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A new composite measure of colonoscopy: the Performance Indicator of Colonic Intubation (PICI)

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submitted 14.1.2017
accepted after revision 26.6.2017

Bibliography
DOI https://doi.org/10.1055/s-0043-115897
Published online: 28.7.2017 | Endoscopy 2018; 50: 40–51

ISSN 0013-726X

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Appendix e1, e2
Online content viewable at:
https://doi.org/10.1055/s-0043-115897

ABSTRACT

Background and study aim Cecal intubation rate (CIR) is an established performance indicator of colonoscopy. In some patients, cecal intubation with acceptable tolerance is only achieved with additional sedation. This study proposes a composite Performance Indicator of Colonic Intubation (PICI), which combines CIR, comfort, and sedation.

Methods Data from 20 085 colonoscopies reported in the 2011 UK national audit were analyzed. PICI was defined as the percentage of procedures achieving cecal intubation with median dose (2 mg) of midazolam or less, and nurse-assessed comfort score of 1 – 3/5. Multivariate logistic regression analysis evaluated possible associations between PICI and patient, unit, colonoscopist, and diagnostic factors.

Results PICI was achieved in 54.1 % of procedures. PICI identified factors affecting performance more frequently than single measures such as CIR and polyp detection, or CIR + comfort alone. Older age, male sex, adequate bowel preparation, and a positive fecal occult blood test as indication were associated with a higher PICI. Unit accreditation, the presence of magnetic imagers in the unit, greater annual volume, fewer years' experience, and higher training/trainer status were associated with higher PICI rates. Procedures in which PICI was achieved were associated with significantly higher polyp detection rates than when PICI was not achieved.

Conclusions PICI provides a simpler picture of performance of colonoscopic intubation than separate measures of CIR, comfort, and sedation. It is associated with more factors that are amenable to change that might improve performance and with higher likelihood of polyp detection. It is proposed that PICI becomes the key performance indicator for intubation of the colon in colonoscopy quality improvement initiatives.

Introduction

Colonoscopy is the gold standard investigation of the colon for patients with symptoms and in many countries it is used for colorectal cancer screening. The quality of colonoscopy is important because poor quality colonoscopy is associated with more frequent adverse outcomes, such as missed cancers [1, 2] and complications. To monitor and improve performance, surrogate performance indicators for colonoscopy are necessary, as adverse outcomes are infrequent and difficult to capture reliably.

There are three components to colonoscopy: safe and comfortable intubation of the cecum; identification of polyps and other pathology; and safe and complete removal of polyps. Cecal intubation rate (CIR) is the traditional performance measure of cecal intubation, but it fails to take account of other variables that might reflect safety and experience, such as patient comfort and sedation.

A desire to achieve a high CIR in combination with suboptimal technique can result in pushing harder to reach the cecum, making the procedure more uncomfortable and possibly less safe. The increasing popularity of propofol suggests that patient tolerance of colonoscopy is an important barrier to widespread patient acceptance of conscious sedation for colonoscopy. However, propofol increases costs [3], and although some of these will be offset by faster colonoscopy (the colonoscopist is not constrained by patient pain) and quicker recovery (patients spend less time recovering than from benzodiazepine sedation), propofol sedation will remain unaffordable in countries where an anesthetist is required to administer it.

In response to concerns about the impact on safety, comfort, and sedation of using an unadjusted CIR as a key performance indicator, the UK Joint Advisory Group on Gastrointestinal Endoscopy (JAG) has required all endoscopy units in the UK to monitor safety, sedation, and patient comfort for all colonoscopies [4]. This study proposes a new measure of colonic intubation, termed the Performance Indicator of Colonic Intubation (PICI), which combines three key parameters of colonic intubation: CIR, sedation, and patient comfort. The data from a national audit of colonoscopy [5] performed in the UK in 2011 were used to develop an initial standard and to test the utility of this measure to assess performance. Data from a single hospital endoscopy service were then analyzed to explore how the PICI might be used in practice and to recommend potential performance targets.

Methods

The methodology and headline results of the 2011 UK national colonoscopy audit were published in 2013 [5]. All National Health Service units performing > 100 colonoscopies per year agreed to participate. All colonoscopists in these units and all adult colonoscopies performed during a 2-week period in March 2011 were recorded on a web-based database. Patient and case mix variables (age, sex, inpatient/outpatient procedure, primary indication for colonoscopy, and quality of bowel preparation), endoscopy unit factors (accreditation status, presence of imaging facilities), and colonoscopist variables (experience and training attainment) were captured. The "presence/absence of a trainer" was a marker of training occurring: if a trainer was present, then a trainee did all or part of that procedure. The "trainee/independent" status indicated whether or not the person doing the procedure was still in a training role.

Accreditation, administered by JAG, occurs on a 5-year cycle and involves a peer-review process that assesses performance against a predetermined set of standards [6].

Colonoscopy performance indicators included CIR, sedation, polyp detection, and nurse-assessed patient comfort using the Gloucester comfort scale [7]. The vast majority of patients received a combination of an opiate and midazolam [5]. It is common practice in the UK and many other countries for the patient to receive an opiate followed by midazolam at the outset of colonoscopy. If more medication is required, midazolam is usually given in preference to more opiate, even though midazolam does not have inherent analgesic properties.

In the absence (at the time) of a validated comfort score for colonoscopy, the Gloucester comfort scale was selected because it was in common use throughout the UK in 2011, and because it correlates well with a simple measure of patient experience [7]. The scale has five levels and assesses three components of discomfort: severity, frequency, and impact on the patient (distress):

1. No discomfort – Talking and comfortable throughout
2. Minimal discomfort – 1 or 2 episodes of mild discomfort with no distress
3. Mild discomfort – More than 2 episodes of discomfort without distress
4. Moderate discomfort – Significant discomfort experienced several times with some distress
5. Severe discomfort – Frequent discomfort with significant distress

The principal diagnosis was noted. The data were validated for completeness and accuracy [5].

Statistical analysis

Achievement of PICI was defined as the proportion of all procedures in the audit that achieved cecal intubation AND less than or equal to the median dose of midazolam (2 mg) AND a nurse-assessed comfort score of 1 – 3 ("comfortable" to "mild discomfort"). PICI is a binary indicator. Procedures in which PICI was not achieved are those in which one or more of the three components of the indicator were not met. Thus:

$$\text{PICI\%} = \frac{\text{procedures with cecal intubation AND comfort score 1–3 AND} \leq \text{2mg midazolam}}{\text{all procedures}}$$

PICI was compared with three further indicators of colonoscopy performance: CIR alone; CIR + comfort score 1 – 3; and polyp detection rate (PDR > 1). In all analyses, CIR was adjusted for examinations not completed because of obstructing lesions.

As all predictor variables were categorical, analysis was based on a comparison of the characteristics of procedures in which the PICI was achieved vs. those in which it was not

achieved. Multivariate binary logistic regression assessed patient, unit, and colonoscopist variables in order to derive odds ratios (ORs) and 95 % confidence intervals (CIs) for those that were independently associated with PICI after controlling for the effects of all other model variables. Regression analysis used the forward entry procedure, in which all variables were retained in the model regardless of statistical significance or individual contribution to the model. All ORs and CIs cited in the analysis were adjusted estimates from multiple logistic regression. To correct for multiple comparisons, a pragmatic reduction in the *P* value considered to indicate statistical significance was adopted (alpha 0.01).

Sensitivity of PICI as a performance indicator

Sensitivity in this context referred to whether PICI was more likely to find differences in performance for the variables captured in the study compared with the other three indicators (CIR, CIR + comfort, and PDR > 1). The data comprised 4 variables related to the patient (age, sex, procedure type, indication) and 10 variables related to the unit or the colonoscopist (bowel preparation, country, accreditation, +/– imager, consultant status, professional group, colonoscopy and training experience, and whether training was occurring). Subgroup analysis was carried out for the variables most likely to be modifiable by change in practice (i. e. 10 unit and colonoscopist variables comprising 25 subgroups).

Relationship of PICI to polyp detection

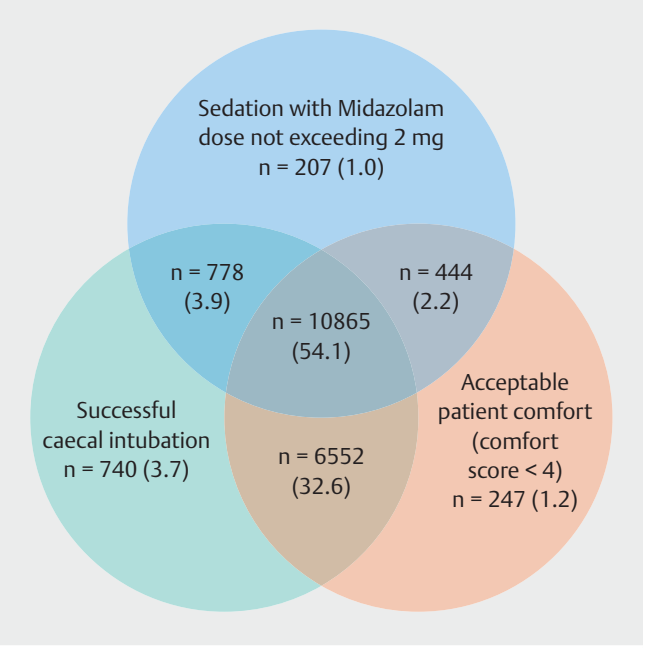
This analysis examined, on a case-by-case basis, whether PICI was achieved and whether a polyp(s) was found, and expresses the relationship in terms of an OR – the relative likelihood of finding polyps if PICI was achieved. There are three analyses: one for one or more polyps; one for 2 (the median) or more polyps; and one for cancer. All analyses were adjusted for other variables that might independently be associated with PICI, PDR, and cancer.

Statistical analysis was undertaken using SPSS version 21 (IBM Corp., Armonk, New York, USA).

Single-site composite cecal intubation rate

Colonoscopy performance data across four sites in Gloucestershire (population 550 000) were collected on a single sequel-based reporting system [7], which contained two data fields (extent of procedure and midazolam dose) that were required to create the PICI. Data were entered immediately following procedures and both fields had to be completed before a report could be generated. Nurse-assessed comfort was recorded separately on the hospital patient administration system. Data from the two databases were combined into a single database [7], which was updated every night to produce real-time performance outputs for colonoscopists, which included PICI from January 2014.

Data were presented on all colonoscopies occurring between 1st January and 31st December 2013 inclusive. In order to provide an accurate reflection of the relationship between volume of procedures and PICI, only data from colonoscopists performing colonoscopy for the entire 1-year period were included in the analysis.



▶ **Fig. 1** Number and proportion of procedures comprising each facet of the Performance Indicator of Colonic Intubation. (In 252 procedures [1.3 %], none of the three quality indicators was achieved.)

Results

Performance data were captured from 20 085 colonoscopies during the 2-week audit, representing 94.1 % of all NHS procedures performed during this time [5].

The criteria for achieving PICI were met in 54.1 % of procedures (n = 10 865) (▶ **Fig. 1**). Procedures undertaken in older patients, males, and in those where the quality of bowel preparation was "adequate" or "excellent" were significantly associated with PICI achievement (comparison of proportions tests all significant to the $P < 0.001$ level, see supplementary ▶ **Table e1**, available online). For all unit and endoscopist variables (with the exception of independent/trainee status of the endoscopist, and presence/absence of a trainer during the procedure), there was a statistically significant difference in the proportion of procedures that achieved PICI (see supplementary ▶ **Table e2**, available online). In all, PICI was achieved in 60.0 % of procedures undertaken in JAG-accredited endoscopy units (vs. 45.4 % in nonaccredited units), 57.9 % of procedures undertaken in units with two or more imagers, and 62.3 % of procedures undertaken by practitioners with course faculty status.

▶ **Table 3** Multivariate modeling – subgroups associated with achievement of the Performance Indicator of Colonic Intubation.

Variable[1]	OR (95 %CI)	*P* value[2]
Patient age		
▪ <50 years	0.38 (0.35 to 0.41)	**<0.001**
▪ 50 – 59 years	0.49 (0.45 to 0.54)	**<0.001**
▪ 60 – 69 years	0.61 (0.56 to 0.66)	**<0.001**
▪ 70 +	Reference	
Patient sex		
▪ Male	1.40 (1.32 to 1.49)	**<0.001**
▪ Female	Reference	
Procedure type		
▪ Inpatient	Reference	
▪ Outpatient	0.98 (0.86 to 1.13)	0.78
Procedure indication		
▪ Diagnostic	Reference	
▪ Surveillance	1.09 (1.00 to 1.18)	**0.04**
▪ BCSP	1.88 (1.66 to 2.12)	**<0.001**
▪ Screening	1.11 (0.95 to 1.29)	0.19
▪ Therapeutic	0.87 (0.74 to 1.03)	0.10
Bowel preparation		
▪ Poor	Reference	
▪ Adequate	1.43 (1.30 to 1.58)	**<0.001**
▪ Excellent	1.63 (1.48 to 1.80)	**<0.001**
Country		
▪ England	Reference	
▪ Scotland	0.38 (0.34 to 0.43)	**<0.001**
▪ Wales	1.52 (1.27 to 1.81)	**<0.001**
▪ Northern Ireland	1.11 (0.95 to 1.30)	0.19
Unit JAG accreditation status		
▪ Accredited	1.26 (1.16 to 1.35)	**<0.001**
▪ Not accredited	Reference	
Imagers per unit		
▪ None	Reference	
▪ One	1.27 (1.18 to 1.37)	**<0.001**
▪ Two or more	1.29 (1.19 to 1.40)	**<0.001**
Professional group of colonoscopist		
▪ Physician	Reference	
▪ Surgeon	1.10 (1.03 to 1.18)	**0.008**
▪ Nurse	1.09 (0.98 to 1.22)	0.12
▪ SAS	1.26 (1.06 to 1.51)	**0.009**
▪ General practitioner	0.83 (0.63 to 1.10)	0.20

▶ **Table 3** (Continuation)

Variable[1]	OR (95 %CI)	*P* value[2]
Independent/trainee colonoscopist		
▪ Independent	1.12 (0.95 to 1.31)	0.17
▪ Trainee	Reference	
Number of years independent		
▪ 0 – 3	Reference	
▪ 3 – 5	1.06 (0.94 to 1.19)	0.36
▪ 5 – 10	0.70 (0.63 to 0.78)	**<0.001**
▪ 10 – 20	0.72 (0.65 to 0.80)	**<0.001**
▪ 20 +	0.67 (0.58 to 0.76)	**<0.001**
Annual number of colonoscopies		
▪ < 100	Reference	
▪ 100 – 199	1.00 (0.91 to 1.10)	0.97
▪ 200 – 299	1.14 (1.03 to 1.26)	**0.01**
▪ 300 – 499	1.28 (1.15 to 1.42)	**<0.001**
▪ 500 +	1.13 (1.00 to 1.29)	0.06
Highest level of training		
▪ None	Reference	
▪ Skills	1.16 (1.04 to 1.28)	**0.005**
▪ TCT	1.33 (1.21 to 1.47)	**<0.001**
▪ Faculty	1.74 (1.57 to 1.92)	**<0.001**
Presence or absence of trainer		
▪ Yes	Reference	
▪ No	0.99 (0.92 to 1.06)	0.73

OR, odds ratio; CI, confidence interval; BCSP, Bowel Cancer Screening Programme; JAG, Joint Advisory Group on Gastrointestinal Endoscopy; SAS, specialist practitioner; TCT, "Train the colonoscopy trainer" course.
[1] 216 procedures excluded from multivariate model owing to missing data (model based on data from 19 869 procedures).
[2] Bold *P* values indicate statistically significant findings at the *P* = 0.01 level.

Multivariate modeling of variables associated with achieving PICI

▶ **Table 3** outlines the ORs, 95 %CIs, and *P* values for all variables in a multivariate model. ORs indicate the likelihood that a given subgroup will be associated with achievement of PICI compared with the relevant "reference" group.

All patient and case mix subgroups were associated with a statistically significant likelihood of achieving PICI, with the exception of procedure type. PICI was significantly more likely to be achieved in procedures undertaken in older patients, males, and those undertaken following a positive fecal occult blood test. For the other variables, adequate or excellent bowel preparation, country, unit JAG accreditation, having one or more imagers in the unit, procedures carried out by surgeons or specialist practitioners, fewer years' experience, greater annual volume, and course participation (including course faculty status) were associated with a significantly higher likelihood of achieving PICI.

There were some important negative findings. There was no statistical difference when independent practitioners were compared with independent trainees. Similarly, trainer presence, indicating that training was occurring, did not show a significant difference.

Multivariate modeling of variables associated with achieving the CIR + comfort indicator

▶ **Table 4** outlines the multivariate modeling for CIR + comfort level 1 – 3, excluding the influence of sedation. In all, 86.7 % of procedures (n = 17 417) met the criteria for the CIR + comfort indicator. The direction of the association compared with PICI was reversed for two subgroups: procedures undertaken in Wales were significantly more likely to achieve PICI than those

▶ **Table 4** Multivariate modeling – subgroups associated with achievement of combined cecal intubation rate plus comfort indicator.

Variable[1]	OR (95 %CI)	*P* value[2]
Patient age		
▪ < 50 years	0.96 (0.85 to 1.08)	0.56
▪ 50 – 59 years	1.08 (0.95 to 2.23)	0.23
▪ 60 – 69 years	0.96 (0.86 to 1.08)	0.52
▪ 70 + years	Reference	
Patient sex		
▪ Male	1.99 (1.83 to 2.18)	**< 0.001**
▪ Female	Reference	
Procedure type		
▪ Inpatient	Reference	
▪ Outpatient	1.38 (1.17 to 1.63)	**< 0.001**
Procedure indication		
▪ Diagnostic	Reference	
▪ Surveillance	1.38 (1.22 to 1.56)	**< 0.001**
▪ BCSP	1.53 (1.26 to 1.86)	**< 0.001**
▪ Screening	1.22 (0.97 to 1.55)	0.09
▪ Therapeutic	1.07 (0.84 to 1.36)	0.61
Bowel preparation		
▪ Poor	Reference	
▪ Adequate	2.86 (2.55 to 3.20)	**< 0.001**
▪ Excellent	3.41 (3.03 to 3.84)	**< 0.001**
Country		
▪ England	Reference	
▪ Scotland	0.83 (0.71 to 0.96)	0.01
▪ Wales	0.70 (0.56 to 0.88)	**0.002**
▪ Northern Ireland	1.46 (1.14 to 1.88)	**0.003**
Unit JAG accreditation status		
▪ Accredited	1.07 (0.96 to 1.19)	0.22
▪ Not accredited	Reference	
Imagers per unit		
▪ None	Reference	
▪ One	1.07 (0.96 to 1.18)	0.23
▪ Two or more	1.15 (1.02 to 1.29)	0.02
Professional group of colonoscopist		
▪ Physician	Reference	
▪ Surgeon	0.80 (0.72 to 0.88)	**< 0.001**
▪ Nurse	0.79 (0.67 to 0.93)	**0.004**
▪ SAS	0.76 (0.60 to 0.97)	0.03
▪ General practitioner	1.12 (0.73 to 1.73)	0.60

▶ **Table 4** (Continuation)

Variable[1]	OR (95 %CI)	*P* value[2]
Independent/trainee colonoscopist		
▪ Independent	0.94 (0.75 to 1.18)	0.58
▪ Trainee	Reference	
Number of years independent		
▪ 0 – 3	Reference	
▪ 3 – 5	1.08 (0.91 to 1.28)	0.36
▪ 5 – 10	0.96 (0.83 to 1.10)	0.54
▪ 10 – 20	1.03 (0.88 to 1.19)	0.74
▪ 20 +	0.88 (0.73 to 1.06)	0.18
Annual number of colonoscopies		
▪ < 100	Reference	
▪ 100 – 199	1.06 (0.93 to 1.20)	0.38
▪ 200 – 299	1.15 (0.99 to 1.31)	0.06
▪ 300 – 499	1.38 (1.19 to 1.60)	**< 0.001**
▪ 500 +	1.93 (1.59 to 2.34)	**< 0.001**
Highest level of training		
▪ None	Reference	
▪ Skills	1.04 (0.91 to 1.19)	0.60
▪ TCT	1.13 (0.99 to 1.29)	0.08
▪ Faculty	1.19 (1.04 to 1.37)	0.013
Presence or absence of trainer		
▪ Yes	Reference	
▪ No	1.06 (0.96 to 1.16)	0.25

OR, odds ratio; CI, confidence interval; BCSP, Bowel Cancer Screening Programme; JAG, Joint Advisory Group on Gastrointestinal Endoscopy; SAS, specialist practitioner; TCT, 'Train the colonoscopy trainer' course.
[1] 216 procedures excluded from multivariate model due to missing data (model based on data from 19869 procedures).
[2] Bold *P* values indicate statistically significant findings at the *P* = 0.01 level.

undertaken in England (OR 1.52, 95 %CI 1.27 to 1.81). In contrast, procedures undertaken in Wales were significantly less likely to achieve the indicator based on CIR + comfort score 1 – 3 than those undertaken in England (OR 0.70, 95 %CI 0.56 to 0.88). Similarly, compared with physicians, surgeons were significantly more likely to achieve PICI, but significantly less likely to achieve the CIR + comfort indicator.

Comparative multivariate modeling of four colonoscopy performance indicators

▶ **Table 5** compares multivariate analyses for four different performance indicators (PICI, CIR + comfort, CIR alone, and PDR > 1). Overall, 17 of the 25 subgroups of the unit, training, and colonoscopist variables showed statistically significant ORs for the likelihood of achieving PICI. Eight of the 25 categories were statistically significant predictors of CIR alone, compared with eight for CIR + comfort level 1 – 3, and four for PDR > 1. Thus, PICI was more sensitive to impact on performance in relation to the subgroups of unit, training, and colonoscopist variables than the other three indicators assessed.

Association between PICI and polyp and cancer detection

Achieving PICI was associated with a significantly higher likelihood of detecting one or more polyps, compared with procedures that did not achieve PICI (OR 1.44, 95 %CI 1.35 to 1.53). The likelihood of detecting two or more polyps was also significantly higher when PICI was achieved (OR 1.45, 95 %CI 1.34 to 1.57). Achieving PICI was associated with an increased likelihood of detecting cancer, although this was not statistically significant (OR 1.14, 95 %CI 0.98 to 1.32).

▶ **Table 5** Comparison between subgroups in multivariate models that were significant predictors of Performance Indicator of Colonic Intubation compared with those that predicted cecal intubation rate (CIR), CIR + comfort, and polyp detection.

Variable[1]	*P* values[2]			
	PICI	CIR alone	CIR + comfort	PDR
Patient age				
▪ < 50 years	**< 0.001**	**0.001**	0.56	**< 0.001**
▪ 50 – 59 years	**< 0.001**	0.05	0.23	**< 0.001**
▪ 60 – 69 years	**< 0.001**	0.04	0.52	0.09
▪ 70 + years	–	–	–	–
Patient sex				
▪ Male	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**
▪ Female	–	–	–	–
Procedure type				
▪ Inpatient	–	–	–	–
▪ Outpatient	0.78	**< 0.001**	**< 0.001**	0.06
Procedure indication				
▪ Diagnostic	–	–	–	–
▪ Surveillance	0.04	**< 0.001**	**< 0.001**	**< 0.001**
▪ BCSP	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**
▪ Screening	0.19	0.20	0.09	**< 0.001**
▪ Therapeutic	0.10	0.43	0.61	**< 0.001**
Bowel preparation				
▪ Poor	–	–	–	–
▪ Adequate	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**
▪ Excellent	**< 0.001**	**< 0.001**	**< 0.001**	**< 0.001**
Country				
▪ England	–	–	–	–
▪ Scotland	**< 0.001**	0.69	0.014	0.14
▪ Wales	**< 0.001**	0.09	**0.002**	0.63
▪ Northern Ireland	0.19	0.14	**0.003**	0.43
Unit JAG accreditation status				
▪ Accredited	**< 0.001**	**0.006**	0.22	0.49
▪ Not accredited	–	–	–	–
Imagers per unit				
▪ None	–	–	–	–
▪ One	**< 0.001**	0.23	0.23	0.05
▪ Two or more	**< 0.001**	0.02	0.02	0.11

▶ **Table 5** (Continuation)

Variable[1]	*P* values[2]			
	PICI	CIR alone	CIR + comfort	PDR
Professional group of colonoscopist				
▪ Physician	–	–	–	–
▪ Surgeon	**0.008**	**<0.001**	**<0.001**	0.09
▪ Nurse	0.12	**<0.001**	**0.004**	0.20
▪ SAS	**0.009**	0.18	0.03	0.15
▪ General practitioner	0.20	0.18	0.60	0.95
Independent/trainee colonoscopist				
▪ Independent	0.17	0.56	0.58	0.92
▪ Trainee	–	–	–	–
Number of years independent				
▪ 0 – 3	–	–	–	–
▪ 3 – 5	0.36	0.82	0.36	0.21
▪ 5 – 10	**<0.001**	0.24	0.54	0.02
▪ 10 – 20	**<0.001**	0.87	0.74	**<0.001**
▪ 20 +	**<0.001**	0.017	0.18	**<0.001**
Annual number of colonoscopies				
▪ < 100	–	–	–	–
▪ 100 – 199	0.97	0.31	0.38	0.93
▪ 200 – 299	**0.01**	0.11	0.06	0.34
▪ 300 – 499	**<0.001**	**0.002**	**<0.001**	0.78
▪ 500 +	0.06	**<0.001**	**<0.001**	0.26
Highest level of training				
▪ None	–	–	–	–
▪ Skills	**0.005**	0.04	0.60	0.58
▪ TCT	**<0.001**	**0.009**	0.08	0.56
▪ Faculty	**<0.001**	0.45	0.013	0.09
Presence or absence of trainer				
▪ Yes	–	–	–	–
▪ No	0.73	0.45	0.25	0.16

PICI, Performance Indicator of Colonic Intubation; CIR, cecal intubation rate; PDR, polyp detection rate; BCSP, Bowel Cancer Screening Programme; JAG, Joint Advisory Group on Gastrointestinal Endoscopy; SAS, specialist practitioner; TCT, "Train the colonoscopy trainer" course.

[1] 216 procedures excluded from multivariate model due to missing data (model based on data from 19869 procedures).

[2] Bold *P* values indicate statistically significant findings at the $P = 0.01$ level.

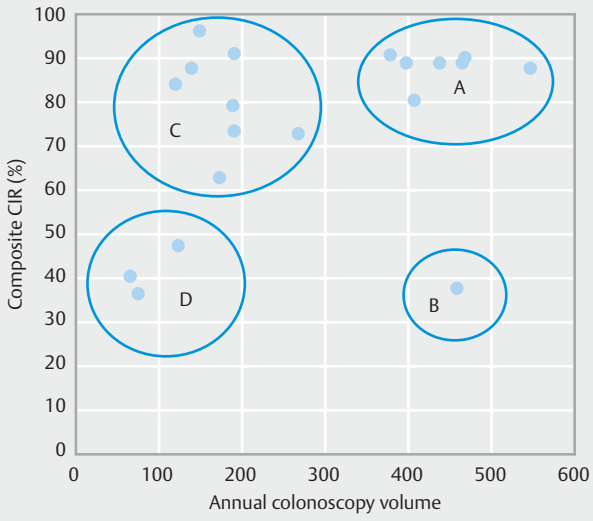
Single-site data

A total of 6236 colonoscopies were performed across four endoscopy sites in Gloucestershire during 2013. After excluding procedures performed by locums or recent appointees (n = 990), 5246 colonoscopies performed by 19 colonoscopists were analyzed. Annual procedure volumes for each colonoscopist ranged from 67 to 546, unadjusted CIR from 91 % to 99 %, level 4/5 comfort scores from 3 % to 14 %, and the average midazolam dosage ranged from 0.8 mg to 2.2 mg for patients aged > 70 years, and 1.1 – 2.4 mg for those aged < 70 years. A quarter (25.0 %) of the procedures were undertaken without sedation.

▶ **Fig. 2** illustrates the relationship between volume of procedures and PICI, which can be broadly arranged into four groupings:

A. High volume/high PICI (80 % – 90 %)
B. High volume/low PICI (38 %)
C. Low volume/high PICI (63 % – 96 %)
D. Low volume/low PICI (36 % – 47 %)

The single colonoscopist in group B had an unadjusted CIR of 99 %, and the greater use of midazolam was the predominant reason for the lower PICI. This particular colonoscopist had an unusual case mix that required more "top-up" sedation, including tertiary referrals for resection of large polyps and colonoscopy performed during hands-on courses. The three colonoscopists in group D had unadjusted CIRs of 91 %, 94 %, and 96 %, respectively.



▶ **Fig. 2** Relationship between volume of procedures and the Performance Indicator of Colonic Intubation for 5246 colonoscopies performed by 19 colonoscopists at a single institution in 1 year (2013).

Discussion

This paper describes a new performance indicator of colonic intubation that provides a simpler picture of colonoscopist expertise than CIR, comfort, and sedation measured separately. Compared with CIR alone, CIR + comfort, or PDR, PICI was better able to identify potentially modifiable colonoscopist and endoscopy unit factors that may affect performance. Thus, PICI may be used to identify individuals in need of additional training more readily than the three component indicators alone. Even though it is principally an indicator of colonic intubation, it complements adenoma detection rate, a surrogate of adequacy of inspection because it is associated with a higher rate of polyp detection.

The association between patient variables and PICI was similar to that found with CIR in other studies [8, 9]: older age; male sex, and a positive fecal occult blood test screen as indication were all associated with a significantly higher likelihood of achieving PICI. PICI also identified previously unreported factors that influence colonic intubation: JAG-accredited endoscopy units [6], units with one or more magnetic imagers, recently certified colonoscopists, and those with higher annual volumes and higher training status had higher rates of PICI.

PICI is an intuitive measure of colonic intubation: it is difficult to intubate the colon to the cecum comfortably with minimal sedation. It may also be safer to intubate the cecum with less pain and less sedation. Detecting significant differences in diagnostic colonic perforation is problematic because perforations are not always immediately apparent and because large sample sizes are required to compare rates. Pain occurs when more force is applied to the colon wall so it seems probable that perforation is less likely to occur if the patient is comfortable and awake. Thus, a high PICI may become a proxy for safer colonoscopy.

We examined how PICI compared with established performance indicators such as CIR, PDR, and CIR + comfort. Use of PICI was more likely to identify differences in performance related to units and colonoscopists than the other indicators: PICI identified significant differences in 17/25 subgroups compared with 8/25 for CIR and 8/25 for CIR + comfort alone.

The validity of this study depends on the completeness and accuracy of the dataset. It was estimated that > 90 % of the activity that occurred in the audit period was captured [5]. Validation of CIR against endoscopy reporting systems showed a good match between audit and reporting system data [5].

Sedation levels and cecal intubation are relatively hard end points, whereas nurse-assessed comfort is not. Assessment of comfort of colonoscopy became mandatory in the UK in 2007 [4]. Nurse-assessed comfort is arguably more reliable than patient-assessed comfort because of the amnesic effect of sedatives. However, differences between units in their experience of the scale may have led to inconsistent assessments of nurse-assessed comfort, but it is difficult to explain how this might have caused systematic bias.

Composite performance indicators have potential limitations. We chose to use the median dose of midazolam and nurse-assessed comfort of < 4 as cutoffs, but do not suggest that higher doses of midazolam are inappropriate. It is possible to obtain a high PICI rate (perhaps > 80 % – 85 %) with low CIR and/or an unacceptable proportion of patients having excessive pain. Thus, a high PICI may only be considered acceptable if

there is a minimum CIR (perhaps 90 %) and maximum level 4/5 pain (perhaps < 10 % or even lower). Application of the PICI may be inappropriate in some situations; for example, complex procedures and procedures performed in hands-on courses often take longer and may require "top-up" sedation.

The prospectively acquired colonoscopy performance data from a single organization illustrated how PICI might be interpreted and utilized in everyday practice. All colonoscopists achieved the required 90 % unadjusted CIR, but data showed disparities in performance that could be divided into four groups. The high-volume colonoscopists had high PICI, with the exception of one colonoscopist who had a unique case mix. Reassuringly, some relatively low-volume colonoscopists (< 200/year) had high a PICI (group C). Thus, according to this measure, an annual volume of 100 – 200 appears to be adequate. However, a second group of low-volume colonoscopists had a PICI below the average (54 %) in the national audit. The practice of these individuals should be subject to further scrutiny. If case mix or other factors cannot explain performance, they should consider increasing their annual volume and/or undergoing further training. Finally, these data suggest that a PICI of 80 % is a reasonable minimum performance target, and 90 % an aspirational one.

This is the first study to demonstrate that endoscopy service accreditation [6] is associated with higher performance of colonoscopy. This may be due to the quality-enhancing effect of accreditation and/or that higher performing units are more likely to achieve accreditation. Units with one or more imager had significantly higher numbers of procedures in which PICI was achieved. This association disappeared with CIR and CIR + comfort (▶ **Table 5**), suggesting that lower sedation levels in these units did not compromise comfort. However, the presence of magnetic imagers might be a marker for another factor that was not captured, such as academic status of the unit. In keeping with studies of volume and CIR [10], high annual volumes are associated with a higher likelihood of achieving PICI.

In the UK, trainees can practice independently after passing a structured competency test [11]. It is reassuring that these "independent" trainees perform as well as independent colonoscopists, and that when a trainee is being trained the PICI is unaffected. These results indicate that the government-sponsored colonoscopy training program, which began in 2000, has been effective and that patients are not adversely affected by training [12].

Finally, colonoscopists were assigned to four levels of training exposure: no experience of courses; attended one or more course; attended a "training the colonoscopy trainer" course; and course faculty [13]. At each level of training experience, PICI achievement significantly increased. This may indicate that the most able colonoscopists chose to participate in and/or deliver courses, and/or that participation improves skills. The most likely explanation is that both factors are influential.

It was not possible to determine adenoma detection in this study but many studies have found a tight relationship between PDR and adenoma detection rates [14, 15]; thus, PDR is regarded as a good proxy for adenoma detection rate. The significant association between PICI and polyp detection suggests that PICI is a marker for vigilance. It is also possible that more polyps are found in more comfortable, less-sedated patients because they are easier to turn on withdrawal [16].

The use of propofol for colonoscopy is increasing and now very common in North America, Australia, and some European countries. However, although propofol enhances patient experience, it is more expensive if an anesthetist is required to administer it. It is possible that propofol is used by some practitioners to mask poor technique and that with deeper sedation they can use more force [17]. A recent American study has shown an increased risk of complications in patients receiving monitored anesthesia services [18]. There are anecdotal reports of colonoscopists finding it difficult to examine patients who are under conscious sedation after being taught to examine patients under propofol sedation, suggesting that propofol sedation limits skill acquisition. It is proposed that prior to using propofol sedation, colonoscopists should demonstrate that they are able to achieve a high PICI.

The PICI might be used in two specific circumstances: first, to identify, support and monitor individuals in need of improvement, and second, for benchmarking. For quality improvement purposes, an individual endoscopy service might create its own PICI measure, using a local comfort scale and sedation threshold (with minimum levels for CIR and comfort scores). Any unit that routinely captures all three parameters (virtually all units in the UK) should be able to use PICI immediately for quality improvement.

In contrast to using PICI to improve quality, all three components of PICI would need to be agreed and defined for benchmarking. The principal constraint on this is a reliable performance measure for comfort: one method would have to be used consistently.

A sensible first step would be to use PICI locally to better identify who might need further skills training. Local jurisdictions, or program-based screening programs, might use one method of assessing patient comfort, allowing comparisons of performance between units, as occurs in the English Bowel Cancer Screening Programme. In the UK, JAG has created a National Endoscopy Database (NED) [19], which draws key indicators from reporting systems. From 2018, upload will become compulsory to maintain unit accreditation. NED uses a single comfort assessment measure so, in time, it will be possible to compare PICI across the country and explore its relationship with other indicators such as post-colonoscopy colorectal cancer.

In summary, this study has developed a new performance indicator of colonic intubation. This measure provides a more nuanced picture of intubation skill and one that is better able to detect differences in performance. The study confirms previous findings that age, sex, and indication affect performance. New findings are that unit accreditation status, availability of imagers, and features of the endoscopist (particularly training status) affect performance. PICI is associated with significantly higher polyp detection. It is proposed that PICI becomes the key performance indicator of colonic intubation for quality improvement of colonoscopy, and that 80 % should be the initial

standard for average case mix. In time, PICI might also be used to benchmark performance of endoscopy services.

Competing interests

Dr. Valori and Dr. Anderson are directors of an endoscopy training company called AnderVal Ltd.

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