Serrated polyps are important colorectal cancer precursors that are variably detected during colonoscopy. We measured serrated polyp detection rate (SPDR) in a large, multicenter, cross-sectional study of colonoscopy quality to identify drivers of SPDR variation.

Methods Colonoscopy and pathology reports were collected for a 2-year period (10/2013-9/2015) from four sites across the United States. Data from reports, including size, location, and histology of polyps, were abstracted using a validated natural language processing algorithm. SPDR was defined as the proportion of colonoscopies with ≥1 serrated polyp (not including hyperplastic polyps). Multivariable logistic regression was performed to determine endoscopist characteristics associated with serrated polyp detection.

Results A total of 104,618 colonoscopies were performed by 201 endoscopists who varied with respect to specialty (86% were gastroenterologists), sex (18% female), years in practice (range 1–51), and number of colonoscopies performed during the study period (range 30–2654). The overall mean SPDR was 5.1% (SD 3.8%, range 0–18.8%). In multivariable analysis, gastroenterology specialization (odds ratio [OR] 1.89, 95% confidence interval [CI] 1.33–2.70), fewer years in practice (<9 years vs. ≥27 years: OR 1.52, 95% CI 1.14–2.04), and higher procedure volumes (highest vs. lowest quartile: OR 1.77, 95% CI 1.27–2.46) were independently associated with serrated polyp detection.

Conclusions Gastroenterology specialization, more recent completion of training, and greater procedure volume are associated with serrated polyp detection. These findings imply that both repetition and training are likely to be important contributors to adequate detection of these important cancer precursors. Additional efforts to improve SPDR are needed.
rectal cancers, supported by evidence that they share molecular features with these cancers [5–8], and are predominantly located in the proximal colon [9], where interval cancers are more likely to occur.

SSPs can be difficult to detect via colonoscopy because of their subtle endoscopic appearance [10] and proximal location (Fig. 1). Multiple studies have demonstrated wide variation in the detection of SSPs both across endoscopists and centers [4, 11–13], but the determinants of this variation are unclear. Whereas some studies have linked SSP or proximal serrated polyp detection to procedural factors, such as withdrawal time [12] and bowel preparation [14], it is unclear to what extent physician factors, such as experience and procedure volume, may be responsible for differences in SSP detection. Better understanding of the drivers of poor SSP detection could help tailor colonoscopy quality improvement efforts.

We aimed to measure endoscopic detection rates of serrated polyps in a large, multicenter cross-sectional study of colonoscopy quality to assess possible contributors to variation in serrated polyp detection across physicians.

Methods

Study design and settings

This was a multicenter, cross-sectional study of colonoscopy quality at four US clinical sites that vary in geography, payment model, and academic vs. private affiliation. Kaiser Permanente Washington (KPW, formerly Group Health Cooperative) is a staff model health maintenance organization based in Washington State with 18 gastroenterologists on staff. Central Illinois Endoscopy (CIE) is a private endoscopy center with 11 gastroenterologists in Peoria, Illinois. The University of North Carolina (UNC) is an academic center with 53 gastroenterologists. University of Pittsburgh Medical Center (UPMC) is based in Western Pennsylvania, with 46 gastroenterologists in its three primarily academic hospitals, and 73 gastroenterologists in affiliate hospitals and private practices. This study was approved by the institutional review boards at all participating centers.
Colonoscopy and pathology reports

Colonoscopy and pathology reports were collected for a 2-year period (10/2013 – 9/2015) from all four sites. The study sample was limited to outpatient colonoscopies performed on patients aged ≥40 years without inflammatory bowel disease. We excluded colonoscopies performed by physicians who performed fewer than 30 colonoscopies over the study period.

Measurement of colonoscopy quality and serrated polyp detection

We extracted relevant data from the colonoscopy and pathology reports using a previously developed natural language processing (NLP) system [15, 16]. Relevant information from the colonoscopy and pathology notes were abstracted using a validated NLP algorithm, including histology, size, and location of polyps [16–18]. Detailed study methods have been published previously [17,18]. The accuracy of the NLP system was confirmed by comparing specific data elements in 2127 colonoscopy and associated pathology reports, which were analyzed both by the NLP system and manually abstracted. The NLP system extracted multiple discrete variables from each colonoscopy report including family history of CRC, documentation of cecal intubation and visualization of the appendiceal orifice and ileocelecal valve, whether there was a prior colonoscopy, indication for procedure (screening, surveillance, or diagnostic), quality of bowel preparation, whether a biopsy or polypectomy was performed, and size of the largest polyp identified. From the pathology reports, for each specimen bottle the NLP system identified the colonic location from which the specimen was obtained, presence of an adenoma, presence of a serrated polyp, and presence of villous changes, high grade dysplasia, or carcinoma in any specimen. Proximal colon was defined as proximal to the splenic flexure or >50 cm from the anal verge, and distal colon was defined as between the splenic flexure and the anal verge or ≤50 cm from the anal verge.

Colonoscopies with serrated polyps were defined as any polyp in the pathology specimen that the pathologist described using the term “serrated.” The serrated polyp detection rate (SPDR) was defined as the proportion of colonoscopies with ≥1 “serrated” polyp. The SPDR does not include reports where only hyperplastic polyps were identified and the term “serrated” was not used. We also conducted a sensitivity analysis of this definition using instead the paired terms “sessile serrated” (instead of “serrated” alone), which showed that 87% of cases identified with the term “serrated” also included the pairing “sessile serrated.” SPDR also included traditional serrated adenomas (TSAs), but because these are rare lesions (prevalence <0.2% in our sample) compared with SSPs, TSAs have a minimal impact on the SPDR measure. Based on manual review of a sample of these reports, our definition of SPDR had high overall accuracy (99%), sensitivity (98%), and positive predictive value (97%) for SSPs [17]. SPDR in this study is analogous to the SSP detection rate reported in other studies [14, 19]. For the primary analysis, all colonoscopies were included in the denominator, but we also conducted a sensitivity analysis with the sample being limited to only screening colonoscopies.

We looked at the correlation between SPDR and other quality metrics to see whether they were similar. In addition to overall SPDR, we calculated the mean SPDR for the proximal and distal colon as the number of serrated polyps detected in that part of the colon divided by the total number of colonoscopies performed by the endoscopist. We also measured the large SPDR as the proportion of cases with one serrated polyp ≥10 mm in size. We calculated adenoma detection rate (ADR) as the proportion of colonoscopies where any adenoma or carcinoma was identified. We also calculated ADR in the proximal and distal colon, and the advanced adenoma detection rate, which was defined as the fraction of all colonoscopies where there was an adenoma with villous or high grade dysplastic changes, or, an adenoma at least 10 mm in size. We identified colonoscopies with an adenoma at least 10 mm in size as those where the largest polyp identified from the colonoscopy was 10 mm or greater and there was an adenoma identified on the pathology specimen. Finally, we calculated the TSA detection rate as the proportion of colonoscopies where the term “traditional serrated adenoma” was found in the associated pathology report.

Endoscopist attributes

Endoscopist attributes including age, sex, specialty, and years in practice were obtained from Doximity, a national database of physician characteristics that compiles data from the National Plan and Provider Enumeration System (NPPES), National Provider Identifier Registry, the Association of American Medical Colleges, the American Board of Medical Subspecialties (ABMS), and state licensing boards, as well as self-registered members and collaborating hospitals and medical schools. This database has been used in prior studies of the physician workforce [20, 21], and has been previously validated [22]. Furthermore, the NPPES and ABMS databases (which are used by Doximity to derive data on sex, specialty, and year of residency graduation) are considered to have high fidelity owing to obligatory participation, and have been shown to be accurate when compared with other physician databases [23,24]. Years of practice was measured as the number of years since completion of residency, as of 2014. We stratified physicians into four roughly equal quartiles to categorize the years that they had been in practice (≤9 years, 10–18 years, 19–26 years, and 27–51 years). The rates of adequate bowel preparation were calculated as the proportion of colonoscopies that each endoscopist rated as excellent, good, fair, or adequate (vs. poor or inadequate). Procedure reports that did not include a description of bowel preparation were assumed to be adequate. Cecal intubation rate was calculated as the proportion of colonoscopies in which the endoscopist documented reaching the cecum. Bowel preparation adequacy and cecal intubation rate were dichotomized at 85% and 95%, respectively, according to established quality metric thresholds [25, 26].

Statistical analysis

Descriptive univariate statistics were calculated for overall SPDR, SPDR by colonic location, detection of large (≥10 mm) serrated polyps, and detection of TSAs. We used bivariate anal-
analysis to describe the proportion of endoscopists that fell above or below the median SPDR in the sample, by endoscopist sex, specialty, years in practice, colonoscopy volume, rate of adequate bowel preparation, and cecal intubation rate. Multivariable analysis was conducted at the procedure level to identify which endoscopist characteristics were independently associated with a colonoscopy with one or more serrated polyps, after adjusting for patient characteristics and study site. Standard errors were adjusted for clustering by physician. This analysis used logistic regression to estimate odds ratios (ORs) and 95% confidence intervals (CI) of a binary outcome of whether or not a particular colonoscopy had a serrated polyp detected. Model covariates included patient characteristics (age, sex, and colonoscopy indication), site fixed effects, as well as endoscopist characteristics (sex, specialty, years in practice, and colonoscopy volume, rate of adequate bowel preparation, and cecal intubation rate). We also conducted sensitivity analyses, limiting the sample to 1) only screening colonoscopies, and 2) only endoscopists with at least 100 procedures during the 2-year study period (≥ 50 per year). Finally, to determine the degree of correlation between polyp detection metrics, we calculated Pearson’s correlation coefficients for each pair of outcome measures (e.g. SPDR and ADR).

Results

Study sample

A total of 104 618 colonoscopies were included in the sample, 44.8% (46 918) of which were screening colonoscopies. The procedures were performed by 201 endoscopists of whom 85.6% were gastroenterologists, and 14% had training in either family medicine or general, thoracic, or colorectal surgery.
Serrated polyp detection

Across all colonoscopies in the sample, 6.3% (n=6622) had at least one serrated polyp. The overall mean SPDR across endoscopists was 5.1% (SD 3.8%, range 0–18.8%). ( Tab.2, Fig. 2). The majority of serrated polyps identified were located in the proximal colon (80.8%). The mean proximal SPDR was 3.9% (SD 3.3%), and the mean large SPDR was 1.0% (SD 1.3%) ( Tab.2). TSAs were rare; in total, there were 160 TSAs identified among all colonoscopies. At the physician level, 40% of endoscopists detected at least one TSA. The mean SPDR also varied across sites from 4.4% to 10.6% ( Supplementary Tab.e3, available online).

Bivariate analyses showed that a higher proportion of gastroenterologists had above-median SPDR than nongastroenterologists (52.9% vs. 31.0%; P = 0.03) ( Tab.1). Additionally, endoscopists in higher quartiles of procedure volume were more likely to have above-median SPDR than endoscopists in the lower-volume quartiles (P<0.001).

Multivariable analyses

In a multivariable logistic regression at the colonoscopy level, we found several endoscopist factors that were independently associated with detecting a serrated polyp during colonoscopy, after controlling for patient characteristics ( Tab.4). Colonoscopies performed by gastroenterologists had nearly twice the odds of detecting a serrated polyp than those performed by nongastroenterologists (OR 1.89, 95%CI 1.33–2.70). Procedures performed by physicians with fewer years in practice (i.e. closer to residency or fellowship training) were also more likely to detect serrated polyps (≤9 years vs. ≥27 years: OR 1.52, 95%CI 1.14–2.04) ( Fig.3a). In addition, we found evidence of a linear trend with respect to procedure volume; compared with endoscopists in the lowest quartile, colonoscopies performed by endoscopists with higher procedure volumes were more likely to detect serrated polyps (for quartiles 2, 3, and 4 vs. 1: OR 1.28, 95%CI 0.91–1.80; OR 1.43, 95%CI 1.01–2.02; and OR 1.77, 95%CI 1.27–2.46, respectively) ( Fig.3b). Endoscopists with lower mean rates of adequate bowel preparation also had lower serrated polyp detection (for rates <85% vs. ≥85%: OR 0.60, 95%CI 0.38–0.97). There was no observed relationship between endoscopist sex or cecal intubation rate and serrated polyp detection. Restricting the sample to only screening colonoscopies showed similar results ( Supplementary Tab.e5, available online). Similarly, restricting the sample to higher-volume endoscopists (at least 100 colonoscopies per 2 years) did not substantially affect the trends observed, apart from a loss in precision ( Supplementary Tab.e6, available online). However, the effect of procedure volume was not statistically significant among the subset of higher-volume endoscopists (for quartile 4 vs. 1: OR 1.26, 95%CI 0.93–1.71).
Correlation with other quality metrics

There was a strong correlation between SPDR and proximal SPDR ($r = 0.96$) with a relatively weaker association between SPDR and ADR and advanced ADR ($r = 0.54$ and $0.35$, respectively) (Fig. 4). Whereas high ADR generally correlated with high SPDR, there was a substantial proportion of endoscopists who exhibited higher detection for one polyp type but not the other, or who performed below the 50th percentile for both measures (Fig. 5).

Discussion

In this multicenter study comprising a large number of colonoscopies and endoscopists, we found evidence of substantial variation between physicians with respect to their detection of serrated polyps. Overall, there was a greater than 19-fold difference between the physicians with highest and lowest SPDRs. Endoscopist characteristics associated with higher serrated polyp detection included gastroenterology specialty training, more recent completion of training, higher colonoscopy procedure volume, and higher rate of adequate bowel preparation. The association between endoscopist characteristics and SPDR that we observed does not appear to be explained by differences in patient mix or study site.

These findings can be applied to quality improvement efforts. For example, the fact that nongastroenterologists and those further removed from training had lower serrated polyp detection rates suggests that some decrement in serrated polyp detection may be related to lack of awareness or knowledge about the importance of serrated polyps in colonoscopy screening. Therefore, educational interventions targeted at these groups could potentially improve serrated polyp detection. Our finding that procedure volume correlated with SPDR could indicate that, because SSPs are rarer than conventional adenomas, more procedures are needed to establish pattern recognition skills for polyp identification. Accordingly, video-based or other training interventions could be useful to improve the detection skills of lower-volume endoscopists who encounter SSPs less often [27]. Alternatively, higher-volume endoscopists may be achieving better examinations of the cecum and proximal colon, where SSPs are more frequently loca-
Table 4: Endoscopist factors associated with detecting a serrated polyp on colonoscopy.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Serrated polyp detection, OR* (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endoscopist sex</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1.00 (Ref)</td>
</tr>
<tr>
<td>Female</td>
<td>1.10 (0.84–1.44)</td>
</tr>
<tr>
<td>Primary specialty</td>
<td></td>
</tr>
<tr>
<td>Gastroenterology</td>
<td>1.89 (1.33–2.70)</td>
</tr>
<tr>
<td>Other</td>
<td>1.00 (Ref)</td>
</tr>
<tr>
<td>Years in practice</td>
<td></td>
</tr>
<tr>
<td>≤9</td>
<td>1.52 (1.14–2.04)</td>
</tr>
<tr>
<td>10–18</td>
<td>1.42 (1.02–1.97)</td>
</tr>
<tr>
<td>19–26</td>
<td>1.33 (1.01–1.75)</td>
</tr>
<tr>
<td>27–51</td>
<td>1.00 (Ref)</td>
</tr>
<tr>
<td>Number of colonoscopies performed over 2-year period</td>
<td></td>
</tr>
<tr>
<td>30–115</td>
<td>1.00 (Ref)</td>
</tr>
<tr>
<td>116–278</td>
<td>1.28 (0.91–1.80)</td>
</tr>
<tr>
<td>279–771</td>
<td>1.43 (1.01–2.02)</td>
</tr>
<tr>
<td>772–2654</td>
<td>1.77 (1.27–2.46)</td>
</tr>
<tr>
<td>Rate of adequate bowel preparation</td>
<td></td>
</tr>
<tr>
<td>&lt;0.85</td>
<td>0.60 (0.38–0.97)</td>
</tr>
<tr>
<td>≥0.85</td>
<td>1.00 (Ref)</td>
</tr>
<tr>
<td>Cecal intubation rate</td>
<td></td>
</tr>
<tr>
<td>&lt;0.95</td>
<td>0.96 (0.75–1.22)</td>
</tr>
<tr>
<td>≥0.95</td>
<td>1.00 (Ref)</td>
</tr>
</tbody>
</table>

OR, odds ratio; CI, confidence interval.
* ORs estimated using multivariable logistic regression model adjusting for patient age, sex, colonoscopy indication, and site of colonoscopy procedure. Standard errors are clustered at the physician level.

The strengths of this analysis are the large number of colonoscopies included, which contributes to the precision of our estimates. This is particularly important, as we were interested in an outcome of serrated polyps, which are substantially less common than conventional adenomas [34]. We also included data from multiple sites that were varied in terms of geography, practice type, and academic vs. private affiliation, contributing to the external validity of our findings.

Limitations that should be considered include the use of an NLP tool to abstract data on procedure and pathology details. Although the NLP algorithm was rigorously developed and tested, it is imperfect; the pipeline may have missed some serrated polyps, and may have flagged some polyps as serrated that were not actually SSPs or TSAs owing to differences in pathologist jargon. However, other non-NLP methods of measuring colonoscopy quality, such as manual review, are also subject to error. Second, we used a measure for SPDR that included all procedures where a polyp was removed and the pathologist included “serrated” in the report. Although this definition in the vast majority of cases resulted in identifying SSPs, it also included a...
small number of TSAs, and some negation statements (e.g. “serrated polyp without definitive features of sessile serrated adenoma”). It is also worth noting that > 80% of the serrated polyps identified by the SPDR measure were located in the proximal colon, which is consistent with the location distribution of SSPs reported in other studies [9]. For these reasons, we used the term “SPDR” instead of “SSP detection rate,” though we believe the former to be an accurate estimate of the latter. Indeed, in a sensitivity analysis, we found that most cases identified as “serrated” were also identified by the term “sessile serrated.” In addition, we did not have information on all endoscopist or procedural characteristics that could contribute to serrated polyp detection. In particular, withdrawal time, endoscopists’ knowledge of the importance of or typical appearance of SSPs, visual gaze patterns, bowel preparation type, and use of narrow-band imaging or high definition endoscopy equipment were not available. Although we were able to evaluate the effect of physician specialty broadly, we were not able to perform any meaningful subgroup analyses given the small number of nongastroenterologists in our sample (n=29 from four different specialties). We also did not have detailed patient-level information on factors that may be associated with the prevalence of serrated polyps, such as smoking or diet.

Another limitation is that we did not capture hyperplastic polyps in our measure of SPDR. First, this means that the SPDR metric is somewhat of a misnomer, as technically, hyperplastic polyps are also serrated polyps [35]. Second, some pathologists may misclassify SSPs as hyperplastic polyps [36], which may explain why hyperplastic polyps in the proximal colon are associated with higher risk [37–40]. Therefore, some of the variation we observe across endoscopists could be due to differences in pathologist readings, as has been described in other studies [13]. Ideally, we would have used a gold-standard pathology assessment of polyps, but in a large, retrospective study, central pathology review was neither practical nor possible. The degree to which this is a limitation is unclear given that an individual endoscopist will have their polyps read by many different pathologists and that this assignment is often random. Furthermore, all four sites had an SPDR of at least 4.4%, which indicates that pathologists at each site were frequently diagnosing SSPs during the study period.

In summary, gastroenterology specialty training, more recent completion of training, and procedure volume were associated with improved serrated polyp detection. These findings imply that both repetition and training are likely to be important contributors to adequate detection of these important cancer precursors, though this requires further study. Additional efforts to improve SPDR are needed in order to optimize the cancer prevention benefit of screening colonoscopy.

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Competing interests
None

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