colonoscopies are performed per year,<sup>20</sup> with a significant percentage being primary screening colonoscopies as opposed to colonoscopies performed after positive FOBT screening in countries such as in the UK. Added pressures of new screening programmes have involved a significant increase in workload in the UK and throughout the world.<sup>1 21 22</sup>

A major variable for assessing quality of all colonoscopy is the rate of interval cancers. For screening colonoscopy this is the most important marker of quality. Interval cancers may occur in individuals screened by another modality such as FOBT, therefore in order to differentiate interval cancers in patients who have undergone colonoscopy and those screened by another means, the term postcolonoscopy colorectal cancer (PCCRC) has been developed.<sup>23</sup> PCCRC rates will become the gold standard in studies assessing surrogate quality variables such as ADR (the rate of procedures where at least one adenoma was detected). The term PCCRC has been used in this review where that is the measure reported in a study but the term interval cancer has been used where the data do not specifically report postprocedural cancers.

## METHODS

In this paper, we review the importance of each of the UK KPI and QA standards and the evidence behind them. The aim of this paper is to provide supporting evidence for these new indicators and standards, and to demonstrate the value and importance of each of the measures. Each measure is addressed in turn including caecal intubation rate (CIR), ADR, bowel preparation, rectal retroflexion, withdrawal time, sedation practice and comfort levels, annual procedure volumes, polyp retrieval rate (PRR), management of suspected malignant lesions including tattooing of lesions, follow-up recommendations and adherence, diagnostic biopsy rate, PCCRC rate and adverse event rates.



CrossMark

**To cite:** Rees CJ, Bevan R, Zimmermann-Fraedrich K, et al. *Gut* 2016;**65**:2045–2060.

It should be borne in mind that much of the data on colonoscopy quality have been derived from the screening setting, and may not be automatically transferrable to diagnostic colonoscopy. The UK standards<sup>8</sup> were developed by a working group where individuals were tasked with reviewing evidence in each area and then standards agreed by consensus of all working group stakeholders. The balance was often struck between available evidence and expert opinion and pragmatism. The German standards<sup>9</sup> were also developed by a working group forming a consensus on the standards.

It is important that a systematic approach is developed regarding the implementation and monitoring of standards. Endoscopy programmes and units have the responsibility for QA and they should develop QA strategies for investigating and monitoring potential underperformance. Graphical representation, for example in the form of funnel plots,<sup>24</sup> allows evaluation of performance around a mean and helps measure performance where the numbers of procedures vary and where some individuals may be performing low numbers of procedures. Where performance appears to fall below agreed standards then investigation should ensure that confounders such as case mix, age and gender of patients are taken into consideration. In addition, the nature of procedures should be considered, for example, complications maybe higher where advanced therapy is undertaken. Monitoring of quality should be a continuous process and early identification of deteriorating performance prior to individuals falling below lower confidence limits is preferable. Where true underperformance is identified, however, strategies to address this should be put in place.

## THE STANDARDS

### Caecal intubation rate

CIR is the most frequently used indicator of colonoscopy quality.<sup>25–28</sup> It is self-evident that complete examination of the large bowel is essential to detect abnormalities,<sup>29–30</sup> however, CIR varies as demonstrated in a number of studies.<sup>11–31–32</sup> Although CRCs are more commonly found in the distal colon (61.5%), 32.7% were found proximal to the splenic flexure, with 15% identified in the caecum or appendix, highlighting the need for complete examination of the colon.<sup>33</sup> Previous work has demonstrated higher PCCRC rates in endoscopists with a lower CIR,<sup>34</sup> and in colonoscopies which were incomplete.<sup>35</sup> PCCRCs were more commonly identified in the right side of the colon.<sup>35</sup> A Canadian database analysis of 1260 PCCRCs showed that endoscopists with high caecal intubation rates and those with higher polypectomy rates had significantly lower rates of PCCRC during follow-up.<sup>34</sup> On the other hand, there is limited evidence with respect to the correlation of caecal intubation and ADR with conflicting results reported.<sup>36–37</sup> However, it can be speculated that lower caecal intubation rates and/or insufficient caecal visualisation may be some of the major reasons for the higher rate of proximal PCCRCs demonstrated in several studies (see online supplementary table S1).

A 2011 UK audit of all colonoscopies performed in a 2 week period demonstrated an unadjusted CIR of 92.3%, rising to 95.8% following adjustment for impassable strictures and poor bowel preparation.<sup>10</sup> This was a significant improvement from a previous audit in 1999, which demonstrated a CIR of 76.9%.<sup>11</sup> This improvement was achieved following introduction of a national training programme and a national emphasis on improving quality. These improvements are also demonstrated elsewhere in the UK in both general endoscopy units and within the Bowel Cancer Screening Programme (BCSP), with unadjusted CIR of 92.5%<sup>38</sup> and 95.2%,<sup>36</sup> respectively. These

large series demonstrate that caecal intubation rates >90% can be readily achieved. The American Society for GI Endoscopy (ASGE)/American College of Gastroenterology (ACG) taskforce for colonoscopy sets a similar standard for diagnostic procedures.<sup>28</sup> A CIR of 95% is recommended by the European Society of GI Endoscopy (ESGE) and the ASGE/ACG for screening colonoscopies.<sup>28–39</sup> Reporting of caecal intubation rates may be presented in a non-adjusted form based upon CIR in all patients where the intention was to reach the caecum, or be adjusted for factors such as impassable strictures and poor bowel preparation. Different studies adjust for different factors and this must be borne in mind when comparing different studies (see online supplementary table S2).<sup>31–32–40–46</sup> It may be assumed that in the screening setting (as opposed to the symptomatic service), a lower rate of poorly prepared colons and strictures will be found, therefore the recommended higher rate for screening versus diagnostic colonoscopy (95% vs 90%) seems to be justified. The European Union (EU) guidelines on the quality of colonoscopy as part of CRC screening demand a minimum CIR of at least 90%, and suggest a rate of 95% is desirable.<sup>23</sup>

Regarding documentation of caecal intubation, the EU guidelines<sup>47</sup> recommend 'auditable photodocumentation of completion', as do American guidelines,<sup>26</sup> but reported practice varies from 50% in the UK<sup>10</sup> to 70%–99% in other parts of Europe.<sup>48–49</sup> The reliability of photodocumentation of the caecum in demonstrating completion has been questioned with ileal photodocumentation advocated as more accurate.<sup>50</sup> Biopsy of the ileum may additionally be useful in confirming completion but can be technically difficult, comes with extra costs and has some associated risks, so it is not recommended as a standard of practice.<sup>51–53</sup>

### Adenoma detection rate

Most CRCs develop through the adenoma-carcinoma sequence.<sup>54</sup> Detection and removal of these adenomas therefore reduces CRC risk. Screening flexible sigmoidoscopy has been repeatedly demonstrated to reduce CRC incidence and mortality,<sup>5</sup> so it is likely that results can be extrapolated to colonoscopy.

The ADR is currently considered the most reliable surrogate marker of PCCRC and is therefore widely used as a marker of colonoscopy quality.<sup>37</sup> A lower ADR is associated with higher rates of PCCRC,<sup>17</sup> as demonstrated by data from the Polish bowel cancer screening programme and a US study. In the Polish study, colonoscopists with an ADR <20% had a hazard ratio (HR) for PCCRC that was 10 times higher than colonoscopists with an ADR ≥20% (absolute risk 0.011% when ADR ≥20% vs 0.115% when ADR <20%).<sup>17</sup> An inverse relationship between ADR and PCCRC rate (and for advanced stage cancer and cancer mortality) has also been demonstrated in a study of over 300 000 screening, surveillance or diagnostic colonoscopies, performed by 136 colonoscopists in the USA.<sup>18</sup> Each 1% increase in ADR was associated with a 3% decrease in the risk of PCCRC. The latter study suggested that there may be no upper cut-off limit for ADR, but elements of that study should be considered. The study was based on a medical insurance database (Kaiser Permanente) and included both screening and diagnostic colonoscopies. Follow-up information from the insurance database was available in only 2/3 of cases and the range of average number of annual colonoscopies per examiner included was wide (27–461), with those undertaking low numbers included. This raises the question as to whether all colonoscopies per examiner were available for the analysis, or whether some endoscopists had also performed examinations for other

insurance providers. It is therefore possible that the ADR in the Kaiser-Permanente database may not completely reflect endoscopists' true ADR.

Both the Polish and US paper are based upon ADR. Other measures of adenoma detection may also be important, for example, the rate of advanced adenoma detection (AADR, those adenomas  $\geq 10$  mm in size, or with villous components or high-grade dysplasia),<sup>55</sup> as advanced adenomas may be more relevant for cancer prevention if detected and removed. The correlation of ADR with AADR seems to yield variable results; a US study including 1933 colonoscopies from 14 colonoscopists showed substantial variations in both ADR and AADR, but no correlation between them.<sup>55</sup> It may well be that a high ADR mainly reflects a high detection rate of mainly small and potentially innocuous adenomas, as recently shown by an analysis of a continuing ADR rise over the years within the German screening programme.<sup>56</sup> The role of sessile serrated polyps (SSP) as precursors for CRC is an area of growing knowledge and importance and as evidence for their incidence becomes more robust.<sup>57</sup> In the future, it may be important to consider the detection of SSPs as a marker of quality.

While ADR is clearly important, variations on this measure of number of adenomas detected may also be developed to gain further insight into colonoscopy quality. ADR reflects the findings of at least one adenoma in an individual but it does not measure the number of adenomas detected in a given individual and it is important that all the adenomas within that individual are found. Mean adenomas per procedure (MAP, the total number of adenomas detected divided by the total number of procedures) and mean adenomas per positive procedures (MAP +, the total number of adenomas detected divided by the number of procedures with at least one adenoma detected) were calculated for 36 000 colonoscopies performed by 177 colonoscopists within the BCSP<sup>36</sup> and demonstrated that some endoscopists detect more adenomas on average per procedure. These quality measures may be a better representation of the performance of an individual in detecting adenomas and may be valuable if used as a feedback measure to allow endoscopists to evaluate their own practice, however, clear correlation with PCCRC rates are not yet available.

One drawback of measuring ADR is that it is dependent on obtaining histology results following the procedure. This requires interrogation of pathology databases to obtain polyp histology, which can be time consuming. The polyp detection rate (PDR) is often simpler to obtain as most electronic endoscopy reporting software calculates it automatically. The relationship between the ADR and PDR has been studied both in the UK and the USA, in screening and symptomatic populations,<sup>58–60</sup> and PDR has been demonstrated to reliably estimate the ADR. ADR is the key performance measure but where it can be demonstrated that a ratio between an endoscopist's PDR and ADR has been developed and validated, then PDR may be an acceptable marker, with ongoing review of the validity of PDR to represent ADR required. However, it should be noted that PDR can be manipulated by endoscopists more easily than ADR. Polypectomy rate may be more reliable than PDR and less susceptible to gaming, and higher polypectomy rates have been shown to correlate with lower proximal PCCRC rates.<sup>34</sup>

ADR varies between observers, centres, cohorts of patients and even within procedures on the same person. One systematic review looked at six studies in which participants underwent tandem (same day) colonoscopies.<sup>61</sup> Miss rates for all polyps and adenomas were 21% and 22%, respectively. A recent UK study demonstrated wide variation in ADR with a global ADR

of 15.9%,<sup>24</sup> although this study included patients of all ages and only those colonoscoped for symptoms (most commonly diarrhoea, iron deficiency anaemia and rectal bleeding). An overview of studies focusing on the factors influencing ADR is shown in online supplementary table S3.<sup>40 43 62–68</sup>

ADR measurements and comparisons are most relevant in screening populations, where the reason for the procedure is consistent and allows for the age of the screening population and the screening modality used. It should be remembered that expected ADR will differ between primary colonoscopy screening, colonoscopy after positive FOBT or faecal immunochemical test (FIT) and colonoscopy within the symptomatic population. ADR may vary for other indications with an overview given in online supplementary table S4.<sup>69–81</sup> It is important that these are considered when setting a standard.

Many methods to attempt to improve ADR have been developed. These include training, endoscopic devices, medication, position change and non-procedural aspects such as scheduling. Detailed discussion of these measures is beyond the scope of this review paper, however, we have provided a brief summary of these methods.

**Training:** A randomised controlled trial (RCT) in Poland revealed that dedicated training of screening centre leaders has led to a sustained effect on colonoscopy performance among leaders themselves and members of the unit as measured by ADR, proximal ADR and non-polypoid lesion detection rate.<sup>82</sup>

**Colonoscopy factors (high definition colonoscopes, image processing):** The use of high definition colonoscopes does not seem to result in increased ADR.<sup>83–89</sup> One cohort study demonstrated an increase in the number of non-flat polyps  $>6$  mm in size when high definition colonoscopes were used.<sup>84</sup> Another study suggested a 4.5% increase in ADR, but this retrospective review did not adjust for confounding factors.<sup>90</sup> Image processing ('virtual chromoendoscopy', where narrow spectra of light are isolated to enhance mucosal visualisation, or postcapture treatment of the image) is incorporated in modern endoscopes such as narrow band imaging (NBI)<sup>91–96</sup> or Fujinon intelligent chromoendoscopy,<sup>94</sup> or both,<sup>97</sup> or autofluorescence imaging (AFI). Some smaller studies have reported positive results,<sup>98 99</sup> but these findings were not confirmed by others,<sup>100</sup> and a Cochrane review of NBI found no evidence for an improvement in ADR over standard endoscopy.<sup>93</sup> For AFI, no large RCTs are yet available. Widening and altering the angle of view has been studied. No improvement was seen with moderate increases from 140° to 170°, but may be demonstrated with colonoscopes with forward plus side viewing optics. Retroflexion of the scope in the colonic lumen, mostly in the proximal colon, increased ADR or decreased adenoma miss rate by 2%–4.5% in most,<sup>101–103</sup> but not all, studies.<sup>104</sup> It is not superior to tandem examination of the right colon,<sup>105 106</sup> which may be an alternative to be discussed.

**Chromoendoscopy:** Whether, as stated in the most recent and largest meta-analysis,<sup>94</sup> conventional chromoendoscopy really has a positive effect on ADR remains doubtful, since this mostly refers to small adenomas, and two of the nine studies analysed were in the setting of IBD. Adding stains to colon preparation fluids, or the administration of oral methylene blue tablets is currently under investigation.<sup>107</sup>

**Antispasmodics:** Antispasmodic medications such as hyoscine butylbromide and glucagon have been used to improve mucosal views during colonoscopy by reducing the spasm of the colon. They have been shown to improve ease of insertion<sup>108</sup> and ileal intubation rates.<sup>109 110</sup> However, in terms of ADR, a consistent increase when antispasmodics are used has not been demonstrated in three meta-analyses.<sup>111–113</sup>

**Position change:** Changing patient position seems to slightly increase ADR,<sup>114</sup> especially if colonoscopy is difficult<sup>115–116</sup>; however again, results vary, with one recent randomised trial suggesting no improvement,<sup>117</sup> one suggesting an improvement in ADR distal to the hepatic flexure<sup>118</sup> and another suggesting that examining the right side of the colon in the left lateral position significantly improved ADR in the right colon.<sup>119</sup>

**Mechanical methods:** Methods such as the use of transparent caps or a balloon around the endoscope tip have been tested in numerous trials. Simple short (3–4 mm) caps at the colonoscope tip were not shown to increase ADR as demonstrated in all but one of six meta-analyses.<sup>94 120–123</sup> A Cochrane review concluded that while PDRs were increased with cap usage, there was not enough evidence for an increase in ADR.<sup>121</sup> Newer and longer caps with side flanges (such as the Endocuff, ARC Medical) increased ADR in two subsequent studies from the same group<sup>124 125</sup>; however, an RCT has shown an increase in the number of adenomas detected, but not in the overall ADR or MAP.<sup>126</sup> A transparent balloon around the colonoscope tip (NaviAid G-EYE) reduced adenoma miss rate in a small tandem study (n=126).<sup>127 128</sup> The so-called third eye endoscope (retrograde view via a small 'baby' endoscope introduced through the working channel) also increased ADR in a back-to-back study,<sup>129–131</sup> but is not in common usage.

**Scheduling:** Some studies suggest ADR is higher in morning procedures than in afternoon colonoscopies,<sup>132–134</sup> but this is not backed up by other studies.<sup>135–137</sup> No variation between weekdays is demonstrated.<sup>138</sup> In part, this is likely partially related to the bowel preparation quality.<sup>139</sup>

## Bowel preparation

Good quality bowel preparation is required in order to perform high quality colonoscopy. Poor preparation has been associated with incomplete tests,<sup>140</sup> prolonged procedure time<sup>141</sup> and with reduced yield.<sup>142</sup> Evidence in the UK from the national colonoscopy audit<sup>10</sup> showed that 22% of failed colonoscopies were due to poor bowel preparation. While no significant difference in large polyps (those >9 mm in size) and cancer detection has been demonstrated related to bowel preparation, a significant difference in detection of smaller polyps and flat lesions has been demonstrated.<sup>143</sup> PCCRC rates have been suggested to be higher in those with inadequate bowel preparation,<sup>144</sup> although this may be multifactorial.

A number of different scoring systems for bowel preparation are used making comparison difficult. At least five validated bowel preparation scales exist<sup>128 145–148</sup>; all involve relatively complex scoring systems and not all are in common usage. The UK BCSP uses a 4-point scale: excellent, adequate, complete despite poor preparation or failed due to poor preparation.<sup>149</sup> The ASGE guidelines do not suggest a preferred system for grading bowel preparation, and the ASGE guidance for screening colonoscopy does not recommend a specific system, but suggests that one system should be used across all providers in order to standardise reporting.<sup>39</sup> It is also important to be clear at what point a score is given. Ideally, it should be given following attempts to clean the colon with washing and suction via the colonoscope.

Although scales have a number of levels, the only consistent differences found in diagnostic rates were between preparation rated as good or poor. Little additional benefit of multiple point scales were found with no additional ADR differences between excellent, good and moderate bowel preparation scores.<sup>62 66 141 150 151</sup> The most widely used scale, the Boston Bowel Preparation Scale,<sup>147 152</sup> demonstrated a correlation with ADR where preparation was rated as perfect,<sup>153</sup> although this

was not confirmed in another recent study.<sup>154</sup> No studies directly correlating preparation with PCCRC are available.

Despite the above limitations of scoring systems, it is self-evident that optimal bowel preparation contributes to the success of colonoscopy. Repeat procedures involve the waste of clinical resources as well as increasing risk and inconvenience to patients. The optimum bowel cleansing preparation should be effective, tolerable for the patient and be safe, without causing excessive shifts in electrolytes or water, and not affecting patient concomitant medication. It should also be safe for people with comorbidities. Multiple different regimens exist, with varying timings, volumes and preparation constituents. The lowest volume (and therefore often better tolerated) preparations contain sodium phosphate, but can cause electrolyte disturbances and as such are not suitable for patients with comorbidities. Fewer side effects are caused by polyethylene glycol (PEG) preparations, but large volumes (up to 4 L) are required, making the preparation less tolerable for patients. Different bowel preparation methods are reviewed in a recent American consensus document.<sup>155</sup> Furthermore, the type and timing of the bowel cleansing agent is an important contributor to the quality of the bowel preparation; however, given the lack of evidence of one superior agent,<sup>39</sup> units should select their preferred agent based on local experience and any existing guidance from gastroenterology bodies (such as the BSG guidance on bowel preparation).<sup>156</sup>

An overview of the studies examining the correlation of bowel cleanliness and colonoscopy quality parameters is given in online supplementary table S5.<sup>11 31 62 66 73 141 147 150 151 153 157 158</sup>

## Rectal examination and rectal retroflexion

Digital rectal examination (DRE) is recommended as a standard part of endoscopic examination of the lower GI tract. It allows examination of the anal canal and lower rectum for pathology, as well as preparing the anal canal for the insertion of the scope.<sup>159</sup> Anal pain or sphincter spasm may occasionally mean that it is difficult to perform a DRE; this may lead to consideration of the use of topical anaesthesia and a narrow scope. A comparison of DRE and rectal retroflexion showed that DRE was sensitive for detection of abnormalities in the lower rectum and upper anal canal that were subsequently demonstrated on retroflexion of the endoscope,<sup>160</sup> therefore, it should be routinely undertaken.

Retroflexion of the colonoscope in the rectum has long been recommended as a technique to allow adequate visualisation of the lower rectum and upper anal canal.<sup>159</sup> A number of studies have demonstrated increased detection of pathology by using retroflexion after standard views of the rectum have been obtained. Older studies of variable size (from n=75 to 1502, total 3600 patients), showed an increased detection rate of between 0.3% and 2% for adenomas.<sup>161–164</sup> Serious rectal injuries related to retroflexion leading to haemorrhage and perforation have infrequently been reported in the literature, mostly as case reports.<sup>89 165–169</sup> One large study of nearly 40 000 colonoscopies addressed this issue.<sup>168</sup> With four rectal perforations in the study group they estimate the risk to be 0.01%. Of these, three were successfully managed conservatively and one required surgical intervention. The risks and benefits of rectal retroflexion should be carefully considered. While the technique leads to an increased yield, it is not without risk. Therefore, it is essential that careful attention is paid to good technique and if resistance is encountered then the endoscopist should carefully consider the reasons for this and have a low threshold for discontinuing the retroflexion. If retroflexion is aborted then

careful antegrade inspection should be performed down to the dentate line.

### Withdrawal time

Most mucosal inspection takes place during withdrawal of the endoscope from the caecum to the rectum and there is an association between ADR and colonoscopy withdrawal time (CWT)—that is, the length of time taken to remove the colonoscope once the caecum or terminal ileum has been reached. The CWT is calculated for each colonoscopist using cases where the investigation was normal (in order to remove the time taken to undertake therapy) then comparing it with ADR in all cases. Initial work demonstrated that a CWT of >6 min was associated with higher ADR,<sup>170</sup> and more recently longer times of 7 or 8 min have been advocated.<sup>171 172</sup> In a review of over 30 000 colonoscopies performed in an FOBT-positive screening population in the UK, a CWT of up to 11 min was associated with a higher ADR with no additional benefit beyond 11 min (ADR 43% with withdrawal 6 min or less, and 46.5% if >10 min).<sup>173</sup>

The relationship between CWT and ADR is likely to be complex, as not all studies support the increasing ADR with lengthening CWT.<sup>174 175</sup> Multiple factors are likely to be responsible for the superior ADR seen with longer CWT, such as time being taken to fully clean and inspect all folds and flexures,<sup>176</sup> suction pools of liquid and employ position changes<sup>144</sup> in order to optimise mucosal views. It should be noted that in at least some of the publications the analysis was retrospective. Prospective studies may allow for calculation of withdrawal time in all cases by stopping the clock for polypectomy, biopsy and other therapy.<sup>177</sup> Increasing CWT has led to conflicting results with regard to an increase in ADR.<sup>171 175</sup> A study in Berlin showed no relation between withdrawal time and ADR, but the range of CWT (6–11 min) was already above the 6 min proposed.<sup>62</sup> Other analyses from Norway and England showed that, using different cut-offs, longer withdrawal times led to higher ADR.<sup>67 173 174</sup> To recommend a specific cut-off such as 6 min is therefore only partially based on good scientific evidence. It may be for this reason that the recent EU guidelines have not published a specific withdrawal time recommendation.<sup>23</sup> The important issue remains that adequate time is taken for mucosal visualisation. It is unlikely that this can be achieved in <6 min, and will sometimes take considerably longer particularly if adequate mucosal views are difficult to achieve for example, with residual colonic fluid. CWT is a surrogate marker for ADR which, as has been outlined, is a surrogate marker for PCCRC; therefore, it is the effect of CWT on ADR that is more important than the CWT itself. An overview of the relevant studies is given in online supplementary table S6.<sup>62 67 170–182</sup>

### Sedation practice and comfort levels

Sedation practice varies across centres and countries. The US and Australian practice tends towards deeper sedation (often using propofol), whereas across Europe, Asia and Africa sedation practice varies widely.<sup>183</sup> In the UK, the majority of colonoscopies are performed under conscious sedation (89%), with 10% unsedated, and <1% under propofol or general anaesthesia.<sup>10</sup> In the UK, propofol sedation may only be administered by an anaesthetist<sup>184</sup> and these logistics may limit its use. Elsewhere, propofol may be administered by the endoscopist, or by an anaesthetic technician. In Germany, a large study of almost 10 000 cases demonstrated low complication rates of propofol-supported colonoscopy (0.03% mask ventilation due to apnoea, 0.39% minor hypoxaemia (oxygen saturation <90%), 0.07% bradycardia, 0.24% hypotension, 0.03%

perforation and 0.12% bleeding) and as such was felt to be safe and cost-effective.<sup>185</sup> However, a US cohort study demonstrated overall increased risk of complications after colonoscopy when anaesthesia was used, specifically with increased risk of perforation, bleeding, abdominal pain and complications of anaesthesia.<sup>186</sup> Safety recommendations for sedation dosages exist in some countries,<sup>184 187</sup> and the ESGE have produced a guideline on the use of propofol.<sup>188</sup>

The approach to sedation may have a strong cultural basis and maybe related to both patients' expectation and clinicians' usual practice. In some countries including Norway, unsedated colonoscopy is the practice in selected centres for >50% of cases. This can be achieved by good training and is well accepted by clinicians and patients.<sup>189</sup>

Sedation practice should be considered alongside comfort, as reduced sedation levels should not be at the expense of patient experience. Comfort levels are affected by many factors including technique and some evidence suggests that endoscopists performing better on other KPI also provide a more comfortable patient experience with less sedation.<sup>190</sup> A national audit<sup>10</sup> demonstrated that moderate or severe discomfort was experienced by approximately 10% of 20 000 cases recorded. Factors known to influence patient comfort include<sup>191</sup> diverticular disease; prior hysterectomy; when colonoscopy was preceded by gastroscopy; female sex; anxiety; irritable bowel and where discomfort was anticipated.

Several systems for scoring patient comfort exist, such as the Gloucester nurse-reported 5-point scale,<sup>190</sup> which combines features of pain, frequency of pain and distress. Patient-reported comfort scores use either 4-point Likert scales or 100 mm visual analogue scales in lightly or unsedated patients.<sup>191</sup> Validation of scores is variable. One well-validated score exists: the Nurse Assessed Patient Comfort Score, an international study<sup>192</sup> in which 300 patients undergoing colonoscopy and their endoscopy nurses rated comfort levels. Even in this validated scoring system, there was discrepancy between the patient-reported levels of comfort and the clinician-reported levels, with lower levels of comfort reported by patients. This has been demonstrated in other studies,<sup>193</sup> and as yet, no patient-derived, validated measures of patient experience of endoscopy exist. It is becoming increasingly recognised that patient experience needs to be optimised primarily to make the procedures tolerable for patients, but also to ensure that procedures are complete, and to optimise attendance for screening and surveillance procedures.<sup>194–196</sup> It should be mentioned that data on the influence of sedation on ADR are not homogeneous, but most to date do not show any correlation.<sup>197–200</sup>

The method used to distend the colon may influence patient comfort during and after colonoscopy. Use of CO<sub>2</sub> to insufflate the colon has been studied extensively and repeatedly demonstrated to improve patient comfort.<sup>39</sup> There are few subjects researched in endoscopy research where agreement is repeatedly reached in all randomised trials regardless of country and settings,<sup>201 202</sup> but the method used to distend the bowel is one such subject. The main effect is on abdominal pain experienced on the day of colonoscopy; this is summarised in three meta-analyses.<sup>203–205</sup> Possible restrictions of CO<sub>2</sub> use in patients with chronic obstructive pulmonary disease (COPD) are not well studied, and capnographic measurements in patients without COPD did not show significant CO<sub>2</sub> increases.<sup>206–208</sup> A Japanese study on colorectal endoscopic submucosal dissection (ESD) in 77 patients with COPD could not detect any differences versus controls.<sup>209</sup> Water-aided colonoscopy (either with water immersion or water exchange) has also been demonstrated

to significantly reduce pain levels when compared with air insufflation.<sup>210</sup>

### Number of colonoscopies performed per year

Competency may be affected by the learning curve of colonoscopy, ongoing number of procedures and lifetime experience. There is considerably more literature on acquisition of competency and the learning curve than on minimal numbers for established practitioners. The most usually studied marker of trainee competency is CIR. In the UK, 200 colonoscopies are currently required before provisional competency can be assessed and 300 procedures for full competency,<sup>211</sup> compared with 140 for colorectal surgery and gastroenterology trainees in the USA.<sup>212</sup> A recent study<sup>213</sup> demonstrated that competency (based on a CIR of 90%) was reached by 233 procedures. Other studies suggest similar procedure numbers required to reach competency, with figures between 150 and 600 reported<sup>214–222</sup>; the data are summarised in a recent review.<sup>221</sup> A study from Harvard showed ADR increases between 50 and 100 colonoscopies, with no further rise thereafter.<sup>180</sup> Similarly, another study observing 11 fellows demonstrated increases in CIR and a decrease of examination times between years 1 and 3, but no change in ADR between years of training.<sup>220</sup> It could be speculated that endoscopists in training may be more attentive,<sup>223</sup> with possibly a shorter learning curve for adenoma detection. In a small study in the Netherlands, it was demonstrated that ADR during training varied widely and correlated to ADR when the individual became a consultant.<sup>224</sup>

Maintaining competence requires ongoing experience, but is much less well studied. It has been suggested that at least 100 procedures per year is the minimum required,<sup>155 225</sup> with some suggesting an even higher volume of 200–300 may be necessary.<sup>225</sup> Other markers of competence such as ADR do not appear to correlate well with procedural numbers.<sup>62</sup> In general, training studies mostly use CIR, however, studies on maintenance of competence have explored ADR.

It is likely that prior experience and annual case volume may be complementary at least with regard to ADR as a quality parameter. A US study showed that for endoscopists with experience of up to 5 years, case volume was correlated with ADR (92.5% for >200 vs 88.5% for <200 annual colonoscopies), while this effect could not be shown in endoscopists with longer colonoscopy practice and experience.<sup>225</sup> Another study showed the highest ADR in the middle groups of case number quintiles as compared with colleagues with very few or many colonoscopies.<sup>226</sup> A study from Berlin showed no influence of case volume on ADR.<sup>62</sup> With regard to colonoscopy completeness, online supplementary table S3 shows that results vary with case volume demonstrating no,<sup>32</sup> a positive,<sup>46</sup> or even a negative influence.<sup>43</sup> In one Canadian study, case volume was correlated with complication rates,<sup>16</sup> which were increased in physicians with very low case volumes.

The current EU guidelines on quality of CRC screening set the cut-off for annual colonoscopy volume at 300.<sup>23</sup> However, this number can be debated with differing programmes proposing different levels. The correlation of case numbers and complication rates stems from two Canadian studies<sup>16 227</sup>; one was a databank analysis of 97 091 outpatient colonoscopies from several Canadian provinces, which did not distinguish between diagnostic and therapeutic colonoscopy for which bleeding and perforation rates may be quite different.<sup>16</sup> The second study was a retrospective data analysis of 24 509 examinations including 13% undergoing sigmoidoscopy. Endoscopists with annual case volume <200 procedures had twice the complication rate. This

study did not include a multivariate analysis.<sup>227</sup> Agreement on the exact minimal numbers per year can be debated and in the UK a minimum of 100 procedures per annum has been agreed.

### Polyp removal, retrieval and histological analysis

After a polyp has been removed, it is currently necessary to retrieve it for histological assessment. Polyps  $\geq 1$  cm diameter have an increased probability of advanced features (high-grade dysplasia, villous components or cancer).<sup>228</sup> Polyps <1 cm less frequently (but still potentially)<sup>54</sup> contain these features, and do still require retrieval. Histology of polyps is used to calculate surveillance intervals based on adenoma numbers<sup>229–231</sup> and in some countries numbers of serrated polyps. Polyp retrieval is also considered a reflection of the technical skill and application of the colonoscopist. Studies have shown no difference in the success rates of methods of polyp retrieval (eg, suction,<sup>232</sup> Roth nets<sup>233</sup>) with some techniques limited by polyp size. The recommended PRRs are  $\geq 90\%$  in the UK and  $\geq 95\%$  in the USA.<sup>26 234 235</sup>

In the future, endoscopic visual assessment of polyps in vivo using enhanced imaging modalities may allow accurate optical identification of adenomatous polyps, which then will not require histological review, reducing histopathology workload.<sup>236</sup> This so-called Detect InSpect Characterise Resect And Discard (DISCARD) strategy—mainly for polyps  $\leq 5$  mm—has been summarised in multiple reviews and meta-analyses,<sup>237–241</sup> and in a recent ASGE recommendation update.<sup>242</sup> This review shows that almost all endoscopic techniques seem to reach high accuracy rates in endoscopic polyp differential diagnosis, mainly based on studies from expert centres.<sup>86 243 244</sup> The Preservation and Incorporation of Valuable Endoscopic Innovations (PIVI) statement issued by the ASGE has issued advice on acceptable performance thresholds for real-time endoscopic assessment of diminutive polyps required before optical diagnosis should be recommended for routine clinical practice.<sup>245</sup> The PIVI statement advises that optical diagnosis can be used for diminutive (1–5 mm) and histological diagnosis for small (6–9 mm) polyps and those summated results used to determine surveillance. Under routine conditions in non-expert centres, such a differential diagnosis does not seem to work,<sup>204 244 246 247</sup> as recently confirmed in a large multicentre UK trial, which indicated that a DISCARD policy was not yet generalisable to routine clinical settings.<sup>248</sup> A further difficulty for polyp differential diagnosis is the increasing focus on sessile serrated adenomas (SSA).<sup>249–251</sup> Their endoscopic detection and histopathological confirmation varies considerably, particularly with regard to the differential between SSA and hyperplastic polyps,<sup>252 253</sup> with substantial rates of reclassification of hyperplastic polyps as SSA on second opinion.<sup>249 254–256</sup> There is also substantial interobserver variability in the histological diagnosis.<sup>249 257 258</sup> New endoscopic assessments<sup>259</sup> and classifications are underway.<sup>260</sup> Given this evidence, further work is required to define the role of a DISCARD strategy in routine clinical practice.

Completeness of resection is another potential quality indicator that would require both endoscopic and histopathological data. Since several factors impede a reliable histological assessment (piecemeal resection by forceps or snare, damage from thermal therapy), this has not been introduced into routine quality parameters. Endoscopic visual assessment of completeness of resection is often said to need improvement.<sup>261</sup>

### Management of suspected malignant lesions and those not suitable for endoscopic resection

As polyps increase in size the risk that they harbour cancer increases, with malignant change found in 2.2%, 18.7% and

42.7% of polyps of size 6–15 mm, 16–25 mm and 26–35 mm, respectively.<sup>262</sup> Submucosal invasion was found in 7.8% of polyps  $\geq 2$  cm in size on a large meta-analysis,<sup>263</sup> and higher rates of submucosal invasion are found in laterally spreading tumours, particularly the non-granular type.<sup>264</sup> Current UK and American guidelines suggest all polyps  $\geq 2$  cm in size should have a tattoo placed nearby to mark their location. Lesions  $< 2$  cm in diameter should be carefully inspected, and potentially have their site marked if they have high-risk features.<sup>265</sup> This also applies to small, subcentimetre polyps that, as described recently, may also have distinctive malignant features. In such instances, polyps should be resected with care, ensuring completeness using very careful injection technique.<sup>266</sup>

The decision as to whether a lesion is amenable to resection may be influenced by physician interpretation and experience.<sup>267</sup> Polyps may appear unresectable due to features suggesting malignancy or technical factors impeding polypectomy such as location, size and polyp characteristics. Different endoscopists with different skill levels may have different views. Assessment of malignancy is difficult with many endoscopic studies using different classification systems.<sup>103 268–270</sup> There are two major polyp classification systems. The Paris classification<sup>268</sup> is based upon polyp shape and relationship to the surrounding mucosa and reflects the morphology of lesions. The Kudo classification<sup>269</sup> based on the pit pattern on the surface of the polyp is very important in indication of malignancy. The Japanese literature mostly involves the combined assessment of ‘mucosal’ (high-grade dysplastic) and submucosally invasive cancers. There are limited Western data. A large Australian polyp study ( $n=479$ ) identified the following univariate risk factors for invasive cancer: Paris classification 0–IIa+IIc, morphology (non-granular surface) and Kudo pit pattern type V.<sup>271</sup> In this study, 31.8% of the 22 Paris type IIc or IIa+IIc lesions, 15.3% of the 98 non-granular lesions and 56% of the 25 Kudo type V polyps had malignant histology equivalent to invasive cancer; and should serve as a reminder to consider invasive cancer within these lesions.<sup>271</sup> Although not done in this study, Kudo type V is ideally substratified to Vn (may be high-grade dysplasia only) and Vi which is more closely correlated to submucosal invasive disease. The recently developed National Institute for Health and Care Excellence classification, which uses enhanced optical imaging techniques to evaluate lesions, showed high levels of accuracy in predicting submucosal invasion.<sup>272</sup> Studies to date have involved image analysis and not yet *in vivo* endoscopic diagnosis. As such, making a prediction about the presence of invasive malignancy in polyps should be based on an assessment of both polyp morphology (such as the Paris classification) as well as microscopic features (such as pit pattern or NBI vascular pattern). The ‘non-lifting sign’ may indicate the possibility of malignancy and submucosal invasion,<sup>273 274</sup> but not reliably so. It is important to differentiate a true non-lifting sign in a polyp where removal has not been previously attempted as compared with non-lifting related to scarring from previous attempted polypectomy. There may be other technical reasons making benign polyps difficult to resect and the ‘non-lifting sign’<sup>273 275</sup> may again be important,<sup>273 274</sup> indicating expected technical difficulties during resection.<sup>271</sup> The differentiation between technically and clinically meaningful endoscopic resectability of a given colonic polyp therefore rests on the combined macroscopic and possibly histological assessment but evidence varies. Assessment of resectability correlates with the experience of the examiner. It has been shown that some polyps deemed not to be resectable by one endoscopist may be resected when referred to expert centres,<sup>276–281</sup> so automatic referral of these patients to

surgery does not seem to be justified. In these expert centres, around 10% of patients ultimately undergo surgery for different reasons.<sup>282 283</sup> Thus, patients with complex polyps should be assessed in centres with full surgical back up, where a minimally invasive endoscopic resection may still be possible. Use of complex polyp multidisciplinary team meetings for such polyps may be beneficial when deciding upon their management.<sup>267</sup>

A complex question relates to which resection technique should be applied to lesions where there is a suspicion of malignancy and this is also limited by difficulty in endoscopic diagnosis of malignancy. The techniques most widely used are endoscopic mucosal resection (EMR) or en bloc endoscopic submucosal dissection (ESD). Detailed discussion is beyond the scope of this review; however, recent studies show an overall success rate of EMR of over 90%,<sup>271 284</sup> but at the cost of repeated colonoscopies for treating remnant or recurrent lesions. ESD on the other hand appears to be complex and associated with a higher complication rate, with excellent midterm results in studies from the Far East.<sup>285–298</sup> The main limitations of these data are that simple adenomas, adenomas with high-grade dysplasia (often referred to as mucosal cancers) and invasive cancers are mixed together. Separate results for submucosal cancers are only rarely shown in detail, and if so, at least in Western studies, a high rate of secondary surgery is reported.<sup>289 290</sup> Long-term outcomes of patients undergoing endoscopic management of submucosal invasive CRCs are now beginning to emerge. In those with low risk features (negative vertical resection margins, well or moderately differentiated adenocarcinoma, lack of lymphovascular invasion and an invasion depth of  $< 1000 \mu\text{m}$ ), the recurrence rate at 5 years was 0.8% vs 6.6% ( $p < 0.05$ ) in those who lacked these features.<sup>299</sup> It has also been shown that in those with high risk features, the risk of local recurrence was significantly higher in submucosal rectal cancers than in submucosal colon cancers.<sup>300</sup> It is also now known that the risk of lymph node metastasis of T1 cancers is around 10%,<sup>301</sup> and can be predicted by the presence of unfavourable histological findings (lymphatic invasion, budding, submucosal invasion  $\geq 1$  mm and poor histological differentiation).<sup>302</sup> Data such as these will inform decision-making at polyp multidisciplinary team meetings, particularly decisions regarding additional surgery.

Tattooing of the mucosa adjacent to all suspected malignant lesions and resection sites of polyps  $\geq 2$  cm (other than those in the lower rectum and those proximal to the ileocaecal valve where landmarks are clear) allows optimal localisation of lesions for further endoscopic assessment or surgical resection<sup>303</sup> and promotes accurate endoscopic surveillance postpolypectomy. This technique was first described in the 1970s.<sup>304</sup> To minimise the risk of injecting the marker through the mucosal wall into the peritoneum and causing a localised inflammatory reaction,<sup>305 306</sup> a two-step method where a bleb of saline is raised just below the mucosal layer and then indelible marker injected into this fluid should be used.<sup>307</sup> There is however a caveat; regular tattooing of all lesions deemed to be unresectable may make subsequent endoscopic resection (as already discussed in this section) more difficult because of scarring and fibrosis at the base of the lesion, so tattoos should not be placed too close to the lesion.

### Follow-up recommendations and adherence

A number of detailed recommendations for follow-up colonoscopy after polypectomy of adenomas exist. These are based upon the number, size and histology of polyps.<sup>229 230 308</sup> From a QA standpoint, adherence to surveillance intervals should be

considered among important quality indicators; a high ADR can be neutralised by poor quality polypectomy and also by poor adherence to follow-up guidelines. This may be also the reason why some studies from Norway and France have not shown any positive effect of polypectomy on decreasing CRC rates. In Norway, follow-up recommendations were 10 years for advanced adenomas, and perhaps therefore, these patients had a higher CRC risk than the normal population; on the other hand, there was no follow-up recommended in smaller (non-advanced) adenomas, and paradoxically, these patients had a lower CRC risk.<sup>309</sup> A French follow-up study after polypectomy within the national screening programme (FOBT followed by colonoscopy if positive) also showed an increased mortality from CRC (standardised incidence ratio 1.26), but this correlated with adherence to follow-up examinations. Patients with follow-up compliance had a lower risk (1.10 vs 4.26).<sup>310</sup> Whether follow-up should be more strictly adhered to or intensified in certain patients with certain adenomas is a very important clinical question and several studies of the value and interval of surveillance are underway.<sup>311–313</sup>

### Diagnostic biopsies for unexplained diarrhoea

A macroscopically normal examination does not exclude all causes of diarrhoea. A study of 809 cases found clinically relevant abnormalities in 15% of cases.<sup>314</sup> In this study, the most common diagnosis was microscopic colitis (80 cases, 10%), including lymphocytic and collagenous colitis.<sup>315</sup> The European Microscopic Colitis Group<sup>316</sup> reports the incidence as similar to that of classical IBD.

Some studies, however, suggest that the majority of causes of diarrhoea can be identified within the range of a flexible sigmoidoscopy.<sup>314</sup> As such, rectal biopsies alone may be sufficient to diagnose or exclude microscopic colitis, particularly in patients under 45 years, where the diagnostic yield of flexible sigmoidoscopy is not significantly different to that of colonoscopy.<sup>317</sup> Other data exist suggesting that changes in the large bowel mucosa may be patchy, and as such, left-sided and right-sided colonic biopsies should be taken for diagnosis.<sup>318–321</sup> However, the cost-effectiveness of this policy has been questioned.<sup>322</sup> Local policies on biopsy for unexplained diarrhoea should be developed.

### Postcolonoscopy colorectal cancer rate

As previously stated, PCCRC, also called colonoscopy interval cancer, is a CRC diagnosed after a colorectal screening examination or test in which no cancer is detected, and before the date of the next recommended examination.<sup>323</sup> PCCRCs may represent a missed cancer, a cancer arising in a missed or incompletely treated adenoma, or a cancer that started to develop after the colonoscopy. PCCRCs are potentially the most important markers of colonoscopy quality but due to their relative rarity and the time delay to diagnosis, PCCRC rates are difficult to measure and interpret.<sup>324</sup>

Online supplementary table S1 provides an overview of studies looking into PCCRCs and explores influencing factors.<sup>17 18 29 30 325–338</sup> It should be noted that almost all these studies are based on retrospective analyses of large databases and the quality of these may vary. A recent study with careful investigation of each case showed that in an institutional database including 43 661 colonoscopies, 21 of 45 cancers reported as interval cancers database were found to be incorrectly recorded due to administrative errors.<sup>339</sup>

Several studies have described PCCRC rates, with wide variation from 0% to 9% (online supplementary table S1).<sup>34</sup> Study

design and definition of PCCRC in terms of time intervals varies between studies, making comparison difficult.<sup>340</sup> One study demonstrated an overall PCCRC rate of 8.5% (in patients diagnosed with CRC who underwent colonoscopy within 3 years prior to cancer diagnosis), but also suggested that these rates have been declining with time, from 10.6% in 2001 to 6.8% in 2008.<sup>324</sup> More recently, it has been demonstrated that a higher FIT haemoglobin concentrations is an independent predictor of PCCRC,<sup>341</sup> and with increasing use of FIT may be an area for future study.

PCCRCs may be related to endoscopist performance, for example, with poor mucosal inspection or incomplete polypectomy, or related to biological factors of the patient, such as aggressive pathology of colorectal lesions. Morphology may be important with the detection of subtle, flat, depressed and serrated lesions highly variable among endoscopists, particularly in the proximal colon.<sup>342 343</sup> Clearly there is overlap, but quality of colonoscopy is strongly endoscopist dependent.<sup>340</sup> Back-to-back colonoscopy studies demonstrate that significant lesions may be missed<sup>12 61</sup> and colonoscopists with high ADR and high polypectomy rates provide increased protection for proximal cancers compared with those with lower polypectomy rates.<sup>34</sup>

Polypectomy technique also influences PCCRC, with incomplete polypectomy contributing to later cancers.<sup>332</sup> Pooled North American postpolypectomy studies<sup>334</sup> demonstrate missed cancer contributing 52% to the PCCRC rate, with 19% possibly due to incomplete polyp resection. A further study<sup>329</sup> found 27% of PCCRCs developed in the same segment as a previous polypectomy suggesting that incomplete treatment may have been a contributory factor.

PCCRCs are hugely important and reducing them is a crucial element of any colonoscopy programme. However, given their relative rarity, difficulties in data acquisition including data protection and the long intervals before they develop mean that their role as markers of quality is limited and currently surrogate markers will continue to be needed.

### Adverse events

Colonoscopy is an invasive procedure, which carries a risk of bleeding, perforation and even death. Although the risk is small with diagnostic colonoscopy, it increases markedly when therapeutic procedures such as polypectomy are performed. There have been several reviews on colonoscopy complications, most recently by ASGE<sup>344</sup> as well as a review specifically focusing on complications of screening colonoscopy.<sup>345</sup> Online supplementary table S7 provides an overview of the most relevant large series.<sup>11 16 48 151 227 345–353</sup>

A very important issue regarding adverse event assessment within QA and/or benchmarking is who records which data with which methodology over which period of time following colonoscopy. Databases such as the German screening colonoscopy registry underreported complications when audited alongside a prospective study.<sup>62</sup> Ease of collection of data varies, depending on whether only acute complications during the procedure or on the day of the procedure, hospital stay (if any) or all complications within a 2-week or 4-week follow-up period are recorded. Whether and to what extent the simple linkage of databases of hospitals, registries and insurance companies is helpful<sup>354</sup> is still uncertain due to variable and often insufficient data quality.

The EU guidelines recommend three methods of QA with regard to complications (contact with all patients at a certain point in time after colonoscopy, review of 30-day mortality, and review of unplanned hospital admissions within 8 days); they

however also admit that not all national or regional databases allow for such analyses. Therefore, the EU guidelines name unplanned admission on the day of colonoscopy (including reason for admission) as a KPI.<sup>23</sup>

### Perforation rates

The proportion of diagnostic to therapeutic procedures performed influences the overall colonoscopic perforation rate. In four large series of 97 000–277 000 colonoscopies, overall perforation rates ranged from 0.03% to 0.085%.<sup>13–16 23</sup> A recent review of studies calculated an overall perforation rate of 0.07% (1 in 1400).<sup>355</sup> Studies have quoted perforation rates ranging from 0% to 0.2% for diagnostic colonoscopy.<sup>151 356</sup> The English BCSP has reported a diagnostic perforation rate of 1 in 3253 (0.03%).<sup>357</sup> The two main risk factors for postpolypectomy perforation are the size and proximal (caecal) location of polyps.<sup>357</sup> Two small prospective polypectomy series reported perforation rates of 1 in 153 (0.65%) and 1 in 368 (0.27%), whereas two slightly larger retrospective series reported rates of 1 in 923 (0.11%) and 1 in 1583 (0.06%).<sup>351 358–360</sup> A recent review of studies calculated the perforation rate in therapeutic colonoscopy to be 0.1%.<sup>355</sup> The English BCSP has reported a perforation rate in polypectomy procedures of 0.09%.<sup>357</sup> It should be acknowledged that, particularly in the era of EMR and ESD techniques, polypectomy perforation rates will vary according to the size, location and complexity of polyps removed.

### Bleeding

The risk of postprocedural bleeding is very small with diagnostic colonoscopy, but increases markedly when polypectomy is performed. Bleeding rates of 0.3%–6.1% for polypectomies are reported.<sup>151 361</sup> The two main risk factors are the size and proximal (caecal) location of polyps.<sup>357 359</sup> Other reported risk factors include comorbidity including cardiovascular or chronic renal disease,<sup>362</sup> age,<sup>361–363</sup> anticoagulant use<sup>361 362</sup> and endoscopist experience.<sup>361</sup> Studies assessing the effect of polyp morphology are inconclusive, with some studies demonstrating higher risks for pedunculated<sup>363</sup> or sessile/thick-stalked polyps,<sup>361</sup> but others showing no effect.<sup>357 364</sup> The recent UK audit reported an overall bleeding rate of 0.26%,<sup>10</sup> and a recent large series reported a colonoscopy bleeding rate of 0.164%.<sup>16</sup> The UK BCSP data illustrate the importance of stratifying bleeding severity: in one study, the overall bleeding rate (including many clinically insignificant bleeds) was calculated as 0.59%; limiting the analysis to intermediate or major severity bleeds (haemoglobin drop of 2 g, blood transfusion, admission to intensive care, unplanned hospital admission for four or more nights, interventional radiology or endoscopy or surgery), the rate was 0.13%<sup>36</sup>; and limiting only to bleeding requiring transfusion, the rate was 0.04%.<sup>357</sup>

### Polypectomy adverse events and size of polyp

Overall, it is primarily polyp size that determines the risk of adverse events of bleeding and perforation.<sup>357</sup> On multivariate analysis, the Munich Polypectomy Study (MUPS) of 2257 patients showed polyp size was the main risk factor for significant adverse events (OR 31.01, 95% CI 7.53 to 128.1).<sup>359</sup> Other studies have reached similar conclusions.<sup>357 361–363 365–368</sup> Several studies have demonstrated that the risk of polypectomy relates to colonic location. The MUPS reported that proximal polyp location was a significant risk factor for major complications (OR 2.40, 95% CI 1.34 to 4.28).<sup>359</sup> A further study of 2106 polypectomies also showed that right-colon

polypectomies had a higher tendency of developing postpolypectomy syndrome and bleeding ( $p=0.002$ ).<sup>369</sup> A case control study of 39 cases demonstrated that polyps in the right colon had an OR of 4.67 for postpolypectomy delayed haemorrhage (1.88–11.61,  $p=0.001$ ),<sup>364</sup> and also suggested that the caecum seemed to be especially at high risk in univariate analysis (OR 13.82, 95% CI 2.66 to 71.73), but this could not be confirmed in multivariate analysis due to small numbers.<sup>357</sup>

### CONCLUSION

Delivery of high quality colonoscopy should be the aim of all colonoscopists and colonoscopy programmes. It is important that quality measures and KPI are developed for all programmes. These measures of quality should be robust<sup>370</sup> and evidence based and programmes should develop systems for data collection and monitoring.<sup>371</sup> High quality colonoscopy should ensure low complication rates, low PCCRC rates and should provide patients with an acceptable procedural experience.

### Author affiliations

<sup>1</sup>Department of Gastroenterology, South Tyneside District Hospital, South Shields, UK

<sup>2</sup>Department of Gastroenterology, North Tees University Hospital, Stockton-on-Tees, UK

<sup>3</sup>Department of Interdisciplinary Endoscopy, University Hospital Hamburg-Eppendorf, Hamburg, Germany

<sup>4</sup>Department of Gastroenterology, Indiana University, Indianapolis, USA

<sup>5</sup>Department of Gastroenterology and Hepatology, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands

<sup>6</sup>Department of Gastroenterology and Hepatology, Edouard Herriot Hospital, Lyon University, Lyon, France

<sup>7</sup>Department of Health Management and Health Economics and KG Jebsen Center for Colorectal Cancer Research, University of Oslo, Oslo, Norway

<sup>8</sup>Department of Gastroenterology, Medical Center for Postgraduate Education and the Maria Skłodowska-Curie Memorial Cancer Center and Institute of Oncology, Warsaw, Poland

<sup>9</sup>Department of Gastroenterology, St Mark's Hospital and Academic Institute, Harrow, UK

<sup>10</sup>Digestive Endoscopy Unit, Catholic University, Rome, Italy

<sup>11</sup>Department of Gastroenterology, Westmead Hospital, Sydney, Australia

**Contributors** All authors were involved in writing this manuscript, which was initially drafted by CJR, RB and TR. All reviewed and agreed the manuscript.

**Competing interests** None declared.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Open Access** This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>

### REFERENCES

- Atkin WS, Edwards R, Kralj-Hans I, *et al*. Once-only flexible sigmoidoscopy screening in prevention of colorectal cancer: a multicentre randomised controlled trial. *Lancet* 2010;375:1624–33.
- Elmunzer BJ, Hayward RA, Schoenfeld PS, *et al*. Effect of flexible sigmoidoscopy-based screening on incidence and mortality of colorectal cancer: a systematic review and meta-analysis of randomized controlled trials. *PLoS Med* 2012;9:e1001352.
- Holme Ø, Løberg M, *et al*. Effect of flexible sigmoidoscopy screening on colorectal cancer incidence and mortality: a randomized clinical trial. *JAMA* 2014;312:606–15.
- Holme Ø, Bretthauer M, Fretheim A, *et al*. Flexible sigmoidoscopy versus faecal occult blood testing for colorectal cancer screening in asymptomatic individuals. *Cochrane Database Syst Rev* 2013;(9):CD009259.
- Brenner H, Stock C, Hoffmeister M. Effect of screening sigmoidoscopy and screening colonoscopy on colorectal cancer incidence and mortality: systematic review and meta-analysis of randomised controlled trials and observational studies. *BMJ* 2014;348:g2467.

- 6 Kaminski MF, Bretthauer M, Zauber AG, *et al.* The NordICC Study: rationale and design of a randomized trial on colonoscopy screening for colorectal cancer. *Endoscopy* 2012;44:695–702.
- 7 Quintero E, Castells A, Bujanda L, *et al.* Colonoscopy versus fecal immunochemical testing in colorectal-cancer screening. *N Engl J Med* 2012;366:697–706.
- 8 Rees CJ, Gibson ST, Rutter MD, *et al.* UK key performance indicators and quality assurance standards for colonoscopy. *Gut* 2016;65:1784–90.
- 9 Denzer U, Beilenhoff U, Eickhoff A, *et al.* [S2k guideline: quality requirements for gastrointestinal endoscopy, AWMF registry no. 021–022]. *Z Gastroenterol* 2015;53:1496–530.
- 10 Gavin DR, Valori RM, Anderson JT, *et al.* The National Colonoscopy Audit: a nationwide assessment of the quality and safety of colonoscopy in the UK. *Gut* 2013;62:242–9.
- 11 Bowles CJA, Leicester R, Romaya C, *et al.* A prospective study of colonoscopy practice in the UK today: are we adequately prepared for national colorectal cancer screening tomorrow? *Gut* 2004;53:277–83.
- 12 Rex DK, Cutler CS, Lemmel GT, *et al.* Colonoscopic miss rates of adenomas determined by back-to-back colonoscopies. *Gastroenterology* 1997;112:24–8.
- 13 Arora G, Mannalithara A, Singh G, *et al.* Risk of perforation from a colonoscopy in adults: a large population-based study. *Gastrointest Endosc* 2009;69:654–64.
- 14 Iqbal CW, Cullinane DC, Schiller HJ, *et al.* Surgical management and outcomes of 165 colonoscopic perforations from a single institution. *Arch Surg* 2008;143:701–6.
- 15 Korman LY, Overholt BF, Box T, *et al.* Perforation during colonoscopy in endoscopic ambulatory surgical centers. *Gastrointest Endosc* 2003;58:554–7.
- 16 Rabeneck L, Paszat LF, Hilsden RJ, *et al.* Bleeding and perforation after outpatient colonoscopy and their risk factors in usual clinical practice. *Gastroenterology* 2008;135:1899–906.
- 17 Kaminski MF, Regula J, Kraszewska E, *et al.* Quality indicators for colonoscopy and the risk of interval cancer. *N Engl J Med* 2010;362:1795–803.
- 18 Corley DA, Jensen CD, Marks AR, *et al.* Adenoma detection rate and risk of colorectal cancer and death. *N Engl J Med* 2014;370:1298–306.
- 19 Health and Social Care Information Centre. Hospital Episode Statistics data, 2011. [www.digital.nhs.uk/hes](http://www.digital.nhs.uk/hes)
- 20 Seeff LC, Manninen DL, Dong FB, *et al.* Is there endoscopic capacity to provide colorectal cancer screening to the unscreened population in the United States? *Gastroenterology* 2004;127:1661–9.
- 21 Atkin WS, Cook CF, Cuzick J, *et al.* Single flexible sigmoidoscopy screening to prevent colorectal cancer: baseline findings of a UK multicentre randomised trial. *Lancet* 2002;359:1291–300.
- 22 Logan RFA, Patnick J, Nickerson C, *et al.* Outcomes of the Bowel Cancer Screening Programme (BCSP) in England after the first 1 million tests. *Gut* 2012;61:1439–46.
- 23 Valori R, Rey JF, Atkin WS, *et al.* European guidelines for quality assurance in colorectal cancer screening and diagnosis. First Edition—quality assurance in endoscopy in colorectal cancer screening and diagnosis. *Endoscopy* 2012;44(Suppl 3):SE88–105.
- 24 Rajasekhar PT, Rutter MD, Bramble MG, *et al.* Achieving high quality colonoscopy: using graphical representation to measure performance and reset standards. *Colorectal Dis* 2012;14:1538–45.
- 25 Lieberman D, Nadel M, Smith RA, *et al.* Standardized colonoscopy reporting and data system: report of the Quality Assurance Task Group of The National Colorectal Cancer Roundtable. *Gastrointest Endosc* 2007;65:757–66.
- 26 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;97:1296–308.
- 27 Rex DK, Johnson DA, Anderson JC, *et al.* American College of Gastroenterology guidelines for colorectal cancer screening 2009. *Am J Gastroenterol* 2009;104:739–7350.
- 28 Rex DK, Petrini JL, Baron TH, *et al.* Quality indicators for colonoscopy. *Am J Gastroenterol* 2006;101:873–85.
- 29 Brenner H, Chang-Claude J, Seiler CM, *et al.* Interval cancers after negative colonoscopy: population-based case-control study. *Gut* 2012;61:1576–82.
- 30 Bressler B, Paszat LF, Chen Z, *et al.* Rates of new or missed colorectal cancers after colonoscopy and their risk factors: a population-based analysis. *Gastroenterol* 2007;132:96–102.
- 31 Aslinia F, Uradomo L, Steele A, *et al.* Quality assessment of colonoscopic cecal intubation: an analysis of 6 years of continuous practice at a university hospital. *Am J Gastroenterol* 2006;101:721–31.
- 32 Shah HA, Paszat LF, Saskin R, *et al.* Factors associated with incomplete colonoscopy: a population-based study. *Gastroenterol* 2007;132:2297–303.
- 33 Cancer Research UK. UK Cancer Incidence (2010) and Mortality (2010) Summary, December 2012. Secondary UK Cancer Incidence (2010) and Mortality (2010) Summary, December 2012, 2012. [http://publications.cancerresearchuk.org/downloads/Product/CS\\_DT\\_INCMORTATES.pdf](http://publications.cancerresearchuk.org/downloads/Product/CS_DT_INCMORTATES.pdf)
- 34 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.
- 35 Morris EJA, Whitehouse LE, Farrell T, *et al.* A retrospective observational study examining the characteristics and outcomes of tumours diagnosed within and without of the English NHS Bowel Cancer Screening Programme. *Br J Cancer* 2012;107:757–64.
- 36 Lee TWJ, Rutter MD, Blanks RG, *et al.* Colonoscopy quality measures: experience from the NHS Bowel Cancer Screening Programme. *Gut* 2012;61:1050–7.
- 37 Millan MS, Gross P, Manilich E, *et al.* Adenoma detection rate: the real indicator of quality in colonoscopy. *Dis Colon Rectum* 2008;51:1217–20.
- 38 Rajasekhar PT, Clifford GM, Lee TWJ, *et al.* Bowel cancer screening is safe, detects earlier stage cancer and adenomas in 50% of cases: experience of the prevalent round of screening from two first wave centres in the North East of England. *Frontline Gastroenterol* 2012;3:10–15.
- 39 Rembacken B, Hassan C, Riemann JF, *et al.* Quality in screening colonoscopy: position statement of the European Society of Gastrointestinal Endoscopy (ESGE). *Endoscopy* 2012;44:957–68.
- 40 Bhangu A, Bowley DM, Horner R, *et al.* Volume and accreditation, but not specialty, affect quality standards in colonoscopy. *Br J Surg* 2012;99:1436–44.
- 41 Dafnis G, Granath F, Pahlman L, *et al.* Patient factors influencing the completion rate in colonoscopy. *Dig Liver Dis* 2005;37:113–18.
- 42 Gupta M, Holub JL, Eisen G. Do indication and demographics for colonoscopy affect completion? A large national database evaluation. *Eur J Gastroenterol Hepatol* 2010;22:620–7.
- 43 Harris JK, Froehlich F, Wietlisbach V, *et al.* Factors associated with the technical performance of colonoscopy: an EPAGE study. *Dig Liver Dis* 2007;39:678–89.
- 44 Kolber MR, Wong CKW, Fedorak RN, *et al.* Prospective study of the quality of colonoscopies performed by primary care physicians: the Alberta primary care endoscopy (APC-Endo) study. *PLoS ONE* 2013;8:e67017.
- 45 Nagrath N, Phull PS. Variation in caecal intubation rates between screening and symptomatic patients. *United European Gastroenterol J* 2014;2:295–300.
- 46 Radaelli F, Meucci G, Sgroi G, *et al.* Technical performance of colonoscopy: the key role of sedation/analgesia and other quality indicators. *Am J Gastroenterol* 2008;103:1122–30.
- 47 Segnan N, Patnick J, von Karsa L. *European Guidelines for Quality Assurance in Colorectal Cancer Screening and Diagnosis*. Publications Office of the European Union 1st edn. 2011.
- 48 Crispin A, Birkner B, Munte A, *et al.* Process quality and incidence of acute complications in a series of more than 230,000 outpatient colonoscopies. *Endoscopy* 2009;41:1018–25.
- 49 de Jonge V, Sint Nicolaas J, Cahen DL, *et al.* Quality evaluation of colonoscopy reporting and colonoscopy performance in daily clinical practice. *Gastrointest Endosc* 2012;75:95–106.
- 50 Powell N, Knight H, Dunn J, *et al.* Images of the terminal ileum are more convincing than cecal images for verifying the extent of colonoscopy. *Endoscopy* 2011;43:196–201.
- 51 Baraza W, Brown S, Shorthouse AJ, *et al.* Direct photographic documentation of ileal mucosa in routine colonoscopy is not an independent valid or reliable proof of completion: quality assurance issues for the national colorectal cancer-screening programme. *Colorectal Dis* 2009;11:89–93.
- 52 Bramble MG, Ironside JW. Creutzfeldt-Jakob disease: implications for gastroenterology. *Gut* 2002;50:888–90.
- 53 Neilson LJ, Bevan R, Panter S, *et al.* Terminal ileal intubation and biopsy in routine colonoscopy practice. *Expert Rev Gastroenterol Hepatol* 2015;9:567–74.
- 54 Morson B. The polyp-cancer sequence in the large bowel. *Proc Roy Soc Med* 1973;67:451–7.
- 55 Greenspan M, Rajan KB, Baig A, *et al.* Advanced adenoma detection rate is independent of nonadvanced adenoma detection rate. *Am J Gastroenterol* 2013;108:1286–92.
- 56 Brenner H, Altenhofen L, Kretschmann J, *et al.* Trends in adenoma detection rates during the first 10 years of the German screening colonoscopy program. *Gastroenterology* 2015;149:356–66.
- 57 Ijspeert JEG, Bevan R, Senore C, *et al.* Rate of serrated polyps and serrated polyposis syndrome in colorectal cancer screening cohorts: a European overview. *Gut* Published Online First: 24 Feb 2016. doi:10.1136/gutjnl-2015-310784.
- 58 Francis DL, Rodriguez-Correa DT, Buchner A, *et al.* Application of a conversion factor to estimate the adenoma detection rate from the polyp detection rate. *Gastrointest Endosc* 2011;73:493–7.
- 59 Patel NC, Islam RS, Wu Q, *et al.* Measurement of polypectomy rate by using administrative claims data with validation against the adenoma detection rate. *Gastrointest Endosc* 2013;77:390–4.
- 60 Rajasekhar PT, Lee TJ, Rutter MD, *et al.* Using a 'conversion factor' to estimate adenoma detection rate. *Endoscopy* 2012;61(Suppl 3):A371.
- 61 van Rijn JC, Reitsma JB, Stoker J, *et al.* Polyp miss rate determined by tandem colonoscopy: a systematic review. *Am J Gastroenterol* 2006;101:343–50.
- 62 Adler A, Wegscheider K, Lieberman D, *et al.* Factors determining the quality of screening colonoscopy: a prospective study on adenoma detection rates, from 12,134 examinations (Berlin colonoscopy project 3, BECOP-3). *Gut* 2013;62:236–41.

- 63 Barret M, Boustiere C, Canard JM, *et al.* Factors associated with adenoma detection rate and diagnosis of polyps and colorectal cancer during colonoscopy in France: results of a prospective, nationwide survey. *PLoS ONE* 2013;18:e68947.
- 64 Bretagne JF, Hamonic S, Piette C, *et al.* Variations between endoscopists in rates of detection of colorectal neoplasia and their impact on a regional screening program based on colonoscopy after fecal occult blood testing. *Gastrointest Endosc* 2010;71:335–41.
- 65 Imperiale TF, Glowinski EA, Juliar BE, *et al.* Variation in polyp detection rates at screening colonoscopy. *Gastrointest Endosc* 2009;69:1288–95.
- 66 Jover R, Zapater P, Polania E, *et al.* Modifiable endoscopic factors that influence the adenoma detection rate in colorectal cancer screening colonoscopies. *Gastrointest Endosc* 2013;77:381–9.
- 67 Lee TJ, Rees CJ, Blanks RG, *et al.* Colonoscopic factors associated with adenoma detection in a national colorectal cancer screening program. *Endoscopy* 2014;46:203–11.
- 68 Regula J, Rupinski M, Kraszewska E, *et al.* Colonoscopy in colorectal-cancer screening for detection of advanced neoplasia. *N Engl J Med* 2006;355:1863–72.
- 69 Adler A, Roll S, Marowski B, *et al.* Appropriateness of colonoscopy in the era of colorectal cancer screening: a prospective, multicenter study in a private-practice setting (Berlin Colonoscopy Project 1, BECOP 1). *Dis Colon Rectum* 2007;50:1628–38.
- 70 Anderson JC, Butterly LF, Goodrich M, *et al.* Differences in detection rates of adenomas and serrated polyps in screening versus surveillance colonoscopies, based on the New Hampshire colonoscopy registry. *Clin Gastroenterol Hepatol* 2013;11:1308–12.
- 71 Chey WD, Nojkov B, Rubenstein JH, *et al.* The yield of colonoscopy in patients with non-constipated irritable bowel syndrome: results from a prospective, controlled US trial. *Am J Gastroenterol* 2010;105:859–65.
- 72 de Bosset V, Froehlich F, Rey JP, *et al.* Do explicit appropriateness criteria enhance the diagnostic yield of colonoscopy? *Endoscopy* 2002;34:360–8.
- 73 Gupta M, Holub JL, Knigge K, *et al.* Constipation is not associated with an increased rate of findings on colonoscopy: results from a national endoscopy consortium. *Endoscopy* 2010;42:208–12.
- 74 Kueh SH, Zhou L, Walmsley RS. The diagnostic yield of colonoscopy in patients with isolated abdominal pain. *N Z Med J* 2013;126:36–44.
- 75 Lason A, Kilander A, Stotzer PO. Diagnostic yield of colonoscopy based on symptoms. *Scan J Gastroenterol* 2008;43:356–62.
- 76 Lieberman DA, de Garmo PL, Fleischer DE, *et al.* Colonic neoplasia in patients with nonspecific GI symptoms. *Gastrointest Endosc* 2000;51:647–51.
- 77 Minoli G, Meucci G, Bortoli A, *et al.* The ASGE guidelines for the appropriate use of colonoscopy in an open access system. *Gastrointest Endosc* 2000;52:39–44.
- 78 Neugut AI, Garbowski GC, Wayne JD, *et al.* Diagnostic yield of colorectal neoplasia with colonoscopy for abdominal pain, change in bowel habits, and rectal bleeding. *Am J Gastroenterol* 1993;88:1179–83.
- 79 Obusec EC, Lian L, Kariv R, *et al.* Diagnostic yield of colonoscopy for constipation as the sole indication. *Colorectal Dis* 2012;14:585–91.
- 80 Patel P, Bercik P, Morgan DG, *et al.* Prevalence of organic disease at colonoscopy in patients with symptoms compatible with irritable bowel syndrome: cross-sectional survey. *Scan J Gastroenterol* 2015;50:816–23.
- 81 Pepin C, Ladabaum U. The yield of lower endoscopy in patients with constipation: survey of a university hospital, a public county hospital, and a Veterans Administration medical center. *Gastrointest Endosc* 2002;56:325–32.
- 82 Kaminski MF, Anderson J, Valori R, *et al.* Leadership training to improve adenoma detection rate in screening colonoscopy: a randomized trial. *Gut* 2016;65:616–24.
- 83 Burke CA, Choure AG, Sanaka MR, *et al.* A comparison of high-definition versus conventional colonoscopes for polyp detection. *Dig Dis Sci* 2010;55:1716–20.
- 84 East JE, Stavrinidis M, Thomas-Gibson S, *et al.* A comparative study of standard vs. high definition colonoscopy for adenoma and hyperplastic polyp detection with optimized withdrawal technique. *Aliment Pharmacol Ther* 2008;28:768–76.
- 85 Erim T, Rivas JM, Velis E, *et al.* Role of high definition colonoscopy in colorectal adenomatous polyp detection. *World J Gastroenterol* 2011;17:4001–6.
- 86 Longcroft-Wheaton G, Brown J, Cowlshaw D, *et al.* High-definition vs. standard-definition colonoscopy in the characterization of small colonic polyps: results from a randomized trial. *Endoscopy* 2012;44:905–10.
- 87 Pellise M, Fernandez-Esparrach G, Cardenas A, *et al.* Impact of wide-angle, high-definition endoscopy in the diagnosis of colorectal neoplasia: a randomized controlled trial. *Gastroenterol* 2008;135:1062–8.
- 88 Subramanian V, Mannath J, Hawkey CJ, *et al.* High definition colonoscopy vs. standard video endoscopy for the detection of colonic polyps: a meta-analysis. *Endoscopy* 2011;43:499–505.
- 89 Tribonias G, Theodoropoulou A, Konstantinidis K, *et al.* Comparison of standard vs high-definition, wide-angle colonoscopy for polyp detection: a randomized controlled trial. *Colorectal Dis* 2010;12:e260–e66.
- 90 Buchner AM, Shahid MW, Heckman MG, *et al.* High-definition colonoscopy detects colorectal polyps at a higher rate than standard White-light colonoscopy. *Clin Gastroenterol Hepatol* 2011;8:364–70.
- 91 Dinesen L, Chua TJ, Kaffes AJ. Meta-analysis of narrow-band imaging versus conventional colonoscopy for adenoma detection. *Gastrointest Endosc* 2012;75:604–11.
- 92 Jin XF, Chai TH, Shi JW, *et al.* Meta-analysis for evaluating the accuracy of endoscopy with narrow band imaging in detecting colorectal adenomas. *J Gastroenterol Hepatol* 2012;27:882–7.
- 93 Nagomi A, Bjelakovic G, Petrovic B. Narrow band imaging versus conventional white light colonoscopy for the detection of colorectal polyps. *Cochrane Database Syst Rev* 2012;1:CD008361.
- 94 Omata F, Ohde S, Deshpande GA, *et al.* Image-enhanced, chromo, and cap-assisted colonoscopy for improving adenoma/neoplasia detection rate: a systematic review and meta-analysis. *Scan J Gastroenterol* 2014;49:222–37.
- 95 Pasha SF, Leighton JA, Das A, *et al.* Comparison of the yield and miss rate of narrow band imaging and white light endoscopy in patients undergoing screening or surveillance colonoscopy: a meta-analysis. *Am J Gastroenterol* 2012;107:363–70.
- 96 Sabbagh LC, Reveiz L, Aponte D, *et al.* Narrow-band imaging does not improve detection of colorectal polyps when compared to conventional colonoscopy: a randomized controlled trial and meta-analysis of published studies. *BMC Gastroenterol* 2011;11:100.
- 97 Chung SJ, Kim D, Song JH, *et al.* Comparison of detection and miss rates of narrow band imaging, flexible spectral imaging chromoendoscopy and white light at screening colonoscopy: a randomised controlled back-to-back study. *Gut* 2014;63:785–91.
- 98 Hoffman A, Loth L, Rey JW, *et al.* High definition plus colonoscopy combined with i-scan tone enhancement vs. high definition colonoscopy for colorectal neoplasia: a randomized trial. *Dig Liver Dis* 2014;46:991–6.
- 99 Hoffman A, Sar F, Goetz M, *et al.* High definition colonoscopy combined with i-Scan is superior in the detection of colorectal neoplasias compared with standard video colonoscopy: a prospective randomized controlled trial. *Endoscopy* 2010;42:827–33.
- 100 Hong SN, Choe WH, Lee JH, *et al.* Prospective, randomized, back-to-back trial evaluating the usefulness of i-SCAN in screening colonoscopy. *Gastrointest Endosc* 2012;75:1011–21.
- 101 Baumann UA. Does retroflexion improve adenoma miss rates on the right side of the colon when using a pediatric variable-stiffness colonoscope during routine colonoscopy? *Endoscopy* 2009;41:654.
- 102 Chandran S, Parker F, Vaughan R, *et al.* Right-sided adenoma detection with retroflexion versus forward-view colonoscopy. *Gastrointest Endosc* 2015;81:608–13.
- 103 Hewett DG, Rex DK. Miss rate of right-sided colon examination during colonoscopy defined by retroflexion: an observational study. *Gastrointest Endosc* 2011;74:246–52.
- 104 Cutler AF, Pop A. Fifteen years later: colonoscopic retroflexion revisited. *Am J Gastroenterol* 1999;76:1537–8.
- 105 Harrison M, Singh N, Rex DK. Impact of proximal colon retroflexion on adenoma miss rates. *Am J Gastroenterol* 2004;99:519–22.
- 106 Kushnir VM, Oh YS, Hollander T, *et al.* Impact of retroflexion vs. second forward view examination of the right colon on adenoma detection: a comparison study. *Am J Gastroenterol* 2015;110:415–22.
- 107 Repici A, Di Stefano AF, Radicioni MM, *et al.* Methylene blue MMX tablets for chromoendoscopy. Safety tolerability and bioavailability in healthy volunteers. *Contemp Clin Trials* 2012;33:260–7.
- 108 Chaptini LA, Janec EM, Seltzer G, *et al.* Sublingual hyoscyamine spray as premedication for colonoscopy: a randomized double-blinded placebo-controlled trial. *Am J Surg* 2008;196:51–5.
- 109 Ansari A, Soon SY, Saunders BP, *et al.* A prospective study of the technical feasibility of ileoscopy at colonoscopy. *Scan J Gastroenterol* 2003;38:1184–6.
- 110 Misra SP, Dwivedi M. Role of intravenously administered hyoscyne butyl bromide in retrograde terminal ileoscopy: a randomized, double-blinded, placebo-controlled trial. *World J Gastroenterol* 2007;13:1820–3.
- 111 Cui PJ, Yao J, Han HZ, *et al.* Does hyoscyne butylbromide really improve polyp detection during colonoscopy? A meta-analysis of randomized controlled trials. *World J Gastroenterol* 2014;20:7034–9.
- 112 Madhoun MF, Ali T, Tierney WM, *et al.* Effect of hyoscyne N-butylbromide on adenoma detection rate: meta-analysis of randomized clinical trials. *Dig Endosc* 2015;27:354–60.
- 113 Rondonotti E, Zolk O, Amato A, *et al.* The impact of hyoscyne-N-butylbromide on adenoma detection during colonoscopy: meta-analysis of randomized, controlled studies. *Gastrointest Endosc* 2014;80:1103–12.
- 114 East JE, Suzuki N, Arebi N, *et al.* Position changes improve visibility during colonoscopy withdrawal: a randomized, blinded, crossover trial. *Gastrointest Endosc* 2007;65:263–9.
- 115 Ghosh S, Iacucci M. Dynamic position change at colonoscopy improves adenoma detection. *Can J Gastroenterol* 2013;27:508.
- 116 Lucendo AJ. Colonoscopy in obese patients: time to change position. *Dig Dis Sci* 2013;58:608–9.

- 117 Ou G, Kim E, Lakzadeh P, *et al.* A randomized controlled trial assessing the effect of prescribed patient position changes during colonoscopy withdrawal on adenoma detection. *Gastrointest Endosc* 2014;80:277–80.
- 118 Köksal AŞ, Kalkan IH, Torun S, *et al.* A simple method to improve adenoma detection rate during colonoscopy: altering patient position. *Can J Gastroenterol* 2013;27:509–12.
- 119 Ball AJ, Johal SS, Riley SA. Position change during colonoscopy withdrawal increases polyp and adenoma detection in the right but not in the left side of the colon: results of a randomized controlled trial. *Gastrointest Endosc* 2015;82:488–94.
- 120 He Q, Li JD, An SL, *et al.* Cap-assisted colonoscopy versus conventional colonoscopy: systematic review and meta-analysis. *Int J Colorectal Dis* 2013;28:279–81.
- 121 Morgan JL, Thomas K, Braungart S, *et al.* Transparent cap colonoscopy versus standard colonoscopy: a systematic review and meta-analysis. *Tech Coloproctol* 2013;17:353–60.
- 122 Ng SC, Tsoi KK, Hirai HW, *et al.* The efficacy of cap-assisted colonoscopy in polyp detection and cecal intubation: a meta-analysis of randomized controlled trials. *Am J Gastroenterol* 2012;107:1165–73.
- 123 Westwood DA, Alexakis N, Connor SJ. Transparent cap-assisted colonoscopy versus standard adult colonoscopy: a systematic review and meta-analysis. *Dis Colon Rectum* 2012;55:218–25.
- 124 Biecker E, Floer M, Heinecke A, *et al.* Novel Endocuff-assisted colonoscopy significantly increases the polyp detection rate: a randomized controlled trial. *J Clin Gastroenterol* 2015;49:413–18.
- 125 Floer M, Biecker E, Fitzlaff R, *et al.* Higher adenoma detection rates with Endocuff-assisted colonoscopy—a randomized controlled multicenter trial. *PLoS ONE* 2014;9:e114267.
- 126 van Doorn SC, van der Vlugt M, Depla ACTM, *et al.* Adenoma detection with Endocuff colonoscopy versus conventional colonoscopy: a multicentre randomised controlled trial. *Gut* Published Online First: 16 Dec 2015. doi:10.1136/gutjnl-2015-310097.
- 127 Halpern Z, Gross SA, Gralnek IM, *et al.* Comparison of adenoma detection and miss rates between a novel balloon colonoscopy and standard colonoscopy: a randomized tandem study. *Endoscopy* 2015;47:238–44.
- 128 Halphen M, Heresbach D, Gruss HJ, *et al.* Validation of the Harefield Cleansing Scale: a tool for the evaluation of bowel cleansing quality in both research and clinical practice. *Gastrointest Endosc* 2013;78:121–31.
- 129 Leufkens AM, DeMarco DC, Rastogi A, *et al.* Effect of a retrograde-viewing device on adenoma detection rate during colonoscopy: the TERRACE study. *Gastrointest Endosc* 2011;73:480–9.
- 130 Leufkens AM, van Oijen MG, Vleggaar FP, *et al.* Factors influencing the miss rate of polyps in a back-to-back colonoscopy study. *Endoscopy* 2012;44:470–5.
- 131 Siersema PD, Rastogi A, Leufkens AM, *et al.* Retrograde-viewing device improves adenoma detection rate in colonoscopies for surveillance and diagnostic workup. *World J Gastroenterol* 2012;18:3400–8.
- 132 Gurudu SR, Ratuapli SK, Leighton JA, *et al.* Adenoma detection rate is not influenced by the timing of colonoscopy when performed in half-day blocks. *Am J Gastroenterol* 2011;106:1466–71.
- 133 Lee A, Iskander JM, Gupta N, *et al.* Queue position in the endoscopic schedule impacts effectiveness of colonoscopy. *Am J Gastroenterol* 2011;106:1457–65.
- 134 Sanaka MR, Deepinder F, Thota PN, *et al.* Adenomas are detected more often in morning than in afternoon colonoscopy. *Am J Gastroenterol* 2009;104:1659–64.
- 135 Freedman JS, Harari DY, Bamji ND, *et al.* The detection of premalignant colon polyps during colonoscopy is stable throughout the workday. *Gastrointest Endosc* 2011;73:1197–206.
- 136 Lurix E, Hernandez AV, Thoma M, *et al.* Adenoma detection rate is not influenced by full-day blocks, time, or modified queue position. *Gastrointest Endosc* 2012;75:827–34.
- 137 Thurtle D, Pullinger M, Tsigarides J, *et al.* Colonoscopic polyp detection rate is stable throughout the workday including evening colonoscopy sessions. *F1000Res* 2014;13:107.
- 138 Jimenez Cantisano BG, Hernandez M, Ramirez A, *et al.* The day of the week does not affect the adenoma detection rate. *Dig Dis Sci* 2014;59:564–8.
- 139 Eun CS, Han DS, Hyun YS, *et al.* The timing of bowel preparation is more important than the timing of colonoscopy in determining the quality of bowel cleansing. *Dig Dis Sci* 2011;56:539–44.
- 140 Hendry PO, Jenkins JT, Diamant RH. The impact of poor bowel preparation on colonoscopy: a prospective single centre study of 10571 colonoscopies. *Colorectal Dis* 2007;9:745–8.
- 141 Bernstein C, Thorn M, Monsees K, *et al.* A prospective study of factors that determine cecal intubation time at colonoscopy. *Gastrointest Endosc* 2005;61:72–5.
- 142 Young Jang J, Jai Chun H. Bowel preparations as quality indicators for colonoscopy. *World J Gastroenterol* 2014;20:2746–50.
- 143 Parra-Blanco A, Nicolas-Perez D, Gimeno-Garcia A, *et al.* The timing of bowel preparation before colonoscopy determines the quality of cleansing, and is a significant factor contributing to the detection of flat lesions: a randomized study. *World J Gastroenterol* 2006;12:6161–6.
- 144 Rex DK. Maximizing detection of adenomas and cancers during colonoscopy. *Am J Gastroenterol* 2006;101:2866–77.
- 145 Aronchick CA, Lipshutz WH, Wright SH, *et al.* Validation of an instrument to assess colon cleansing. *Am J Gastroenterol* 1999;94:2667.
- 146 Gerard DP, Foster DB, Raiser MW, *et al.* Validation of a new bowel preparation scale for measuring colon cleansing for colonoscopy: the Chicago bowel preparation scale. *Clin Transl Gastroenterol* 2013;4:e43.
- 147 Lai EJ, Calderwood AH, Doros G, *et al.* The Boston bowel preparation scale: a valid and reliable instrument for colonoscopy-oriented research. *Gastrointest Endosc* 2009;69:620–5.
- 148 Rostom A, Jolicoeur E. Validation of a new scale for the assessment of bowel preparation quality. *Gastrointest Endosc* 2004;59:482–6.
- 149 Chilton A, Rutter MD. *Quality Assurance Guidelines for Colonoscopy*. NHS Cancer Screening Programmes, 2011.
- 150 Froehlich F, Wietlisbach V, Gonvers JJ, *et al.* Impact of colonic cleansing on quality and diagnostic yield of colonoscopy: the European Panel of Appropriateness of Gastrointestinal Endoscopy European multicenter study. *Gastrointest Endosc* 2005;61:378–84.
- 151 Nelson DB, McQuaid KR, Bond JH, *et al.* Procedural success and complications of large scale screening colonoscopy. *Gastrointest Endosc* 2002;55:307–14.
- 152 Calderwood AH, Jacobson BC. Comprehensive validation of the Boston Bowel Preparation Scale. *Gastrointest Endosc* 2010;72:686–92.
- 153 Kim EJ, Park YI, Kim YS, *et al.* A Korean experience of the use of Boston bowel preparation scale: a valid and reliable instrument for colonoscopy-oriented research. *Saudi J Gastroenterol* 2014;20:219–24.
- 154 Mahadev S, Green PH, Lebwohl B. Rates of suboptimal preparation for colonoscopy differ markedly between providers: impact on adenoma detection rates. *J Clin Gastroenterol* 2015;49:746–50.
- 155 Wexner SD, Beck DE, Baron TH, *et al.* A consensus document on bowel preparation before colonoscopy: prepared by a Task Force from the American Society of Colon and Rectal Surgeons (ASCRS), the American Society for Gastrointestinal Endoscopy (ASGE), and the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES). *Gastrointest Endosc* 2006;63:894–909.
- 156 Connor A, Tolan D, Hughes S, *et al.* Consensus guidelines for the safe prescription and administration of oral bowel-cleansing agents. *Gut* 2012;61:1525–32.
- 157 Harewood GC, Sharma VK, de Garmo P. Impact of colonoscopy preparation quality on detection of suspected colonic neoplasia. *Gastrointest Endosc* 2003;2003:76–9.
- 158 Kim WH, Cho YJ, Park JY, *et al.* Factors affecting insertion time and patient discomfort during colonoscopy. *Gastrointest Endosc* 2000;52:600–5.
- 159 Cotton PB, Williams CB. *Chapter 9. Practical gastrointestinal endoscopy*. 4th edn. Wiley-Blackwell, 1996:218–20.
- 160 El Younis CM. Correlation of preprocedure digital rectal examination and rectal retroflexion during colonoscopy of asymptomatic patients. *Gastroenterol Hepatol* 2009;5:201–4.
- 161 Grobe JL, Kozarek RA, Sanowski RA. Colonoscopic retroflexion in the evaluation of rectal disease. *Am J Gastroenterol* 1982;77:856–8.
- 162 Hanson JM, Atkin WS, Cunliffe WJ, *et al.* Rectal retroflexion: an essential part of lower gastrointestinal endoscopic examination. *Dis Colon Rectum* 2001;44:1706–8.
- 163 Saad A, Rex DK. Routine rectal retroflexion during colonoscopy has low yield for neoplasia. *World J Gastroenterol* 2008;14:6503–5.
- 164 Varadarajulu S, Ramsey WH. Utility of retroflexion in lower gastrointestinal endoscopy. *J Clin Gastroenterol* 2001;32:235–7.
- 165 Ahlwat SK, Charabaty A, Benjamin S. Rectal perforation caused by retroflexion maneuver during colonoscopy: closure with endoscopic clips. *Gastrointest Endosc* 2008;67:771–3.
- 166 Bechtold ML, Hammad HT, Arif M, *et al.* Perforation upon retroflexion: an endoscopic complication and repair. *Endoscopy* 2009;41(Suppl 2):E155–6.
- 167 Katsinelos P, Kountouras J, Chatzimavroudis G, *et al.* Endoscopic closure of a large iatrogenic rectal perforation using endoloop/clips technique. *Acta Gastroenterol Belg* 2009;72:357–9.
- 168 Quallick MR, Brown WR. Rectal perforation during colonoscopic retroflexion: a large, prospective experience in an academic center. *Gastrointest Endosc* 2009;69:960–3.
- 169 Sullivan JL, Maxwell PJ, Kastenber DM, *et al.* Rectal perforation by retroflexion of the colonoscopy managed by endoclip closure. *American Surgeon* 2010;76:108–10.
- 170 Overholt BF, Brooks-Belli L, Grace M, *et al.* Withdrawal times and associated factors in colonoscopy: a quality assurance multicenter assessment. *J Clin Gastroenterol* 2010;44:e80–6.
- 171 Barclay RL, Vicari JJ, Greenlaw RL. Effect of a time-dependent colonoscopic withdrawal protocol on adenoma detection during screening colonoscopy. *Clin Gastroenterol Hepatol* 2008;6:1091–8.

- 172 Simmons DT, Harewood GC, Baron TH, *et al.* Impact of endoscopist withdrawal speed on polyp yield: implications for optimal colonoscopy withdrawal time. *Aliment Pharmacol Ther* 2006;24:965–71.
- 173 Lee TWJ, Blanks RG, Rees CJ, *et al.* Longer mean colonoscopy withdrawal time is associated with increased adenoma detection: evidence from the Bowel Cancer Screening Programme in England. *Endoscopy* 2013;45:20–6.
- 174 Moritz V, Bretthauer M, Ruud HK, *et al.* Withdrawal time as a quality indicator for colonoscopy: a nationwide analysis. *Surg Endosc* 2012;44:476–81.
- 175 Sawhney MS, Cury MS, Neeman N, *et al.* Effect of institution-wide policy of colonoscopy withdrawal time > or = 7 minutes on polyp detection. *Gastroenterol* 2008;135:1892–8.
- 176 Lee RH, Tang RS, Muthusamy VR, *et al.* Quality of colonoscopy withdrawal technique and variability in adenoma detection rates (with videos). *Gastrointest Endosc* 2011;74:128–34.
- 177 Barclay RL, Vicari JJ, Doughty AS, *et al.* Colonoscopic withdrawal times and adenoma detection during screening colonoscopy. *N Engl J Med* 2006;355:2533–41.
- 178 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;109:417–26.
- 179 Gellad ZF, Weiss DG, Ahnen DJ, *et al.* Colonoscopy withdrawal time and risk of neoplasia at 5 years: results from VA Cooperative Studies Program 380. *Am J Gastroenterol* 2010;105:1746–52.
- 180 Gromski MA, Miller CA, Lee SH, *et al.* Trainees' adenoma detection rate is higher if ≥10 minutes is spent on withdrawal during colonoscopy. *Surg Endosc* 2012;26:1337–42.
- 181 Lin OS, Kozarek RA, Arai A, *et al.* The effect of periodic monitoring and feedback on screening colonoscopy withdrawal times, polyp detection rates, and patient satisfaction scores. *Gastrointest Endosc* 2010;71:1253–9.
- 182 Taber A, Romagnuolo J. Effect of simply recording colonoscopy withdrawal time on polyp and adenoma detection rates. *Gastrointest Endosc* 2010;71:782–6.
- 183 Ladas SD, Satake Y, Mostafa I, *et al.* Sedation practices for gastrointestinal endoscopy in Europe, North America, Asia, Africa and Australia. *Digestion* 2010;82:74–6.
- 184 British Society of Gastroenterology. Safety and sedation during endoscopic procedures. 2003. Published by the BSG, available online at [www.bsg.org.uk/pdf\\_word\\_docs/sedation.doc](http://www.bsg.org.uk/pdf_word_docs/sedation.doc)
- 185 Friedrich K, Stremmel W, Sieg A. Endoscopist-administered propofol sedation is safe: a prospective evaluation of 10,000 patients in an outpatient practice. *J Gastrointest Liver Dis* 2012;21:259–63.
- 186 Wernli KJ, Brenner AT, Rutter CM, *et al.* Risks associated with anaesthesia services during colonoscopy. *Gastroenterology* 2016;150:888–94.
- 187 Lord DA, Bell GD, Gray A, *et al.* Sedation for gastrointestinal endoscopic procedures in the elderly: getting safer but still not nearly safe enough. 2006. Published by the BSG, available at [www.bsg.org.uk/pdf\\_word\\_docs/sedation\\_elderly.pdf](http://www.bsg.org.uk/pdf_word_docs/sedation_elderly.pdf)
- 188 Dumonceau JM, Riphaut A, Schreiber F, *et al.* Non-anesthesiologist administration of propofol for gastrointestinal endoscopy: European Society of Gastrointestinal Endoscopy, European Society of Gastroenterology and Endoscopy Nurses and Associates Guideline—Updated June 2015. *Endoscopy* 2015;47:1175–89.
- 189 Seip B, Bretthauer M, Dahler S, *et al.* Patient satisfaction with on-demand sedation for outpatient colonoscopy. *Endoscopy* 2010;42:639–46.
- 190 Ekkelenkamp VE, Dowler K, Valori RM, *et al.* Patient comfort and quality in colonoscopy. *World J Gastroenterol* 2013;19:2355–61.
- 191 Elphick DA, Donnelly MT, Smith KS, *et al.* Factors associated with abdominal discomfort during colonoscopy: a prospective analysis. *Eur J Gastroenterol Hepatol* 2009;21:1076–82.
- 192 Rostom A, Ross ED, Dubé C, *et al.* Development and validation of a nurse-assessed patient comfort score for colonoscopy. *Gastrointest Endosc* 2013;77:255–61.
- 193 Munson GW, Van Norstrand MD, O'Donnell JJ. Intraprocedural evaluation of comfort for sedated outpatient upper endoscopy and colonoscopy: the La Crosse (WI) Intra-endoscopy Sedation Comfort Score. *Gastroenterol Nurs* 2011;34:296–302.
- 194 Bytzer P, Lindeberg B. Impact of an information video before colonoscopy on patient satisfaction and anxiety—a randomized trial. *Endoscopy* 2007;39:710–14.
- 195 Loftus R, Nugent Z, Graff LA, *et al.* Patient satisfaction with the endoscopy experience and willingness to return in a central Canadian health region. *Can J Gastroenterol* 2013;27:259–66.
- 196 Rex DK, Imperiale TF, Portish V. Patients willing to try colonoscopy without sedation: associated clinical factors and results of a randomized controlled trial. *Gastrointest Endosc* 1999;49:554–9.
- 197 Bannert C, Reinhart K, Dunkler D, *et al.* Sedation in screening colonoscopy: impact on quality indicators and complications. *Am J Gastroenterol* 2012;107:1837–48.
- 198 Metwally M, Agresti N, Hale WB, *et al.* Conscious or unconscious: the impact of sedation choice on colon adenoma detection. *World J Gastroenterol* 2011;17:3912–15.
- 199 Paspatis GA, Tribonias G, Manolaraki MM, *et al.* Deep sedation compared with moderate sedation in polyp detection during colonoscopy: a randomized controlled trial. *Colorectal Dis* 2011;13:e137–44.
- 200 Triantafyllou K, Sioulas AD, Kalli T, *et al.* Optimized sedation improves colonoscopy quality long-term. *Gastroenterol Res Pract* 2015;2015:195093.
- 201 Mayr M, Miller A, Gauger U, *et al.* CO<sub>2</sub> versus air insufflation for private practice routine colonoscopy: results of a randomized double blind trial. *Z Gastroenterol* 2012;50:445–8.
- 202 Riss S, Akan B, Mikola B, *et al.* CO<sub>2</sub> insufflation during colonoscopy decreases post-interventional pain in deeply sedated patients: a randomized controlled trial. *Wien Klin Wochenschr* 2009;121:464–8.
- 203 Sajid MS, Caswell J, Bhatti MI, *et al.* Carbon dioxide insufflation vs conventional air insufflation for colonoscopy: a systematic review and meta-analysis of published randomized controlled trials. *Colorectal Dis* 2015;17:111–23.
- 204 Vu HT, Sayuk GS, Hollander TG, *et al.* Resect and discard approach to colon polyps: real-world applicability among academic and community gastroenterologists. *Dig Dis Sci* 2015;60:502–8.
- 205 Wang WL, Wu ZH, Sun Q, *et al.* Meta-analysis: the use of carbon dioxide insufflation vs. room air insufflation for gastrointestinal endoscopy. *Aliment Pharmacol Ther* 2012;35:1145–54.
- 206 Bretthauer M, Lyngge AB, Thiis-Evensen E, *et al.* Carbon dioxide insufflation in colonoscopy: safe and effective in sedated patients. *Endoscopy* 2005;37:706–9.
- 207 Geyer M, Guller U, Beglinger Ch. Carbon dioxide insufflation in colonoscopy is safe: a prospective trial of 347 patients. *Diagn Ther Endosc* 2012;2012:692532.
- 208 Seo EH, Kim TO, Park MJ, *et al.* The efficacy and safety of carbon dioxide insufflation during colonoscopy with consecutive esophagogastroduodenoscopy in moderately sedated outpatients: a randomized, double-blind, controlled trial. *J Clin Gastroenterol* 2013;47:e45–9.
- 209 Yoshida M, Imai K, Hotta K, *et al.* Carbon dioxide insufflation during colorectal endoscopic submucosal dissection for patients with obstructive ventilatory disturbance. *Int J Colorectal Dis* 2014;29:364–71.
- 210 Leung FW, Amato A, Ell C, *et al.* Water-aided colonoscopy: a systematic review. *Gastrointest Endosc* 2012;76:657–66.
- 211 JAG. Trainee certification overview. Secondary trainee certification overview. <http://www.thejag.org.uk/TrainingforEndoscopists/EndoscopyTrainees/TraineeCertification/Overview.aspx>
- 212 ACGME. ACGME RRC for CRS minimum case numbers, 2011. Online presentation, available at [www.acgme.org/portals/0/pfassets/nov6crsphaseii.pdf](http://www.acgme.org/portals/0/pfassets/nov6crsphaseii.pdf)
- 213 Ward ST, Mohammed MA, Walt R, *et al.* An analysis of the learning curve to achieve competency at colonoscopy using the JETS database. *Gut* 2014;63:1476–754.
- 214 Gómez V, Wallace MB. Training and teaching innovations in colonoscopy. *Gastroenterol Clin North Am* 2013;42:659–70.
- 215 Park HJ, Hong JH, Kim HS, *et al.* Predictive factors affecting cecal intubation failure in colonoscopy trainees. *BMC Med Educ* 2013;13:5.
- 216 Sedlack RE. Training to competency in colonoscopy: assessing and defining competency standards. *Gastrointest Endosc* 2011;74:355–66.
- 217 Sedlack RE, Coyle WJ, Obstein KL, *et al.* ASGE's assessment of competency in endoscopy evaluation tools for colonoscopy and EGD. *Gastrointest Endosc* 2014;79:1–7.
- 218 Sedlack RE, Shami VM, Adler DG, *et al.* Colonoscopy core curriculum. *Gastrointest Endosc* 2012;76:482–90.
- 219 Spier BJ, Benson M, Pfau PR, *et al.* Colonoscopy training in gastroenterology fellowships: determining competence. *Gastrointest Endosc* 2010;71:319–24.
- 220 Spier BJ, Durkin ET, Walker AJ, *et al.* Surgical resident's training in colonoscopy: numbers, competency, and perceptions. *Surg Endosc* 2010;24:2556–61.
- 221 Shahidi N, Ou G, Telford J, *et al.* Establishing the learning curve for achieving competency in performing colonoscopy: a systematic review. *Gastrointest Endosc* 2014;80:410–16.
- 222 Walsh CM, Ling SC, Khanna N, *et al.* Gastrointestinal endoscopy competency assessment tool: development of a procedure-specific assessment tool for colonoscopy. *Gastrointest Endosc* 2014;79:798–807.
- 223 Buchner AM, Shahid MW, Heckman MG, *et al.* Trainee participation is associated with increased small adenoma detection. *Gastrointest Endosc* 2011;73:1223–31.
- 224 van Doorn SC, Klanderman RB, Hazewinkel Y, *et al.* Adenoma detection rate varies greatly during colonoscopy training. *Gastrointest Endosc* 2015;82:122–9.
- 225 Harewood GC. Relationship of colonoscopy completion rates and endoscopist features. *Dig Dis Sci* 2005;50:47–51.
- 226 Ko CW, Dominitz JA, Green P, *et al.* Specialty differences in polyp detection, removal, and biopsy during colonoscopy. *Am J Med* 2010;123:528–35.
- 227 Singh H, Penfold RB, DeCoster C, *et al.* Colonoscopy and its complications across a Canadian regional health authority. *Gastrointest Endosc* 2009;69:665–71.
- 228 Atkin WS, Morson BC, Cuzick J. Long-term risk of colorectal cancer after excision of rectosigmoid adenomas. *N Engl J Med* 1992;326:658–62.
- 229 Atkin WS, Saunders BP. Surveillance guidelines after removal of colorectal adenomatous polyps. *Gut* 2002;51(Suppl 5):v6–9.

- 230 Hassan C, Quintero E, Dumonceau JM, *et al.* Post-polypectomy colonoscopy surveillance: European Society of Gastrointestinal Endoscopy (ESGE) Guideline. *Endoscopy* 2013;45:842–51.
- 231 Winawer S, Zauber AG, Fletcher RH, *et al.* Guidelines for colonoscopy surveillance after polypectomy: a consensus update by the US Multi-Society Task Force on Colorectal Cancer and the American Cancer Society. *Gastroenterol* 2006;130:1872–85.
- 232 Deenadayalu VP, Rex DK. Colon polyp retrieval after cold snaring. *Gastrointest Endosc* 2005;62:253–6.
- 233 Miller K, Wayne JD. Polyp retrieval after colonoscopic polypectomy: use of the Roth Retrieval Net. *Gastrointest Endosc* 2001;54:505–7.
- 234 Riley SA. Colonoscopic polypectomy and endoscopic mucosal resection: a practical guide. 2008. published by the BSG, available at [www.bsg.org.uk/pdf\\_word\\_docs/polypectomy\\_08.pdf](http://www.bsg.org.uk/pdf_word_docs/polypectomy_08.pdf)
- 235 Rees CJ, Painter J, Valori R, *et al.* BSG quality and safety indicators for endoscopy. 2007. published by the BSG, available at [www.bsg.org.uk/attachments/170\\_bsg\\_grs\\_indic07.pdf](http://www.bsg.org.uk/attachments/170_bsg_grs_indic07.pdf)
- 236 Ignjatovic A, East JE, Suzuki N, *et al.* Optical diagnosis of small colorectal polyps at routine colonoscopy (Detect InSpect Characterise Resect and Discard; DISCARD trial): a prospective cohort study. *Lancet Oncol* 2009;10:1171–8.
- 237 Brown SR, Baraza W, Hurlstone P. Chromoscopy versus conventional endoscopy for the detection of polyps in the colon and rectum. *Cochrane Database Syst Rev* 2007;(4):1469–93.
- 238 Lopez-Ceron M, Sanabria E, Pellise M. Colonic polyps: is it useful to characterize them with advanced endoscopy? *World J Gastroenterol* 2014;20:8449–57.
- 239 McGill SK, Evangelou E, Ioannidis JP, *et al.* Narrow band imaging to differentiate neoplastic and non-neoplastic colorectal polyps in real time: a meta-analysis of diagnostic operating characteristics. *Gut* 2013;62:1704–13.
- 240 Wanders LK, East JE, Uitenhuis SE, *et al.* Diagnostic performance of narrowed spectrum endoscopy, autofluorescence imaging, and confocal laser endomicroscopy for optical diagnosis of colonic polyps: a meta-analysis. *Lancet Oncol* 2013;14:1337–47.
- 241 Wu L, Li Y, Li Z, *et al.* Diagnostic accuracy of narrow-band imaging for the differentiation of neoplastic from non-neoplastic colorectal polyps: a meta-analysis. *Colorectal Dis* 2013;15:3–11.
- 242 Abu Dayyeh BK, Thosani N, Konda V, *et al.* ASGE Technology Committee systematic review and meta-analysis assessing the ASGE PIVI thresholds for adopting real-time endoscopic assessment of the histology of diminutive colorectal polyps. *Gastrointest Endosc* 2015;81:502.e1–02.e16.
- 243 Longcroft-Wheaton G, Brown J, Cowlishaw D, *et al.* High-definition vs. standard-definition endoscopy with indigo carmine for the in vivo diagnosis of colonic polyps. *United European Gastroenterol J* 2013;1:425–9.
- 244 Schachschal G, Mayr M, Treszl A, *et al.* Endoscopic versus histological characterisation of polyps during screening colonoscopy. *Gut* 2014;63:458–65.
- 245 Rex DK, Kahi C, O'Brien M, *et al.* The American Society for Gastrointestinal Endoscopy PIVI (Preservation and Incorporation of Valuable Endoscopic Innovations) on real-time endoscopic assessment of the histology of diminutive colorectal polyps. *Gastrointest Endosc* 2011;73:419–22.
- 246 Ladabaum U, Fioritto A, Mitani A, *et al.* Real-time optical biopsy of colon polyps with narrow band imaging in community practice does not yet meet key thresholds for clinical decisions. *Gastroenterol* 2013;144:81–91.
- 247 Sharma P, Frye J, Frizelle F. Accuracy of visual prediction of pathology of colorectal polyps: how accurate are we? *ANZ J Surg* 2014;84:365–70.
- 248 Rees CJ, Rajasekhar PT, Wilson A, *et al.* Narrow band imaging optical diagnosis of small colorectal polyps in routine clinical practice: the Detect Inspect Characterise Resect and Discard 2 (DISCARD 2) study. *Gut* Published Online First: 19 Apr 2016. doi:10.1136/gutjnl-2015-310584.
- 249 Bettington M, Walker N, Rosty C, *et al.* Critical appraisal of the diagnosis of the sessile serrated adenoma. *Am J Surg Pathol* 2014;38:158–66.
- 250 Rex DK, Ahnen DJ, Baron JA, *et al.* Serrated lesions of the colorectum: review and recommendations from an expert panel. *Am J Gastroenterol* 2012;107:1315–29.
- 251 Zou B, Wong BCY. Do serrated adenomas have higher malignant potential than traditional adenomas? *J Gastroenterol Hepatol* 2007;22:1701–3.
- 252 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;105:2656–64.
- 253 Payne SR, Church TR, Wandell M, *et al.* Endoscopic detection of proximal serrated lesions and pathologic identification of sessile serrated adenomas/polyps vary on the basis of center. *Clin Gastroenterol Hepatol* 2014;12:1119–26.
- 254 Glatz K, Pritt B, Glatz D, *et al.* A multinational, internet-based assessment of observer variability in the diagnosis of serrated colorectal polyps. *Am J Clin Pathol* 2007;127:938–45.
- 255 Khalid O, Radaideh S, Cummings OW, *et al.* Reinterpretation of histology of proximal colon polyps called hyperplastic in 2001. *World J Gastroenterol* 2009;15:3767–70.
- 256 Singh H, Bay D, Ip S, *et al.* Pathological reassessment of hyperplastic colon polyps in a city-wide pathology practice: implications for polyp surveillance recommendations. *Gastrointest Endosc* 2012;76:1003–8.
- 257 Farris AB, Misdraji J, Srivastava A, *et al.* Sessile serrated adenoma: challenging discrimination from other serrated colonic polyps. *Am J Surg Pathol* 2008;32:30–5.
- 258 Wong NA, Hunt LP, Novelli MR, *et al.* Observer agreement in the diagnosis of serrated polyps of the large bowel. *Histopathology* 2009;55:63–6.
- 259 Yamada M, Sakamoto T, Otake Y, *et al.* Investigating endoscopic features of sessile serrated adenomas/polyps by using narrow-band imaging with optical magnification. *Gastrointest Endosc* 2015;82:108–17.
- 260 IJsepeert JE, Bastiaansen BA, van Leerdam ME, *et al.* Development and validation of the WASP classification system for optical diagnosis of adenomas, hyperplastic polyps and sessile serrated adenomas/polyps. *Gut* 2016;65:963–70.
- 261 Liu S, Ho SB, Krinsky ML. Quality of polyp resection during colonoscopy: are we achieving polyp clearance? *Dig Dis Sci* 2012;57:1786–91.
- 262 Nusko G, Mansmann U, Partzsch U, *et al.* Invasive carcinoma in colorectal adenomas: multivariate analysis of patient and adenoma characteristics. *Endoscopy* 1997;29:626–31.
- 263 Hassan C, Repici A, Sharma P, *et al.* Efficacy and safety of endoscopic resection of large colorectal polyps: a systematic review and meta-analysis. *Gut* 2016;65:806–20.
- 264 Uraoka T, Saito Y, Matsuda T, *et al.* Endoscopic indications for endoscopic mucosal resection of laterally spreading tumours in the colorectum. *Gut* 2006;55:1592–7.
- 265 Chilton A, Rutter M *et al.* Quality assurance guidelines for colonoscopy. NHS BSCP Publication 6. 2010.
- 266 Bugajski M, Kaminski MF, Orłowska J, *et al.* Suspicious macroscopic features of small malignant colorectal polyps. *Scand J Gastroenterol* 2015;50:1261–7.
- 267 Rutter MD, Chattree A, Barbour JA, *et al.* British Society of Gastroenterology/ Association of Coloproctologists of Great Britain and Ireland guidelines for the management of large non-pedunculated colorectal polyps. *Gut* 2015;64:1847–73.
- 268 The Paris endoscopic classification of superficial neoplastic lesions: esophagus, stomach, and colon: November 30 to December 1, 2002. *Gastrointest Endosc* 2003;58(6 Suppl):S3–43.
- 269 Kudo S, Tamura S, Nakajima T, *et al.* Diagnosis of colorectal tumorous lesions by magnifying endoscopy. *Gastrointest Endosc* 1996;44:8–14.
- 270 Neilson LJ, Rutter MD, Saunders BP, *et al.* Assessment and management of the malignant colorectal polyp. *Frontline Gastroenterol* 2015;6:117–26.
- 271 Moss A, Bourke MJ, Williams SJ, *et al.* Endoscopic mucosal resection outcomes and prediction of submucosal cancer from advanced colonic mucosal neoplasia. *Gastroenterol* 2011;140:1909–18.
- 272 Hayashi N, Tanaka S, Hewett DG, *et al.* Endoscopic prediction of deep submucosal invasive carcinoma: validation of the narrow-band imaging international colorectal endoscopic (NICE) classification. *Gastrointest Endosc* 2013;78:625–32.
- 273 Ishiguro A, Uno Y, Ishiguro Y, *et al.* Correlation of lifting versus non-lifting and microscopic depth of invasion in early colorectal cancer. *Gastrointest Endosc* 1999;50:329–33.
- 274 Kobayashi N, Saito Y, Sano Y, *et al.* Determining the treatment strategy for colorectal neoplastic lesions: endoscopic assessment or the non-lifting sign for diagnosing invasion depth? *Endoscopy* 2007;39:701–5.
- 275 Uno Y, Munakata A. The non-lifting sign of invasive colon cancer. *Gastrointest Endosc* 1994;40:485–9.
- 276 Aziz Adam A, Wani S, Kahi C, *et al.* Physician assessment and management of complex colon polyps: a multicenter video-based survey study. *Am J Gastroenterol* 2014;109:1312–24.
- 277 Buchner AM, Guarner-Argente C, Ginsberg GG. Outcomes of EMR of defiant colorectal lesions directed to an endoscopy referral center. *Gastrointest Endosc* 2012;76:255–63.
- 278 Church JM. Avoiding surgery in patients with colorectal polyps. *Dis Colon Rectum* 2003;46:1513–16.
- 279 Friedland S, Banerjee S, Kochar R, *et al.* Outcomes of repeat colonoscopy in patients with polyps referred for surgery without biopsy-proven cancer. *Gastrointest Endosc* 2014;79:101–7.
- 280 Lipof T, Bartus C, Sardella W, *et al.* Preoperative colonoscopy decreases the need for laparoscopic management of colonic polyps. *Dis Colon Rectum* 2005;48:1076–80.
- 281 Voloyiannis T, Snyder MJ, Bailey RR, *et al.* Management of the difficult colon polyp referred for resection: resect or rescope? *Dis Colon Rectum* 2008;51:292–5.
- 282 Desgrappes R, Beauchamp C, Henno S, *et al.* Prevalence and predictive factors of the need for surgery for advanced colorectal adenoma. *Colorectal Dis* 2013;15:683–8.
- 283 Swan MP, Bourke MJ, Alexander S, *et al.* Large refractory colonic polyps: is it time to change our practice? A prospective study of the clinical and economic impact of a tertiary referral colonic mucosal resection and polypectomy service (with videos). *Gastrointest Endosc* 2009;70:1128–36.
- 284 Knabe M, Pohl J, Gerges C, *et al.* Standardized long-term follow-up after endoscopic resection of large, nonpedunculated colorectal lesions: a prospective two-center study. *Am J Gastroenterol* 2014;109:183–9.

- 285 Farhat S, Chaussade S, Ponchon T, *et al.* Endoscopic submucosal dissection in a European setting. A multi-institutional report of a technique in development. *Endoscopy* 2011;43:664–70.
- 286 Jung DH, Youn YH, Kim JH, *et al.* Endoscopic submucosal dissection for colorectal lateral spreading tumors larger than 10 cm: is it feasible? *Gastrointest Endosc* 2015;81:614–20.
- 287 Lang GD, Konda VJ, Siddiqui UD, *et al.* A single-center experience of endoscopic submucosal dissection performed in a Western setting. *Dig Dis Sci* 2015;60:531–6.
- 288 Lee EJ, Lee JB, Lee SH, *et al.* Endoscopic submucosal dissection for colorectal tumors—1,000 colorectal ESD cases: one specialized institute's experiences. *Surg Endosc* 2013;27:31–9.
- 289 Mizushima T, Kato M, Iwanaga I, *et al.* Technical difficulty according to location, and risk factors for perforation, in endoscopic submucosal dissection of colorectal tumors. *Surg Endosc* 2015;29:133–9.
- 290 Nishiyama H, Isomoto H, Yamaguchi N, *et al.* Endoscopic submucosal dissection for colorectal epithelial neoplasms. *Dis Colon Rectum* 2010;53:161–8.
- 291 Ozawa S, Tanaka S, Hayashi N, *et al.* Risk factors for vertical incomplete resection in endoscopic submucosal dissection as total excisional biopsy for submucosal invasive colorectal carcinoma. *Int J Colorectal Dis* 2013;28:1247–56.
- 292 Probst A, Golger D, Anthuber M, *et al.* Endoscopic submucosal dissection in large sessile lesions of the rectosigmoid: learning curve in a European center. *Endoscopy* 2012;44:660–7.
- 293 Rahmi G, Hotayt B, Chaussade S, *et al.* Endoscopic submucosal dissection for superficial rectal tumors: prospective evaluation in France. *Endoscopy* 2014;46:670–6.
- 294 Repici A, Hassan C, De Paula Pessoa D, *et al.* Efficacy and safety of endoscopic submucosal dissection for colorectal neoplasia: a systematic review. *Endoscopy* 2012;44:137–50.
- 295 Repici A, Hassan C, Pagano N, *et al.* High efficacy of endoscopic submucosal dissection for rectal laterally spreading tumors larger than 3 cm. *Gastrointest Endosc* 2013;77:96–101.
- 296 Spychalski M, Dziki A. Safe and efficient colorectal endoscopic submucosal dissection in European settings: is successful implementation of the procedure possible? *Dig Endosc* 2015;27:368–73.
- 297 Takeuchi Y, Iishi H, Tanaka S, *et al.* Factors associated with technical difficulties and adverse events of colorectal endoscopic submucosal dissection: retrospective exploratory factor analysis of a multicenter prospective cohort. *Int J Colorectal Dis* 2014;29:1275–84.
- 298 Tanaka S, Oka S, Kaneko I, *et al.* Endoscopic submucosal dissection for colorectal neoplasia: possibility of standardization. *Gastrointest Endosc* 2007;66:100–7.
- 299 Yoda Y, Ikematsu H, Matsuda T, *et al.* A large-scale multicenter study of long-term outcomes after endoscopic resection for submucosal invasive colorectal cancer. *Endoscopy* 2013;45:718–24.
- 300 Ikematsu H, Yoda Y, Matsuda T, *et al.* Long-term outcomes after resection for submucosal invasive colorectal cancers. *Gastroenterology* 2013;144:551–9.
- 301 Gunderson LL, Jessup JM, Sargent DJ, *et al.* Revised tumor and node categorization for rectal cancer based on surveillance, epidemiology, and end results and rectal pooled analysis outcomes. *J Clin Oncol* 2010;28:256–63.
- 302 Bosch SL, Teerenstra S, de Wilt JHW, *et al.* Predicting lymph node metastasis in pT1 colorectal cancer: a systematic review of risk factors providing rationale for therapy decisions. *Endoscopy* 2013;45:827–41.
- 303 McArthur CS, Roayaie S, Wayne JD. Safety of preoperation endoscopic tattoo with India ink for identification of colonic lesions. *Surg Endosc* 1999;13:543–6.
- 304 Ponsky JL, King JF. Endoscopic marking of colonic lesions. *Gastrointest Endosc* 1975;22:42–3.
- 305 Hyman N, Wayne JD. Endoscopic four quadrant tattoo for the identification of colonic lesions at surgery. *Gastrointest Endosc* 1991;37:56–8.
- 306 Shatz BA, Thavorides V. Colonic tattoo for follow-up of endoscopic sessile polypectomy. *Gastrointest Endosc* 1991;37:59–60.
- 307 Sawaki A, Nakamura T, Suzuki T, *et al.* A two-step method marking polypectomy sites in the colon and rectum. *Gastrointest Endosc* 2003;57:735–7.
- 308 Lieberman DA, Rex DK, Winawer SJ, *et al.* Guidelines for colonoscopy surveillance after screening and polypectomy: a consensus update by the US multi-society task force on colorectal cancer. *Gastroenterology* 2012;143:844–57.
- 309 Loberg M, Kalager M, Holme O, *et al.* Long-term colorectal-cancer mortality after adenoma removal. *N Engl J Med* 2014;371:799–807.
- 310 Cottet V, Jooste V, Fournel I, *et al.* Long-term risk of colorectal cancer after adenoma removal: a population-based cohort study. *Gut* 2012;61:1180–6.
- 311 Saini SD, Kim HM, Schoenfeld P. Incidence of advanced adenomas at surveillance colonoscopy in patients with a personal history of colon adenomas: a meta-analysis and systematic review. *Gastrointest Endosc* 2006;64:614–26.
- 312 Seo JY, Chun J, Lee C, *et al.* Novel risk stratification for recurrence after endoscopic resection of advanced colorectal adenoma. *Gastrointest Endosc* 2015;81:655–64.
- 313 Stock C, Hoffmeister M, Birkner B, *et al.* Performance of additional colonoscopies and yield of neoplasms within 3 years after screening colonoscopy: a historical cohort study. *Endoscopy* 2013;45:537–46.
- 314 Fine KD, Seidel RH, Do K. The prevalence, anatomic distribution, and diagnosis of colonic causes of chronic diarrhea. *Gastrointest Endosc* 2000;51:318.
- 315 Lindstrom CG. 'Collagenous colitis' with watery diarrhoea—a new entity? *Pathol Eur* 1976;11:87.
- 316 Münch A, Aust D, Bohr J, *et al.* Microscopic colitis: current status, present and future challenges: statements of the European Microscopic Colitis Group. *J Crohns Colitis* 2012;6:932–45.
- 317 Thomas PD, Forbes A, Green J, *et al.* Guidelines for the investigation of chronic diarrhoea, 2nd edition. *Gut* 2003;52(Suppl 5):v1–15.
- 318 Carpenter HA, Tremaine WJ, Batts KP, *et al.* Sequential histologic evaluations in collagenous colitis. Correlations with disease behavior and sampling strategy. *Dig Dis Sci* 1992;37:1903–9.
- 319 Pardi DS, Loftus EV, Smyrk TC, *et al.* The epidemiology of microscopic colitis: a population based study in Olmsted County, Minnesota. *Gut* 2007;56:504–8.
- 320 Tanaka M, Mazzoleni G, Riddell RH. Distribution of collagenous colitis: utility of flexible sigmoidoscopy. *Gut* 1992;33:65–70.
- 321 Williams JJ, Beck PL, Andrews CN, *et al.* Microscopic colitis—a common cause of diarrhoea in older adults. *Age Ageing* 2010;39:162–8.
- 322 Htouras A, Collins P, Speake W, *et al.* Diagnostic yield and economic implications of endoscopic colonic biopsies in patients with chronic diarrhoea. *Colorectal Dis* 2012;14:965–8.
- 323 Sanduleanu S, le Clercq CMC, Dekker E, *et al.* Definition and taxonomy of interval colorectal cancers: a proposal for standardising nomenclature. *Gut* 2015;64:1257–67.
- 324 Valori R. Rates of post colonoscopy colorectal cancer are significantly affected by methodology, but are nevertheless declining steadily in the English National Health Service [Abstract]. *United Eur Gastroenterol J* 2013;1(1 Suppl):A69.
- 325 Baxter NN, Goldwasser MA, Paszat LF, *et al.* Association of colonoscopy and death from colorectal cancer. *Ann Intern Med* 2009;150:1–8.
- 326 Brenner H, Chang-Claude J, Jansen L, *et al.* Role of colonoscopy and polyp characteristics in colorectal cancer after colonoscopic polyp detection: a population-based case-control study. *Ann Intern Med* 2012;157:225–32.
- 327 Brenner H, Chang-Claude J, Seiler CM, *et al.* Protection from colorectal cancer after colonoscopy: a population-based, case-control study. *Ann Intern Med* 2011;154:22–30.
- 328 Bressler B, Paszat LF, Vinden C, *et al.* Colonoscopic miss rates for right-sided colon cancer: a population-based analysis. *Gastroenterology* 2004;127:452–6.
- 329 Farrar WD, Sawhney MS, Nelson DB, *et al.* Colorectal cancers found after a complete colonoscopy. *Clin Gastroenterol Hepatol* 2006;4:1259–64.
- 330 Imperiale TF, Glowinski EA, Lin-Cooper C, *et al.* Five-year risk of colorectal neoplasia after negative screening colonoscopy. *N Engl J Med* 2008;359:1218–24.
- 331 Leaper M, Johnston MJ, Barclay M, *et al.* Reasons for failure to diagnose colorectal carcinoma at colonoscopy. *Endoscopy* 2004;36:499–503.
- 332 Pabby A, Schoen RE, Weissfeld JL, *et al.* Analysis of colorectal cancer occurrence during surveillance colonoscopy in the dietary polyp prevention trial. *Gastrointest Endosc* 2005;61:385–91.
- 333 Pohl H, Robertson DJ. Colorectal cancers detected after colonoscopy frequently result from missed lesions. *Clin Gastroenterol Hepatol* 2010;8:858–64.
- 334 Robertson DJ, Lieberman DA, Winawer SJ, *et al.* Colorectal cancers soon after colonoscopy: a pooled multicohort analysis. *Gut* 2014;63:949–56.
- 335 Samadder NJ, Curtin K, Tuohy TM, *et al.* Characteristics of missed or interval colorectal cancer and patient survival: a population-based study. *Gastroenterology* 2014;146:950–60.
- 336 Singh H, Nugent Z, Mahmud SM, *et al.* Predictors of colorectal cancer after negative colonoscopy: a population-based study. *Am J Gastroenterol* 2010;105:663–73.
- 337 Singh H, Turner D, Xue L, *et al.* Risk of developing colorectal cancer following a negative colonoscopy examination: evidence for a 10-year interval between colonoscopies. *JAMA* 2006;295:2366–73.
- 338 Singh S, Singh PP, Murad MH, *et al.* Prevalence, risk factors, and outcomes of interval colorectal cancers: a systematic review and meta-analysis. *Am J Gastroenterol* 2014;109:1375–89.
- 339 Gotfried J, Bernstein M, Ehrlich AC, *et al.* Administrative Database Research Overestimates the Rate of Interval Colon Cancer. *J Clin Gastroenterol* 2015;49:483–90.
- 340 Sanduleanu S, Masclee AM, Meijer GA. Interval cancers after colonoscopy—insights and recommendations. *Nat Rev Gastroenterol Hepatol* 2012;9:550–4.
- 341 Chiu SY, Chuang SL, Chen SL, *et al.* Faecal haemoglobin concentration influences risk prediction of interval cancers resulting from inadequate colonoscopy quality: analysis of the Taiwanese Nationwide Colorectal Cancer Screening Program. *Gut* Published Online First: 29 Oct 2015. doi:10.1136/gutjnl-2015-310256.
- 342 Kahi CJ, Imperiale TF, Juliar BE, *et al.* Effect of screening colonoscopy on colorectal cancer incidence and mortality. *Clin Gastroenterol Hepatol* 2009;7:770–5.
- 343 Rondagh EJA, NBouwens MWE, Riedl RG, *et al.* Endoscopic appearance of proximal colorectal neoplasms and potential implications for colonoscopy in cancer prevention. *Gastrointest Endosc* 2012;75:1218–25.
- 344 Fisher DA, Maple JT, Ben-Menachem T, *et al.* Complications of colonoscopy. *Gastrointest Endosc* 2011;74:745–52.

- 345 Niv Y, Hazazi R, Levi Z, *et al.* Screening colonoscopy for colorectal cancer in asymptomatic people: a meta-analysis. *Dig Dis Sci* 2008;2008:3049–54.
- 346 Adler A, Lieberman D, Ainalai A, *et al.* Data quality of the German screening colonoscopy registry. *Endoscopy* 2013;45:813–8.
- 347 Bokemeyer B, Bock H, Hüppe D, *et al.* Screening colonoscopy for colorectal cancer prevention: results from a German online registry on 269000 cases. *Eur J Gastroenterol Hepatol* 2009;21:650–5.
- 348 Kang HY, Kang HW, Kim SG, *et al.* Incidence and management of colonoscopic perforations in Korea. *Digestion* 2008;78:218–23.
- 349 Ko CW, Riffle S, Michaels L, *et al.* Serious complications within 30 days of screening and surveillance colonoscopy are uncommon. *Clin Gastroenterol Hepatol* 2010;8:166–73.
- 350 Pox CP, Altenhofen L, Brenner H, *et al.* Efficacy of a nationwide screening colonoscopy program for colorectal cancer. *Gastroenterol* 2012;142:1460–67.e2.
- 351 Sieg A, Hachmoeller-Eisenbach U, Eisenbach T. Prospective evaluation of complications in outpatient GI endoscopy: a survey among German gastroenterologists. *Gastrointest Endosc* 2001;53:620–7.
- 352 Warren JL, Klabunde CN, Mariotto AB, *et al.* Adverse events after outpatient colonoscopy in the Medicare population. *Ann Intern Med* 2009;150:849–57.
- 353 Zubarik R, Fleischer DE, Mastropietro C, *et al.* Prospective analysis of complications 30 days after outpatient colonoscopy. *Gastrointest Endosc* 1999;50:322–8.
- 354 Stock C, Ihle P, Sieg A, *et al.* Adverse events requiring hospitalization within 30 days after outpatient screening and nonscreening colonoscopies. *Gastrointest Endosc* 2013;77:419–29.
- 355 Panteris V, Haringsma J, Kuipers EJ. Colonoscopy perforation rate, mechanisms and outcome: from diagnostic to therapeutic colonoscopy. *Endoscopy* 2009;41:941–51.
- 356 Silvis SE, Nebel O, Rogers G, *et al.* Endoscopic complications. Results of the 1974 American Society for Gastrointestinal Endoscopy Survey. *JAMA* 1976;235:928–30.
- 357 Rutter MD, Nickerson C, Rees CJ, *et al.* Risk factors for adverse events related to polypectomy in the English Bowel Cancer Screening Programme. *Endoscopy* 2014;46:90–7.
- 358 Gondal G, Grotmol T, Hofstad B, *et al.* The Norwegian Colorectal Cancer Prevention (NORCCAP) Screening Study: baseline findings and implementations for clinical work-up in age groups 50–64 years. *Scand J Gastroenterol* 2003;38:635–42.
- 359 Heldwein W, Dollhopf M, Rösch T, *et al.* The Munich Polypectomy Study (MUPS): prospective analysis of complications and risk factors in 4000 colonic snare polypectomies. *Endoscopy* 2005;37:1116–22.
- 360 Levin TR, Zhao W, Conell C, *et al.* Complications of colonoscopy in an integrated health care delivery system. *Ann Intern Med* 2006;145:880–6.
- 361 Rosen L, Bub DS, Reed JF, *et al.* Hemorrhage following colonoscopic polypectomy. *Dis Colon Rectum* 1993;36:1126–31.
- 362 Kim HS, Kim TI, Kim WH, *et al.* Risk factors for immediate postpolypectomy bleeding of the colon: a multicenter study. *Am J Gastroenterol* 2006;101:1333–41.
- 363 Saraya T, Ikematsu H, Fu KI, *et al.* Evaluation of complications related to therapeutic colonoscopy using the bipolar snare. *Surg Endosc* 2012;26:533–40.
- 364 Buddingh KT, Herngreen T, Haringsma J, *et al.* Location in the right hemi-colon is an independent risk factor for delayed post-polypectomy hemorrhage: a multi-center case-control study. *Am J Gastroenterol* 2011;106:1119–24.
- 365 Consolo P, Luigiano C, Strangio G, *et al.* Efficacy, risk factors and complications of endoscopic polypectomy: ten year experience at a single center. *World J Gastroenterol* 2008;14:2364–9.
- 366 Gimeno-García AZ, de Ganzo ZA, Sosa AJ, *et al.* Incidence and predictors of postpolypectomy bleeding in colorectal polyps larger than 10 mm. *Eur J Gastroenterol Hepatol* 2012;24:520–6.
- 367 Sawhney MS, Salfiti N, Nelson DB, *et al.* Risk factors for severe delayed postpolypectomy bleeding. *Endoscopy* 2008;40:115–19.
- 368 Watabe H, Yamaji Y, Okamoto M, *et al.* Risk assessment for delayed hemorrhagic complication of colonic polypectomy: polyp-related factors and patient-related factors. *Gastrointest Endosc* 2006;64:73–8.
- 369 Choo WK, Subhani J. Complication rates of colonic polypectomy in relation to polyp characteristics and techniques: a district hospital experience. *J Interv Gastroenterol* 2012;2:8–11.
- 370 Rutter MD, Senore C, Bisschops R, *et al.* The European Society of Gastrointestinal Endoscopy Quality Improvement Initiative: developing performance measures. *Endoscopy* 2016;48:81–9.
- 371 van Doorn SC, van Vliet J, Fockens P, *et al.* A novel colonoscopy reporting system enabling quality assurance. *Endoscopy* 2014;46:181–7.