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ORIGINAL ARTICLE

Leadership training to improve adenoma detection rate in screening colonoscopy: a randomised trial

Michal F Kaminski,[1] John Anderson,[2] Roland Valori,[3] Ewa Kraszewska,[1] Maciej Rupinski,[1] Jacek Pachlewski,[1] Ewa Wronska,[1] Michael Bretthauer,[4,5] Siwan Thomas-Gibson,[6] Ernst J Kuipers,[7] Jaroslaw Regula[1]

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For numbered affiliations see end of article.

Correspondence to
Dr Michal F Kaminski, Department of Gastroenterological Oncology, Institute of Oncology, Roentgen Street 5, Warsaw 02-781, Poland; mfkaminski@coi.waw.pl

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ABSTRACT

Objective Suboptimal adenoma detection rate (ADR) at colonoscopy is associated with increased risk of interval colorectal cancer. It is uncertain how ADR might be improved. We compared the effect of leadership training versus feedback only on colonoscopy quality in a countrywide randomised trial.

Design 40 colonoscopy screening centres with suboptimal performance in the Polish screening programme (centre leader ADR ≤25% during preintervention phase January to December 2011) were randomised to either a Train-Colonoscopy-Leaders (TCLs) programme (assessment, hands-on training, post-training feedback) or feedback only (individual quality measures). Colonoscopies performed June to December 2012 (early postintervention) and January to December 2013 (late postintervention) were used to calculate changes in quality measures. Primary outcome was change in leaders' ADR. Mixed effect models using ORs and 95% CIs were computed.

Results The study included 24 582 colonoscopies performed by 38 leaders and 56 617 colonoscopies performed by 138 endoscopists at the participating centres. The absolute difference between the TCL and feedback groups in mean ADR improvement of leaders was 7.1% and 4.2% in early and late postintervention phases, respectively. The TCL group had larger improvement in ADR in early (OR 1.61; 95% CI 1.29 to 2.01; p<0.001) and late (OR 1.35; 95% CI 1.10 to 1.66; p=0.004) postintervention phases. In the late postintervention phase, the absolute difference between the TCL and feedback groups in mean ADR improvement of entire centres was 3.9% (OR 1.25; 95% CI 1.04 to 1.50; p=0.017).

Conclusions Teaching centre leaders in colonoscopy training improved important quality measures in screening colonoscopy.

Trial registration number NCT01667198.

Significance of this study

What is already known on this subject?

- Suboptimal adenoma detection at colonoscopy is associated with increased risk of interval colorectal cancer and colorectal cancer death.
- Interventions targeting endoscopist performance have been generally ineffective for improving adenoma detection rates.
- One small study performed at single academic institution showed adenoma detection rate improvement with training.

What are the new findings?

- Dedicated Train-Colonoscopy-Leaders course significantly improved adenoma detection rate, proximal adenoma detection rate and non-polypoid lesion detection rate in screening colonoscopy.
- The training of screening centre leaders in teaching high quality colonoscopy changed their own practice and had also significant effect on overall centre performance.
- The Train-Colonoscopy-Leaders course had sustained effect on colonoscopy performance over 1.5 years.

How might it impact on clinical practice in the foreseeable future?

- Developed training curriculum may help to improve adenoma detection rate and non-polypoid lesion detection rate at colonoscopy.

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INTRODUCTION

During recent years, several studies have shown that important patient outcome measures such as interval cancer rates after screening colonoscopy or mortality after cancer surgery are related to quality of hospitals and individual physicians.[1–3] However, there is a lack of high quality studies investigating the effect of quality improvement interventions on patient outcome measures.

Screening colonoscopy is widely used for prevention and early detection of colorectal cancer (CRC).[4] High quality colonoscopy achieving accurate detection and removal of adenomas is considered the key to screening efficacy.[5–7] Professional societies recommend that endoscopists measure quality indicators such as adenoma detection rate (ADR), caecal intubation rate (CIR) and colonoscope withdrawal time.[6 7] We have previously shown that an individual endoscopist's ADR is an independent predictor for interval cancer after screening colonoscopy.[1] Recently, a large US study confirmed this association and expanded it to include CRC death.[3] Thus, adenoma detection is of paramount importance for the success of CRC screening programmes. However, it has been uncertain how to improve ADR in endoscopists with suboptimal performance.

Simple interventions, such as involvement of a trainee or video recording of the colonoscopy,[8–11] or an institutional policy to keep colonoscope withdrawal time above the recommended limits[12 13] has not shown significant improvements of ADR.[14] It has been proposed that improving ADR requires a multifaceted change[15 16] in the knowledge, skills and motivation of endoscopists. Audit and feedback of screening colonoscopy quality indicators have proven to be moderately effective in improving adenoma detection for some but not all endoscopists,[17 18] and an educational intervention improved adenoma detection of gastroenterologists at one academic institution.[19] Multicentre, comparative studies on the effect of quality improvement strategies to increase ADR are lacking.

The present large-scale randomised trial investigates the effect of a hands-on training course for leading colonoscopists at screening centres to improve their adenoma finding skills and overall screening centre performance compared with a simple audit and feedback.

METHODS

Study design

This was a multicentre, randomised (1:1 ratio), single-blind, parallel-group study performed in 40 centres of the National Colorectal Cancer Screening Programme (NCRCSP) in Poland.

The NCRCSP is a colonoscopy-based programme involving asymptomatic subjects 40–66 years of age.[20 21] Each participating centre has one dedicated leading colonoscopist who is responsible for coordination and supervision of the programme locally (screening centre leader; usually formal head of the endoscopy unit who underwent training in administration of the screening centre when entering the NCRCSP). We compared the effect of two educational interventions on ADR of these screening centre leaders and all endoscopists working at their centres.

The study was conducted in four phases: (i) preintervention phase, (ii) intervention phase, (iii) early postintervention phase and (iv) late postintervention phase. In the preintervention phase (1 January 2011 to 31 December 2011), colonoscopy quality indicators were extracted from the NCRCSP database. Centre leaders were unaware of the study during this phase. At the start of the intervention phase, screening centre leaders were randomly assigned to either a designated educational intervention ('Train-Colonoscopy-Leaders course' (TCL)) or to routine audit and feedback. Both interventions started on 1 June 2012 and the TCL phase was completed by 30 August 2012. Quality indicators were measured in the early postintervention phase (1 June 2012 to 31 December 2012; leaders were aware of being closely monitored) and in the late postintervention phase (1 January 2013 to 31 December 2013; leaders were unaware of being closely monitored) using the same method.

The study was approved by the Research Ethical Committee of the Maria Sklodowska-Curie Memorial Cancer Centre and Institute of Oncology, Warsaw, Poland (#17/2012). Written informed consent was obtained from all screening participants entering the NCRCSP and all screening centre leaders. The study was registered with ClinicalTrials.gov, NCT01667198.

Endpoints and definitions

Study endpoints were differences between preintervention and postintervention colonoscopy quality indicators in the two arms using all colonoscopies recorded in the NCRCSP database. The screening colonoscopy procedures have been described previously.[20] Findings at screening colonoscopy were categorised on the basis of the most advanced lesion identified.[20] Polyps that were not removed or retrieved were categorised as non-neoplastic and not taken into account when calculating ADR.

The primary study endpoint was the change in screening centre leaders' ADR from preintervention to early postintervention phase. ADR was defined as the proportion of screened subjects in whom at least one adenoma was identified.[7] Predefined secondary endpoints for the early postintervention phase were proximal ADR (defined as ADRs proximal to the splenic flexure), non-polypoid lesion detection rate and CIR, all of which were evaluated for both screening centre leaders and for the centres. All these endpoints were subsequently measured for the late postintervention phase compared with the preintervention phase. CIR was defined as the proportion of colonoscopies in which the endoscope tip reached proximal to the ileocaecal valve and the entire caecum was visualised.[7] Non-polypoid lesions were defined as lesions 5 mm or larger which were depressed, completely flat or elevated less than 2.5 mm.[22]

Study colonoscopists

All screening centre leaders who performed at least 30 NCRCSP screening colonoscopies in 2011 and achieved an ADR lower than 25% were eligible for the study (40 out of 93 centres in the NCRCSP) unless they discontinued participating in the NCRCSP in 2012.

Randomisation and masking

In May 2012, eligible screening centre leaders were randomly assigned in a 1:1 ratio to the TCL group or the feedback group. Randomisation lists were computer-generated and stratified by screening centre leader baseline ADR category (<11%, 11%–14.9%, 15%–19.9%, 20.0%–24.9%).[1] Participating screening centre leaders were informed that they were participating in a trial testing two different training programmes dedicated for trainers but were not informed about trial aims and endpoints. All other colonoscopists were not informed about the study but were aware of being monitored as a routine part of the NCRCSP. In the year 2013 (late postintervention phase), all colonoscopists (including screening centre leaders) were aware only of being monitored as a routine part of the NCRCSP.

Feedback group

Screening centre leaders randomised to the feedback group received (by email and surface mail) feedback on their individual preintervention screening colonoscopy quality indicators along with aggregated results for the entire screening centre. The individual results were presented in a table to enable comparison with anonymised results of all endoscopists who performed at least 30 colonoscopies within the NCRCSP (see online supplementary appendix 1). In addition, a link to a webpage containing data on individual and overall colonoscopy quality indicators from the last 4 years of the NCRCSP was provided. The email feedback was provided also after early postintervention phase.

TCLs group

Screening centre leaders randomised to the TCL group were invited to participate in a TCL course consisting of three phases: (i) pretraining assessment, (ii) hands-on training and (iii) post-training evaluation and feedback (see online supplementary appendix 2). The underlying hypothesis of the training intervention was to train the leaders on how to teach high quality colonoscopy and thereby to facilitate self-development and disseminate high standards of care.

The pretraining assessment phase involved a 2-h visit held in June and July 2012 at each screening centre. It used an environmental assessment checklist to find reasons for suboptimal performance. After the pretraining visit, local endoscopy nurses observed 10 consecutive colonoscopies performed by the screening centre leader to assess patient discomfort (using a 100 mm visual analogue scale) and withdrawal technique.[23] Local endoscopy nurses were trained to assess withdrawal technique and discomfort by the study team. Prior to starting the hands-on training phase, the TCL trainers were subject to a 2-day intensive training course by UK trainers (JA, RV) providing them with techniques used in skills improvement, training the trainer and leadership training programmes developed in the UK. During these 2 days, the focus was on using techniques known to change professional practice.[24] The hands-on training phase consisted of two half-a-day courses at the NCRCSP coordinating centre. The hands-on training course included at least one session for each participating screening centre leader playing the role of a trainee (performing colonoscopy) and at least one as a trainer (supervising colonoscopy), observed by the other course participants (by video streaming). The TCL trainers from the Institute of Oncology facilitated discussion on the training episode among all participants. The schedule of each course was modified to address issues identified in the pretraining assessment. Six to seven screening colonoscopy leaders were trained during each training session (held between July and August 2012).

The post-training evaluation encompassed evaluation of the screening centre leaders' colonoscopy performance (extracted from the database) during the first 30 procedures following the hands-on training course, and a further nurse assessment of 10 consecutive colonoscopies identical to that done in the pretraining phase. Finally, all leaders in the TCL group received feedback on individual performance along with aggregated results for the entire screening centre and access to the same webpage as leaders in the control group. The email feedback was provided also after early postintervention phase. According to protocol of the study, we had not planned to assess whether leaders extended training to other colleagues within the screening centre. Upon reviewers' request, we have performed a brief telephone survey among leaders asking whether they have extended training to their colleagues.

Power estimates and statistical analyses

We considered an absolute ADR improvement of 3% in the screening centre leaders randomised to the TCL group compared with 1.5% in those randomised to the feedback group[17] as clinically meaningful to detect. A sample size of 34 screening centre leaders provided 80% power to detect a mean difference in ADR improvement of 1.5% with an estimated SD of 1.5% and a two-sided significance level (α) of 0.05. We planned to include 40 leader colonoscopists to take account of compliance with the study.

For the primary endpoint, we used a generalised linear mixed effects model with random colonoscopists and colonoscopists' specific study phase effects, and fixed effects for the study group, phase, study group by phase interaction, and patient age and sex.[25] A generalised linear mixed effects model allows analysing changes in colonoscopists' performance over time treating them as a random sample from wider population and incorporating the possible correlation among outputs of participants examined by the same colonoscopists. The model allowed expressing the change in ADR at the participant level using ORs with corresponding 95% CIs. The OR for the interaction term reflects an excess in the OR of adenoma detection during the postintervention phases versus the preintervention phase in the TCL compared with the feedback group. Similar models were fitted for the secondary endpoints, including all the analyses comparing late postintervention phase and preintervention phase. Continuous variables (withdrawal technique scores, withdrawal time and patient pain scores) were checked for normality and compared using appropriate parametric or non-parametric tests. A p value of <0.05 was considered statistically significant. All reported p values are two-sided and not adjusted for multiple testing. The analyses were performed using Stata Statistical Software V.12 (Stata Corporation, College Station, Texas, USA).

RESULTS

Of the 40 screening centre leaders enrolled and randomised in a 1:1 ratio, one in each group was excluded due to consent withdrawal or lack of participation in the NCRCSP in 2012. Furthermore, in 2013, one screening centre leader in each group left the centre. Thus, all analyses comparing early postintervention phase and preintervention phase include 38 endoscopist leaders and their centres, whereas analyses comparing late postintervention phase and preintervention phase include 36 endoscopist leaders and 38 centres (figure 1). Data analyses are based on 24 582 colonoscopies performed by endoscopist leaders (10 983 in the preintervention, 6358 in the early postintervention, and 7241 in the late postintervention phase, respectively) and 56 617 colonoscopies performed in total at the participating centres throughout the trial phases (24 519 in the preintervention, 14 654 in the early postintervention and 17 454 in the late postintervention phase).

The intervention groups were well balanced with regard to baseline characteristics, colonoscopy experience and colonoscopy trainer experience (table 1). Screening centre leaders from both groups represented various medical specialties and types of practices, including academic, non-academic and private.

Screening centre leaders' performance

The characteristics of the screenees and colonoscopy procedures by randomisation group and study phase are summarised in table 2.

Early postintervention phase versus preintervention phase

As shown in figure 2, in the early postintervention phase, the mean ADR of screening centre leaders in the TCL group improved by 8.2% (from 17.4% to 25.6%) compared with 1.1% (from 18.5% to 19.6%) in the feedback groups, (absolute difference 7.1%). The mean proximal ADR and non-polypoid lesion detection rate of screening centre leaders in the TCL group improved by 5.5% and 3.0%, respectively, whereas they improved by 1.6% and deteriorated by 0.5% in the feedback group, respectively (table 2). In the generalised linear mixed effects models, participation in the TCL course was associated with significant ADR improvement (OR 1.61; 95% CI 1.29 to 2.01; $p<0.001$), proximal ADR improvement (OR 1.58; 95% CI 1.19 to 2.11; $p<0.001$) and non-polypoid lesion detection rate improvement (OR 2.78; 95% CI 1.53 to 5.05; $p=0.001$) as compared with the feedback group. The mean CIR of screening centre leaders did not differ between the groups (OR 1.03; 95% CI 0.56 to 1.90; $p=0.92$). The changes in the mean ADR were observed across all endoscopist specialties and types of screening facilities (see online supplementary table S3 and supplementary table S4 for the results of expanded model).

The changes in the above mentioned different detection rates were in line with results of the assessments by endoscopy nurses of 18 leaders in the TCL group (one centre leader was not

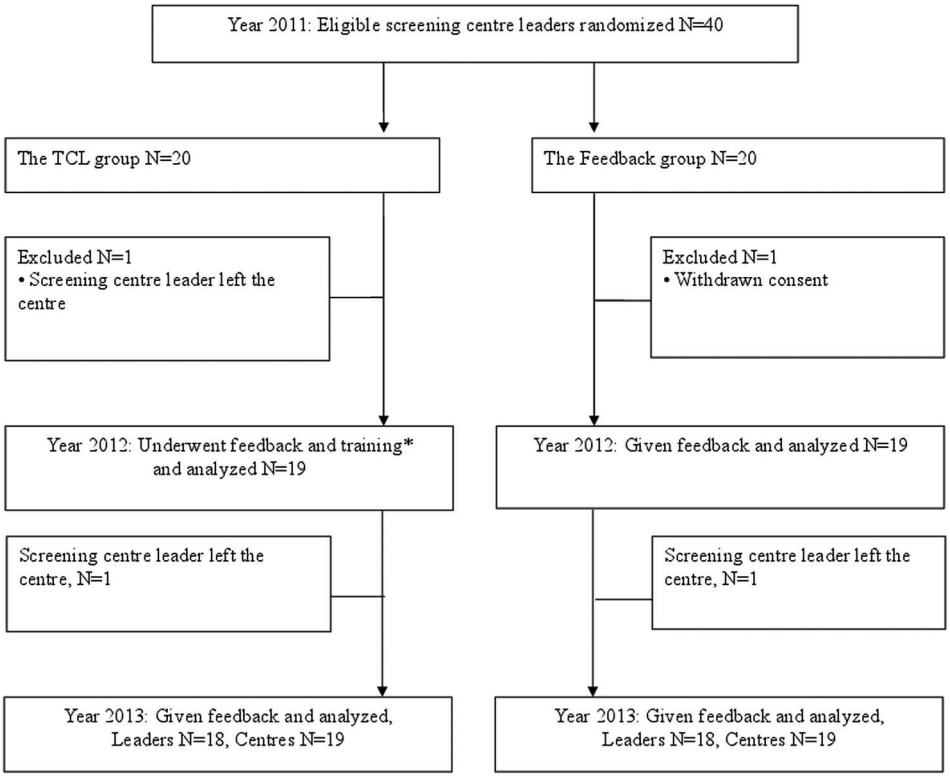

Figure 1 Study flowchart. *One screening centre leader did not participate in the nurse assessment.

assessed by nurses). Mean colonoscopy withdrawal technique significantly improved from 63.5 (±9.8) points to 68.2 (±7.8) points (p=0.004), whereas mean colonoscopy withdrawal time and mean pain scores remained unchanged (12.1±6.7 min to 12.5±9.0 min; p=0.54, and 18.4±17.2 mm to 12.8±10.8 mm; p=0.16, respectively).

Table 1 Baseline characteristics of 38 screening centre leaders and their colonoscopy and trainer experience in Train-Colonoscopy-Leader (TCL) and feedback groups, respectively

	TCL group, N=19	Feedback group, N=19
Baseline characteristics		
Mean age (±SD)	48.5 (4.5)	48.8 (6.0)
Male sex—n (%)	15 (78.9)	17 (89.5)
Specialty—n (%)		
Gastroenterology	10 (52.6)	14 (73.7)
General/oncological surgery	8 (42.1)	5 (26.3)
Other	1 (5.3)	0 (0.0)
Type of screening centre—n (%)		
Academic	2 (10.5)	1 (5.3)
Non-academic	7 (36.8)	9 (47.4)
Private practice	10 (52.6)	9 (47.4)
Colonoscopy experience*		
Years, mean (±SD)	15.1 (5.4)	15.2 (6.0)
Estimated number of colonoscopies performed—n (%)		
1000–4999	4 (21.1)	2 (10.5)
5000–9999	8 (42.1)	9 (47.4)
10 000 or more	7 (36.8)	7 (36.8)
Interested to undergo additional training—n (%)		
Yes	11 (57.9)	13 (68.4)
No	2 (10.5)	4 (21.1)
Not sure/not reported	6 (31.6)	2 (10.5)
Previous experience as a colonoscopy trainer—n (%)		
Yes	13 (68.4)	12 (63.2)
No	5 (26.3)	5 (26.3)
Not sure/not reported	1 (5.3)	2 (10.5)

Because of rounding, percentages may not total 100.
*Data not available for one leader from the feedback group.

Late postintervention phase versus preintervention phase

As shown in figure 2, in the late postintervention phase the mean ADR of screening centre leaders in the TCL group deteriorated by 1.7% compared with early postintervention phase, but still remained improved by 6.5% compared with preintervention phase. In the feedback group, the mean ADR of screening centre leaders in the late postintervention phase improved by 1.2% compared with early postintervention phase and in total by 2.3% compared with preintervention phase. The absolute difference in the mean ADR improvement in the late postintervention phase compared with preintervention phase was 4.2% in favour of the TCL group. Results for proximal ADR and non-polypoid lesion detection rate in the late postintervention phase are shown in figure 2 and table 2.

In the generalised linear mixed effects models, participation in the TCL course was associated with sustained significant ADR improvement (OR 1.35; 95% CI 1.10 to 1.66; p=0.004) compared with the feedback group. The proximal ADR improvement (OR 1.33; 95% CI 0.98 to 1.80; p=0.07) and non-polypoid lesion detection rate improvement (OR 1.57; 95% CI 0.76 to 3.24; p=0.219) were no longer statistically significantly higher compared with the feedback group.

Screening centre performance

The characteristics of the screenees and colonoscopy procedures by randomisation group and study phase are summarised in table 3.

Early postintervention phase versus preintervention phase

The non-polypoid lesion detection rate improved by 1.5% (from 1.6% to 3.1%) and 0.2% (from 1.6% to 1.8%) in the TCL and feedback screening centres, respectively (for changes

Table 2 Screenee and procedure characteristics and colonoscopy performance by randomisation group (Train-Colonoscopy-Leader (TCL) and feedback groups) and study phase (procedures performed by screening centre leaders)

	The TCL group (19 endoscopists)*			The feedback group (19 endoscopists)*		
	Preintervention phase, N=6217	Early postintervention phase, N=3381	Late postintervention phase, N=3826	Preintervention phase, N=4766	Early postintervention phase, N=2977	Late postintervention phase, N=3415
Screenee variables						
Age, mean (±SD)	56.4 (5.4)	56.9 (5.4)	56.9 (5.4)	56.7 (5.2)	57.0 (5.3)	57.1 (5.1)
Male sex—n (%)	2237 (36.0)	1175 (34.7)	1525 (39.9)	1783 (37.4)	1123 (37.7)	1385 (40.7)
Procedure variables						
Intravenous sedation—n (%)	4000 (64.3%)	2011 (59.5%)	2330 (60.9%)	2644 (55.5%)	1628 (54.7%)	1877 (55.0)
Adequate bowel preparation†—n (%)	5833 (93.8%)	3240 (95.8%)	3610 (94.4%)	4520 (94.8%)	2724 (91.5%)	3185 (93.3%)
Total colonoscopy—n (%)	5995 (96.4%)	3268 (96.7%)	3690 (96.4%)	4631 (97.2%)	2870 (96.4%)	3322 (97.3%)
Screenees with adenoma or cancer—n (%)	1023 (16.4%)	812 (24.0%)	897 (23.4%)	898 (18.8%)	574 (19.3%)	719 (21.1%)
Screenees with polyps not removed/retrieved—n (%)	31 (0.5%)	20 (0.6%)	14 (0.4%)	26 (0.5%)	18 (0.6%)	25 (0.7%)
Screenees with proximal‡ adenoma or cancer—n (%)	430 (6.9%)	421 (12.4%)	452 (11.8%)	426 (8.9%)	312 (10.5%)	389 (11.4%)
Screenees with non-polypoid lesion§—n (%)	112 (1.8%)	128 (3.8%)	143 (3.7%)	79 (1.7%)	45 (1.5%)	84 (2.5%)
Screening centre leader performance variables						
Number of colonoscopies, median (range)	258 (40–898)	182 (21–443)	187 (20–519)	187 (120–384)	88 (57–296)	124 (34–514)
Adenoma detection rate, mean (±SD)	17.4% (3.2)	25.6% (8.2)	23.9% (4.7)	18.5% (3.6)	19.6% (6.5)	20.8% (6.1)
Proximal‡ adenoma detection rate, mean (±SD)	7.8% (2.6)	13.3% (6.1)	12.0% (4.9)	8.6% (3.7)	10.2% (4.9)	10.2% (4.9)
Non-polypoid lesion§ detection rate, mean (±SD)	1.8% (1.9)	4.8% (4.5)	3.8% (4.0)	2.0% (2.0)	1.5% (1.3)	2.1% (2.2)
Caecal intubation rate, mean (±SD)	96.5% (4.2)	95.8% (4.4)	96.3% (4.5)	96.5% (2.7)	95.2% (4.6)	96.2% (4.1)

*In the late postintervention phase, one leader in each group left the screening centre; the remaining 36 endoscopists were used for analyses.
†Bowel preparation was assessed by endoscopists.
‡Proximal to the splenic flexure.
§Non-polypoid lesion was defined as a lesion 5 mm or larger which was depressed, completely flat or elevated less than 2.5 mm.

in other quality indicators, see table 3). In the generalised linear mixed effects models, participation of the leader endoscopist in the TCL course was associated with significant overall non-polypoid lesion detection rate improvement in the screening centre (OR 1.85; 95% CI 1.19 to 2.86; p=0.006), but not with ADR (OR 1.11; 95% CI 0.93 to 1.34; p=0.25) or proximal ADR (OR 1.17; 95% CI 0.91 to 1.50; p=0.21), or CIR (OR 0.86; 95% CI 0.58 to 1.29; p=0.47).

Late postintervention phase versus preintervention phase

As shown in figure 2, in the late postintervention phase, the mean ADR, proximal ADR and non-polypoid lesion detection rate of entire screening centres improved by 5.7%, 3.9% and 2.5%, respectively, in the TCL group as compared with 1.8%, 1.8% and 0.6%, in the feedback group, respectively.

In the generalised linear mixed effects models, participation in the TCL course was associated with significant ADR improvement (OR 1.25; 95% CI 1.04 to 1.50; p=0.017) and non-polypoid lesion detection rate improvement (OR 1.76; 95% CI 1.11 to 2.82; p=0.017) but not significant proximal ADR improvement (OR 1.23; 95% CI 0.97 to 1.55; p=0.082), as compared with the feedback group.

Brief telephone survey among screening centre leaders revealed that in the postintervention phase, 12 of them (63.2%) have already delivered the training in their centres, and the rest either had no candidates for training (15.8%), or plan to deliver training in the future (15.8%), or left the centre (5.3%). The mean ADR improved by 7.6% (from 18.2% to 25.8%) in the centres where training had been already delivered and by 3.1% (from 18.7% to 21.8%) in the remaining centres.

DISCUSSION

This is the first multicentre randomised comparative trial which shows that a dedicated Train-Colonoscopy-Leaders course improves important quality indicators in colonoscopy. The training of screening centre leaders in teaching high quality colonoscopy resulted in sustained change of their own practice and the performance of the centre as a whole.

Our training course represents a novel concept, aiming at multifaceted change in endoscopists' skills and behaviours. The training was targeted at screening centre leaders with the aim of ensuring they appreciated the importance of high standards and providing them with a variety of techniques to train their teams on how to meet these standards. The training did focus on teaching high quality colonoscopy, withdrawal technique and non-polypoid lesion recognition, and on barriers for improvements in ADR at individual centres including aspects of organisation, workforce, communication, training and quality control. Our training course used techniques drawn from skills improvement, training the trainer and leadership courses developed in the UK. This methodology is based on key principles of adult learning and changing professional practice.[24]

Our primary study focus was leader's performance. We demonstrated that the TCL course resulted in a significant and sustained leader's ADR improvement; thereby, we confirmed that one of the best ways to learn is by teaching.[26]

The robust design of our study allowed us also to investigate the effect of training at the screening centre level. Indeed, in the late postintervention phase, we observed significant improvement in the ADR and non-polypoid lesion detection rate at the screening centre level. It was unrealistic to expect this to be evident in the early postintervention phase as it takes time to deliver the training to other endoscopists in screening centres. Our large-scale nationwide study results extend those of a recent single centre study showing ADR improvement with a short educational intervention.[19]

Proximal colorectal adenomas and non-polypoid lesions may play an important role in the development of interval

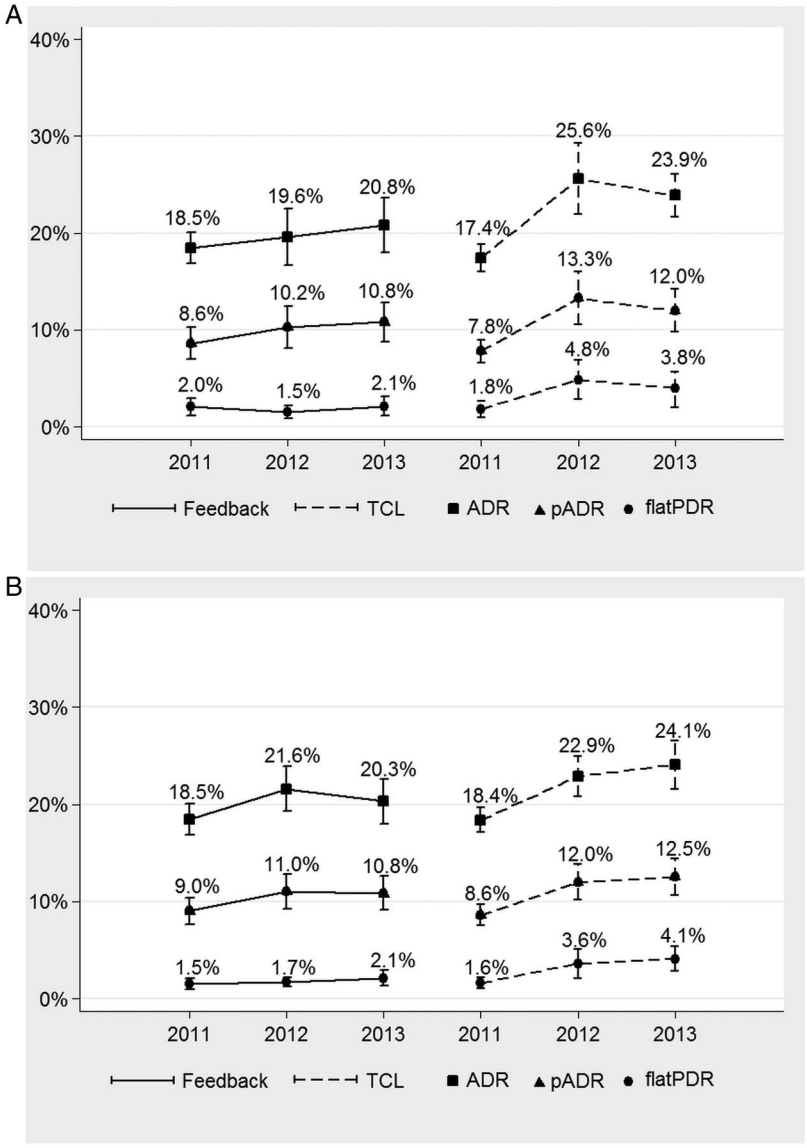

Figure 2 Mean (with 95% CIs) adenoma detection rate (ADR), proximal adenoma detection rate (pADR) and non-polypoid lesion detection rate (flatPDR) in the preintervention phase (2011), early postintervention phase (2012) and late postintervention phase (2013) by study group. Panel A shows data for screening centre leaders. Panel B shows data for entire screening centres. TCL, Train-Colonoscopy-Leader group; Feedback, feedback group.

CRCs.[27 28] Our study is the first to demonstrate significant improvement in proximal ADR and non-polypoid lesion detection rate following quality improvement intervention. These results are in line with the primary goals of the training curriculum: emphasis on detection of subtle, non-polypoid lesions and visualisation of the proximal colon.

Endoscopist specialty and type of facility in which colonoscopy was performed have been associated with the risk of interval CRC.[29] In our study, ADR improvement was observed across all endoscopist specialties, colonoscopy experience and types of screening facilities (see online supplementary table S3). In contrast, in previous studies on quality improvement through educational intervention, only gastroenterologists from academic institutions were included.[13 19]

The underlying hypothesis of our educational interventions was that the improvement in the detection of adenomas translates into reduced interval CRC rates. A recent large-scale study suggests that each 1% increase in ADR may result in a 3% decrease in the risk of interval cancer.[3] We intend to follow our study cohort to investigate if improvement in ADR translates into reduced interval CRC rates.

Our study has some limitations. First, the cost-effectiveness of the training intervention is unknown. However, assuming that the relative risk of interval CRC among endoscopists with high and low ADR is comparable or greater than that observed for gastroenterologist and non-gastroenterologist endoscopists,[29 30] it is likely that training to improve ADR will be as cost-effective as shifting screening colonoscopies from non-gastroenterologist endoscopists to gastroenterologist endoscopists.[31] Second, total colonoscopy and withdrawal time were not routinely measured in our study. Thus, impact of the study interventions on procedure times is unknown. However, short term assessments, done by endoscopy nurses before and after intervention, suggest that observed improvement in ADR in the TCL group was most likely due to improved withdrawal technique rather than longer withdrawal time. This observation is in line with results of a previous study which showed that compared with withdrawal time, withdrawal technique might better differentiate between endoscopists with varying ADRs.[32] Third, continuous, more frequent feedback of colonoscopy quality might be more effective than annual feedback. We decided to give feedback annually because of the sample size required to give a sufficiently precise estimate of ADR.[33] Fourth, screening centre leaders were aware of being monitored under the study conditions. This might have affected their postintervention colonoscopy performance (the so-called Hawthorne effect[34]). Indeed, it is likely that some Hawthorne

Table 3 Screenee and procedure characteristics and colonoscopy performance by randomisation group and study phase (procedures performed by all endoscopists at the study centres)

Variables	The TCL group (70 endoscopists, 19 centres)			The feedback group (68 endoscopists, 19 centres)		
	Preintervention phase, N=14 264	Early postintervention phase, N=8657	Late postintervention phase, N=10 615	Preintervention phase, N=10 255	Early postintervention phase, N=5987	Late postintervention phase, N=6839
Screenee variables						
Age, mean (±SD)	56.3 (5.6)	56.4 (5.8)	56.5 (5.8)	56.7 (5.2)	57.0 (5.4)	57.1 (5.2)
Male sex—n (%)	5414 (38.0)	3242 (37.4)	4360 (41.1%)	3853 (37.6)	2239 (37.4)	2786 (40.7%)
Procedure variables						
Intravenous sedation—n (%)	7944 (55.7%)	4395 (50.8%)	4986 (47.0%)	5037 (49.1%)	2848 (47.6%)	3342 (48.9%)
Adequate bowel preparation*—n (%)	13 495 (94.6%)	8302 (95.9%)	10 185 (95.9%)	9635 (94.0%)	5519 (92.9%)	6441 (94.2%)
Total colonoscopy—n (%)	13 776 (96.6%)	8366 (96.6%)	10 269 (96.7%)	9839 (95.9%)	5747 (96.0%)	6631 (97.0%)
Screenees with adenoma or cancer—n (%)	2621 (18.4%)	1996 (23.1%)	2495 (23.5%)	1938 (18.9%)	1279 (21.4%)	1407 (20.6%)
Screenees with polyps not removed/retrieved—n (%)	73 (0.5%)	49 (0.6%)	41 (0.4%)	52 (0.5%)	31 (0.5%)	50 (0.7%)
Screenees with proximal† adenoma or cancer—n (%)	1204 (8.4%)	1037 (12.0%)	1280 (12.1%)	929 (9.1%)	647 (10.8%)	739 (10.8%)
Screenees with non-polypoid‡ lesion—n (%)	230 (1.6%)	270 (3.1%)	399 (3.8%)	161 (1.6%)	109 (1.8%)	142 (2.1%)
Entire screening centre performance variables						
No. of endoscopists per centre						
Mean (±SD)	3.7 (2.7)	3.7 (2.6)	3.7 (2.6)	3.5 (1.6)	3.6 (1.7)	3.6 (1.5)
Median (range)	3 (1–13)	3 (1–12)	3 (1–13)	4 (1–7)	4 (1–7)	4 (1–7)
Number of colonoscopies, median (range)	633 (147–2357)	336 (74–1787)	380 (150–2400)	539 (198–1097)	300 (106–670)	336 (204–600)
Adenoma detection rate, mean (±SD)	18.4% (2.9)	22.9% (4.7)	24.1% (5.6)	18.5% (3.6)	21.6% (5.1)	20.3% (5.1)
Proximal† adenoma detection rate, mean (±SD)	8.6% (2.5)	12.0% (4.0)	12.5% (4.3)	9.0% (3.2)	11.0% (4.0)	10.8% (3.9)
Non-polypoid lesion‡ detection rate, mean (±SD)	1.6% (1.3)	3.6% (3.4)	4.1 (2.8)	1.5% (1.3)	1.7% (1.1)	2.1 (1.7)
Caecal intubation rate, mean (±SD)	96.3% (3.2)	96.6% (2.4)	96.5% (2.7)	95.6% (2.5)	95.8% (3.3)	95.9% (3.4)

*Bowel preparation was assessed by endoscopists.
†Proximal to the splenic flexure.
‡Non-polypoid lesion was defined as a lesion 5 mm or larger which was depressed, completely flat or elevated less than 2.5 mm.

effect occurred in our study because in the late postintervention phase, colonoscopy performance of screening centre leaders declined slightly compared with the early postintervention phase. However, a Hawthorne effect had likely relatively small impact on our study results. Furthermore, this study included screening centre leaders with ADRs below 25%. It is uncertain if our results are applicable to leaders of endoscopy units outside screening setting and endoscopists with ADRs higher than 25%. Fifth, two screening centre leaders in each study group were lost to follow-up in the late postintervention phase, and thus the analyses for this period were not purely on an intention to treat basis. However, in the analyses we included all the data from screenees who underwent examination by endoscopists who performed screening examinations in the postintervention phase and did not withdraw their consent to participate in the trial, regardless of whether the training was complete or not (one screening centre leader did not participate in the pretraining and the post-training assessment but was included in the analyses). Moreover, in the late postintervention phase, we analysed all the centres that continued the screening programme, despite two leaders leaving their centres.

In summary, participation in a short, dedicated training intervention for screening centre leaders resulted in a greater improvement in ADR than audit and feedback of individual colonoscopy quality indicators. The observed quality improvement among leading colonoscopists and its dissemination on the entire screening centres support its widespread implementation.

Author affiliations
[1]Department of Gastroenterology and Hepatology, Medical Centre for Postgraduate Education and the Maria Sklodowska-Curie Memorial Cancer Centre and Institute of Oncology, Warsaw, Poland
[2]Department of Gastroenterology, Gloucestershire Hospitals NHS Foundation Trust, Gloucester, UK
[3]Department of Gastroenterology, Gloucestershire Royal Hospital, Gloucester, UK
[4]Department of Health Economy and Health Management, University of Oslo, Oslo, Norway
[5]Department of Gastroenterology, Oslo University Hospital Rikshospitalet, Oslo, Norway
[6]Wolfson Unit for Endoscopy, St. Mark's Hospital, London, UK
[7]Departments of Gastroenterology and Hepatology, and Internal Medicine, Erasmus Medical Centre, Rotterdam, The Netherlands

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Supplementary Appendix 1. Feedback on individual colonoscopy quality indicators presented in a league table.

		Name and Surname	No.	ADR %	CIR %
ADR ≥ 30% and CIR ≥ 95%	1		62	53.2%	98.4%
	2		148	45.9%	99.3%
	3		153	44.4%	98.7%
	4	Xxxxx Xxxxxxxxxxxxxxxx	53	41.5%	100.0%
	5		94	40.4%	95.7%
	6		219	39.3%	100.0%
	7		125	39.2%	97.6%
	8		75	38.7%	96.0%
	9		50	38.0%	98.0%
	10		383	35.8%	99.5%
	11		94	35.1%	97.9%
	12		120	35.0%	99.2%
	13		497	34.2%	99.6%
	14		204	32.4%	98.5%
	15		149	32.2%	100.0%
	16		53	32.1%	100.0%
	17		75	32.0%	96.0%
	18		93	31.2%	96.8%
	19		135	31.1%	97.0%
	20		295	30.8%	99.0%
	21		65	30.8%	98.5%
	22		108	30.6%	98.1%
	23		33	30.3%	97.0%
	24		124	29.8%	96.0%
	25		74	29.7%	97.3%
	26		307	29.6%	99.0%
ADR ≥ 25% < 30% and CIR ≥ 95%	27		148	29.1%	98.6%
	28		59	28.8%	94.9%
	29		87	28.7%	96.6%
	30		84	28.6%	98.8%
	31		303	28.4%	99.0%
	32		115	27.8%	98.3%
	33		36	27.8%	97.2%
	34		184	27.7%	97.8%
	35		65	27.7%	100.0%
	36		47	27.7%	100.0%
	37		120	27.5%	96.7%
	38		143	27.3%	96.5%
	39		77	27.3%	96.1%
	40		400	27.3%	97.8%
	41		182	26.9%	99.5%
	42		289	26.6%	99.3%
	43		214	26.6%	98.6%
	44		140	26.4%	97.9%
	45		145	26.2%	99.3%

	46		340	26.2%	99.1%
	47		100	26.0%	96.0%
	48		185	25.9%	98.9%
	49		336	25.3%	98.2%
	50		335	25.1%	99.4%
	51		96	25.0%	99.0%
	52		56	25.0%	100.0%
	53		36	25.0%	97.2%
	54		36	25.0%	100.0%
	55		399	24.6%	97.7%
ADR ≥ 20% < 25% and CIR ≥ 95%	56		298	24.5%	99.3%
	57		147	24.5%	97.3%
	58		78	24.4%	94.9%
	59		87	24.1%	96.6%
	60		258	24.0%	97.7%
	61		139	23.7%	97.1%
	62		297	23.6%	99.0%
	63		192	23.4%	97.9%
	64		94	23.4%	98.9%
	65		235	23.3%	97.4%
	66		165	23.0%	98.2%
	67		96	22.9%	100.0%
	68		599	22.9%	99.8%
	69		35	22.9%	100.0%
	70		66	22.7%	97.0%
	71		44	22.7%	100.0%
	72		304	22.7%	96.1%
	73		141	22.7%	95.0%
	74		115	22.6%	100.0%
	75		164	22.6%	100.0%
	76		240	22.5%	94.6%
	77		67	22.4%	95.5%
	78		282	22.3%	99.3%
	79		94	22.3%	98.9%
	80		239	22.2%	97.9%
	81		154	22.1%	96.8%
	82		436	22.0%	96.8%
	83		100	22.0%	98.0%
	84		91	22.0%	95.6%
	85		201	21.9%	100.0%
	86		32	21.9%	96.9%
	87		1026	21.7%	97.0%
	88		97	21.6%	97.9%
	89		125	21.6%	96.8%
	90		51	21.6%	96.1%
	91		158	21.5%	97.5%
	92		256	21.5%	98.8%

	93		177	21.5%	95.5%
	94		212	21.2%	97.6%
	95		408	20.8%	97.3%
	96		584	20.5%	97.3%
	97		258	20.5%	94.6%
	98		370	20.5%	95.7%
	99		386	20.2%	98.2%
	100		104	20.2%	98.1%
	101		139	20.1%	99.3%
	102		115	20.0%	99.1%
	103		100	20.0%	99.0%
	104		40	20.0%	97.5%
ADR ≥ 20% and CIR ≥ 90% < 95%	105		35	42.9%	91.4%
	106		35	34.3%	91.4%
	107		121	32.2%	92.6%
	108		205	29.8%	92.2%
	109		34	29.4%	94.1%
	110		73	27.4%	93.2%
	111		60	26.7%	91.7%
	112		91	26.4%	92.3%
	113		90	25.6%	94.4%
	114		185	24.3%	91.9%
	115		99	24.2%	92.9%
	116		137	24.1%	89.8%
	117		218	22.9%	92.7%
	118		104	21.2%	91.3%
	119		134	20.9%	92.5%
	120		108	20.4%	94.4%
ADR ≥ 15% <20% and CIR ≥ 95%	121		146	19.9%	98.6%
	122		106	19.8%	99.1%
	123		56	19.6%	96.4%
	124		214	19.6%	97.2%
	125		291	19.6%	99.7%
	126		216	19.4%	97.2%
	127		31	19.4%	96.8%
	128		146	19.2%	99.3%
	129		100	19.0%	96.0%
	130		143	18.9%	97.9%
	131		181	18.8%	100.0%
	132		80	18.8%	95.0%
	133		151	18.5%	96.7%
	134		81	18.5%	95.1%
	135		99	18.2%	98.0%
	136		66	18.2%	100.0%
	137		39	17.9%	94.9%
	138		212	17.9%	96.7%
	139		218	17.9%	98.2%
	140		181	17.7%	99.4%
	141		80	17.5%	100.0%

	142	373	17.4%	94.9%
	143	511	17.4%	98.8%
	144	58	17.2%	96.6%
	145	151	17.2%	97.4%
	146	282	17.0%	97.5%
	147	177	16.9%	97.7%
	148	83	16.9%	95.2%
	149	509	16.7%	97.6%
	150	204	16.7%	97.1%
	151	36	16.7%	100.0%
	152	200	16.5%	100.0%
	153	200	16.5%	99.5%
	154	68	16.2%	98.5%
	155	100	16.0%	99.0%
	156	152	15.8%	99.3%
	157	318	15.4%	94.7%
	158	59	15.3%	98.3%
	159	66	15.2%	95.5%
	160	60	15.0%	96.7%
ADR ≥ 15% <20% and CIR ≥ 90% < 95%	161	61	19.7%	93.4%
	162	87	19.5%	94.3%
	163	287	18.8%	91.3%
	164	138	18.1%	92.0%
	165	35	17.1%	94.3%
	166	71	16.9%	93.0%
	167	184	16.8%	90.8%
	168	102	16.7%	92.2%
	169	30	16.7%	93.3%
	170	31	16.1%	93.5%
	171	288	16.0%	93.4%
	172	39	15.4%	94.9%
	173	33	15.2%	90.9%
ADR ≥ 10% <15% and CIR ≥ 95%	174	114	14.9%	99.1%
	175	504	14.7%	97.6%
	176	377	14.6%	98.7%
	177	579	14.5%	97.6%
	178	211	14.2%	98.1%
	179	536	14.2%	99.3%
	180	270	14.1%	100.0%
	181	57	14.0%	96.5%
	182	100	14.0%	98.0%
	183	386	13.7%	97.9%
	184	73	13.7%	97.3%
	185	53	13.2%	100.0%
	186	422	13.0%	99.1%
	187	308	13.0%	99.7%
	188	155	12.9%	99.4%
	189	226	12.8%	100.0%
	190	48	12.5%	97.9%
	191	73	12.3%	100.0%
	192	131	12.2%	98.5%

	193		115	12.2%	98.3%
	194		500	12.0%	100.0%
	195		137	11.7%	96.4%
	196		179	11.2%	95.5%
	197		149	10.7%	96.6%
	198		212	10.4%	97.6%
	199		200	10.0%	99.5%
	200		50	10.0%	98.0%
ADR > 10% <15% and CIR ≥ 90%< 95%	201		67	14.9%	92.5%
	202		411	14.4%	94.2%
	203		151	12.6%	91.4%
	204		78	12.8%	93.6%
ADR ≥ 10% and CIR < 90%	205		134	27.6%	87.3%
	206		45	22.2%	73.3%
	207		68	22.1%	86.8%
	208		62	21.0%	85.5%
	209		146	19.9%	87.7%
	210		32	18.8%	62.5%
	211		33	18.2%	87.9%
	212		72	18.1%	88.9%
	213		110	16.4%	85.5%
	214		38	15.8%	89.5%
	215		102	14.7%	89.2%
	216		146	13.7%	88.4%
	217		61	13.1%	83.6%
	218		221	11.8%	88.7%
	219		47	10.6%	87.2%
	220		39	10.3%	87.2%
	221		39	10.3%	87.2%
ADR < 10% and CIR ≥ 90%	222		52	9.6%	100.0%
	223		42	9.5%	97.6%
	224		80	8.8%	96.3%
	225		237	8.4%	93.2%
	226		64	7.8%	100.0%
	227		48	6.3%	100.0%
	228		105	5.7%	94.3%
	229		63	4.8%	98.4%
	230		31	3.2%	96.8%
	231		51	2.0%	98.0%

Supplementary Appendix 2. The programme of the Train-the-Colonoscopy Leaders course.

1. **Pre-training assessment at each leaders' screening center**
   - Screening centre leaders' questionnaire (demographics, specialty, colonoscopy experience, colonoscopy training, experience as a trainer, interest in training, self-reported measures of colonoscopy competence)
   - Environmental assessment checklist (organization and workforce, endoscopic equipment and rooms, training, communication assessed by investigators; motivation self-assessed by screening center leader)
   - Screening center leaders' withdrawal time and technique,[18] and patients pain scores (100mm visual analog scale) assessed by a trained (at least 5 video cases done with investigators) endoscopy nurse (10 consecutive procedures assessed); sent back to the investigators
   - Feedback on individual screening colonoscopy quality indicators; Supplementary Appendix 1.

2. **Hands-on-training at the Maria Sklodowska-Curie Memorial Cancer Center and Institute on Oncology, Warsaw**

   a. **Day 1**
   - Introduction (faculty, participants, set the agenda)
   - Objective setting (delegate's background & aims)
   - Close discussion on the high quality colonoscopy (patient and program perspective)
   - Discussion on barriers and solutions to improve ADR
   - Demonstration of colonoscopy withdrawal videos (inappropriate fold inspection, inadequate bowel distension, inappropriate suctioning technique): discussion on the points of disagreement

- The principles of Pendleton's rules and the idea of conscious competence

b. Day 2

- Close discussion on patients position changes on colonoscopy withdrawal
- Set (align agendas, ground rules, educational contract), dialogue (language, performance enhancing instruction, environment) and closure (summary, performance enhancing feedback, take home message) of the hands-on-training episode
- Each participant performs one colonoscopy withdrawal as an examiner and one colonoscopy withdrawal as a trainer
- Videocases: lesion recognition, assessment, delineation
- Videocases: discussion of basic polypectomy technique
- Feedback from faculty: summary and take home message

3. Post-training evaluation and feedback

- Screening center leaders' withdrawal time and technique,[18] and patients pain scores (100mm visual analog scale) assessed by a trained endoscopy nurse (10 consecutive procedures assessed); sent back to the investigators
- Ceacal intubation rate and adenoma detection rate assessed in the first 30 screening colonoscopies following training; extracted by investigators from the database
- Feedback on adenoma detection rate, ceacal intubation rate, withdrawal technique and patients pain scores sent via email by the investigators

Supplementary Table S3. The detection rates of adenomas by endoscopist characteristics, randomization group in the pre-intervention and early post-intervention phase (procedures performed by screening centre leaders).

Variables	Number of patients (number of patients with adenomas, %)			
	The TCL group		The feedback group	
	Baseline phase	Post-intervention phase	Baseline phase	Post-intervention phase
Screening centre leader specialty				
Gastroenterology	3,285 (560, 17.0%)	1,879 (449, 23.9%)	3,453 (644, 18.7%)	2,371 (437, 18.4%)
General surgery or other	2,932 (463, 15.8%)	1,502 (363, 24.2%)	1,313 (254, 19.3%)	606 (137, 22.6%)
Colonoscopy experience (estimated number)*				
1000 – 4999 colonoscopies	503 (96, 19.1%)	240 (65, 27.1%)	396 (74, 18.7%)	353 (62, 17.6%)
5000 – 9999 colonoscopies	3,285 (507, 15.4%)	1,753 (372, 21.2%)	1,374 (275, 20.0%)	900 (164, 18.2%)
10 000 or more colonoscopies	2,429 (420, 17.3%)	1,388 (375, 27.0%)	2,857 (530, 18.6%)	1,697 (345, 20.3%)
Interested to undergo additional training				
Yes	3,906 (617, 15.8%)	2,200 (511, 23.2%)	3,331 (630, 18.9%)	2,353 (445, 18.9%)
No	821 (140, 17.1%)	474 (107, 22.6%)	1,217 (229, 18.8%)	554 (118, 21.3%)

Not sure/Not reported	1,490 (266, 17.9%)	707 (194, 27.4%)	218 (39, 17.9%)	70 (11, 15.7%)
Type of screening facility				
Public, academic	624 (104, 16.7%)	203 (51, 25.1%)	187 (37, 19.8%)	99 (21, 21.2%)
Public, non-academic	1,400 (244, 17.4%)	623 (150, 24.1%)	1,760 (297, 16.9%)	1,099 (177, 16.1%)
Private practice	4,193 (675, 16.1%)	2,555 (611, 23.9%)	2,819 (564, 20.0%)	1,779 (376, 21.1%)

* Data not available for one leader from the feedback group

Because of rounding, percentages may not total 100.

Supplementary Table S4. Expanded generalized linear mixed effects model for the change in screening centre leaders' ADR between the pre-intervention and early post-intervention phase.

Variables	Odds ratio (95% confidence intervals)	P value
Study group		
TCL vs. Feedback group	0.96 (0.81-1.13)	0.61
Study phase		
Post-intervention vs. Pre-intervention phase	1.00 (0.85-1.19)	0.97
Study group by phase interaction	1.66 (1.32-2.08)	<0.001
Screenees' characteristics		
Male vs. Female	2.11 (1.95-2.29)	<0.001
50-54 vs. 40-49 years	1.45 (1.21-1.73)	<0.001
55-59 vs. 40-49 years	1.89 (1.59-2.25)	<0.001
60-66 vs. 40-49 years	2.31 (1.95-2.75)	<0.001
Bowel preparation*		
Good vs. Very good	1.08 (0.97-1.21)	0.16

Moderate vs. Very good	0.98 (0.86-1.13)	0.81
Poor vs. Very good	1.03 (0.84-1.26)	0.79
Very poor vs. Very good	0.88 (0.48-1.60)	0.67
Type of screening facility		
Public, non-academic vs. Public, academic	0.97 (0.71-1.34)	0.87
Private practice vs. Public, academic	1.00 (0.74-1.36)	1.00
Screening centre leader specialty		
Internal medicine/Pediatrics vs. Gastroenterology	0.66 (0.38-1.14)	0.13
General surgery vs. Gastroenterology	0.96 (0.80-1.14)	0.64

* Assessed by endoscopists using Aronchick scale