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Leveraging Electronic Health Records to Measure Low-Value Screening Colonoscopy

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INTRODUCTION

Among more than 6 million screening colonoscopies performed annually in the United States, up to one-third may represent potential overuse.[1,2] Colorectal cancer (CRC) screening overuse is defined as screening in specific clinical scenarios that provide no net benefit to individuals, such as screening too frequently or outside the age of eligibility.[3-5] Colonoscopy overuse is an important problem because it can cause direct patient harm (eg, 0.3% complication rate leading to hospitalization or death), raise health care costs, and reduce availability of appropriate endoscopy for other individuals.[3,6,7] Minimizing inappropriate colonoscopies will expand access to high-value screening, which is particularly salient in light of new US Preventative Services Task Force (USPSTF) guidelines that recommend all individuals age 45-49 engage in CRC screening in addition to individuals ages 50-75.[8,9]

Despite its known harms, screening colonoscopy overuse persists in part because health systems do not routinely measure it.[5,10,11] Most existing performance metrics focus on health care underutilization, which can incentivize providers to order more screening tests to earn revenue for each service and to earn bonuses from pay-for-performance programs.[3,5,10,12] Although electronic health record (EHR)-based performance measures have been used to measure CRC screening overuse, they have been primarily developed and tested in the Veterans Health Administration (VA) where no fee-for-service payment incentive to overuse tests exists.[13-18] In this context, we aimed to develop an electronic measure (e-measure) of screening colonoscopy overuse at a large, nonfederal academic medical center to inform future quality improvement interventions that aim to increase appropriate use of colonoscopy and promote high-value care.

METHODS

Study Setting and E-Measure Design

UCLA Health is a large, urban academic health system with more than 408,000 primary care patients, 81 primary care clinics, and 5 outpatient endoscopy units. We used a previously applied approach to develop an e-measure of screening colonoscopy overuse.[13] Our measure uses a 2-step process to identify screening colonoscopy overuse among colonoscopies ordered for any indication. First, the e-measure uses ICD-9, ICD-10, and CPT codes (Appendix A, available online) and EHR data elements to identify average-risk screening colonoscopies by excluding those performed for nonscreening indications, such as diagnostic

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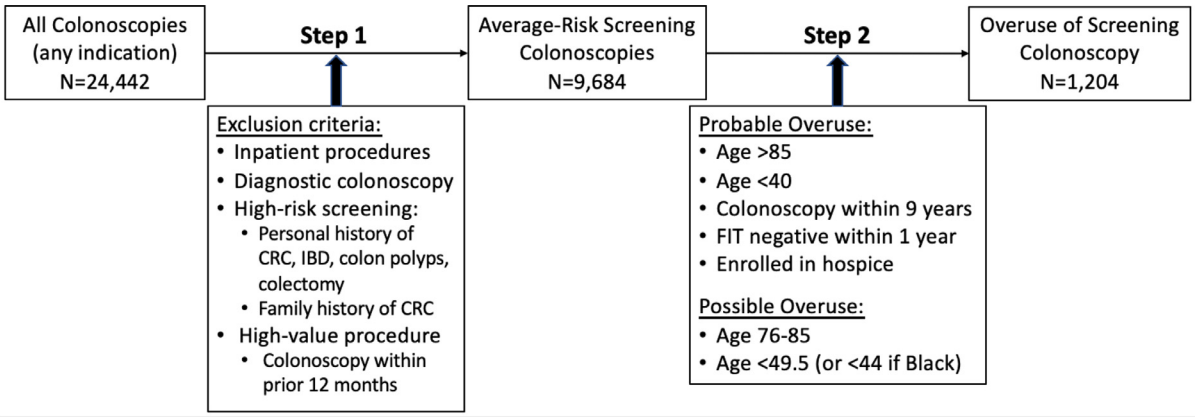

Figure 1 Electronic measure (e-measure) 2-step algorithm to identify overuse of average risk screening colonoscopies among colonoscopies ordered for any indication in our health system.

procedures or surveillance colonoscopies for patients with prior colorectal polyps or CRC (Figure 1, Step 1). Second, the measure identifies possible or probable overuse of screening colonoscopy within this population using a discrete set of inclusion criteria (Figure 1, Step 2). The remaining colonoscopies are labeled as appropriate screening.

E-Measure Development and Validation

To develop and test the e-measure, we used data for all colonoscopies ordered across our health system between January 1, 2018, and December 31, 2018 (N = 24,442). The final e-measure categorized each colonoscopy as either 1) a nonscreening procedure (esophagogastroduodenoscopy [EGD] co-referral, symptomatic/diagnostic procedure, high-risk screening, high-value diagnostic procedure, or inpatient procedure), 2) appropriate screening, or 3) screening overuse. Screening overuse was defined as meeting criteria for possible or probable overuse (Figure 1, Step 2). Per USPSTF guidelines at the time, CRC screening was indicated in individuals ages 50 to 75; screening in people ages 76-85 was individualized based on life expectancy, and we accordingly labeled this population "possible overuse" to reflect uncertainty or possibility that these colonoscopies may actually be appropriate screening.[8]

Based on methods from our prior work, we selected a stratified random subset of cases from each of these 3 categories (appropriate screening, screening overuse, nonscreening procedure) at an approximate ratio of 1:2:3 to develop a cohort of 400 colonoscopies and performed a validation study using manual chart abstraction as the gold standard.[19] This sampling strategy allowed for sufficient sample sizes of each e-measure output such that rarer subgroups (eg, screening overuse, inpatient or high-value diagnostic nonscreening procedures) were adequately sampled to obtain statistical power to assess performance for each category and improve the estimate of diagnostic accuracy for overuse. Although this artificial oversampling of certain categories allowed for efficient e-measure development and validation, it may be less effective for estimating population prevalence of overuse.

Supervised by a board-certified gastroenterologist, manual chart review was performed by 4 internal medicine physician abstractors (CS, JG, MM, SK) who first reviewed 10 test cases and came to 100% inter-rater agreement through discussion. Data for the entire cohort were then collected using a standardized chart abstraction tool. After data collection, one expert abstractor (CS) performed data quality checks on 10 random charts from each abstractor's data set and reviewed all discrepancies between the e-measure and manual categorization; discrepancies were resolved in discussion, which was supervised by a board-certified gastroenterologist.

Data Analysis

After development of the final e-measure, our primary aim was to determine the sensitivity and specificity (referred to as "unadjusted" performance) of the e-measure to 1) identify average-risk CRC screening cases among colonoscopies ordered for any indication (step 1), and 2) identify overuse of screening colonoscopies among all colonoscopies ordered (step 2). As overuse cases were oversampled in our validation cohort to improve e-measure development, we then used an inverse-probability weighting based estimator of agreement statistics to adjust these results for our sampling strategy to estimate performance of the measure in a completely random sample (referred to as "adjusted" performance).[20] Our discussion focuses on adjusted performance results, which allow for more reliable estimates of overuse at the population level. We then determined the frequency of each type of error made by the e-measure to quantify its test characteristics. For overuse cases, we determined the frequencies for underlying reasons for overuse. Finally, we used the e-measure to estimate frequency of screening colonoscopy overuse across our entire health system, by patient characteristics and by primary care clinic, using χ^2 tests or Fisher exact tests for comparisons.[19]

RESULTS

E-Measure Validation Cohort

Within the stratified random validation cohort (n = 400), screening colonoscopy overuse was 18.3% (n = 73) per chart review and 34.5% (n = 138) per the e-measure. In step 1, the e-measure identified average-risk screening colonoscopies at an adjusted sensitivity of 97.1% and adjusted specificity of 87.8% (unadjusted sensitivity 97.6%, unadjusted specificity 70.4%; Table 1). The false-positive rate was 29.6% (n = 81) and false-negative rate was 2.4% (n = 3) for this step (Appendix B, available online).

The e-measure identified screening colonoscopy overuse at an overall adjusted sensitivity and adjusted specificity of 48.7% and 97.4%, respectively (unadjusted sensitivity 93.2%, unadjusted specificity 78.6%; Table 1, Step 2). The false-positive rate was 21.4% (n = 70) and false-negative rate was 6.8% (n = 5) for step 2 (Appendix C, available online). Among 73 cases of screening overuse identified by manual chart review within the validation cohort, the reasons for overuse were colonoscopy order within 1 year of negative fecal immunochemical testing (FIT) (n = 26, 35.6%), within 9 years of prior colonoscopy (n = 17, 23.3%), and outside the age of screening eligibility (n = 30, 41.1%). Among the 30 cases outside screening age, 23 (31.5%) were below and 7 (9.6%) were above the age of screening eligibility (Figure 1, Step 2).

Table 1 E-Measure Performance to Identify Screening Colonoscopy Overuse in the Validation Cohort, N = 400 colonoscopies ordered for any indication.

E-measure Algorithm	Sensitivity	Specificity
Step 1: Identification of average-risk screening colonoscopies	97.6%	70.4%
Unadjusted performance*	97.1%	87.8%
Adjusted performance†		
Step 2: Identification of overuse of average-risk screening colonoscopies‡	93.2%	78.6%
	48.7%	97.4%
Unadjusted performance*		
Adjusted performance†		

*Performance of the e-measure to identify screening colonoscopy overuse in the stratified random validation cohort.

†Performance of the e-measure to identify screening colonoscopy overuse in the overall population, using inverse-probability weighting to adjust for sampling strategy used to develop the validation cohort (eg, oversampling of overuse cases).

‡These test characteristics represent the overall performance of the measure, N = 400.

E-Measure Estimated Prevalence of Screening Colonoscopy Overuse Among Total Cohort

After excluding nonscreening procedures, the e-measure identified 9685 average-risk screening colonoscopies ordered across our health system between January 1, 2018, and December 31, 2018, and 1204 (12.4%; 95% confidence interval [C]I 11.8-13.1) of these colonoscopies met criteria for overuse. Overuse was more common among non-Black patients (12.6% vs 8.9%, $P < .01$) and males (13.2% vs 11.7%, $P = .03$) (Table 2). Within the 81 primary care clinics, the proportion of screening colonoscopies per clinic that met overuse criteria was highly variable (range 0%-50.0%; Figure 2). Twenty-seven clinics (33.3%) contributed to >80% of overuse cases (Figure 2). Patient age, gender, and race were not significantly different in these 27 high-utilization clinics compared with the remaining 54 clinics.

DISCUSSION

We developed an e-measure that had an overall adjusted performance that was highly specific at identifying

Table 2 Patient-Level Characteristics Among Those Who Were Ordered an Average-Risk Screening Colonoscopy at UCLA Health During the Study Period. N = 9684.

Patient Characteristics	Total (N = 9684) n (%)*	Overuse (n = 1204) n (%)†	High-Value Screening (n = 8480) n (%)‡	*P* Value§
Age				
<40	190 (2.0%)	190 (100%)	0 (0%)	<.001
40-44	91 (0.9%)	91 (100%)	0 (0%)	
45-49	406 (4.2%)	251 (61.8%)	155 (38.2%)	
50-75	8863 (91.5%)	538 (6.1%)	8325 (93.9%)	
76-85	122 (1.3%)	122 (100%)	0 (0%)	
>85	12 (0.1%)	12 (100%)	0 (0%)	
Gender				
Male	4812 (49.7%)	633 (13.2%)	4179 (86.9%)	.034
Female	4872 (50.3%)	571 (11.7%)	4301 (88.3%)	
Race/Ethnicity				
Black	553 (5.7%)	49 (8.9%)	504 (91.1%)	.008
Non-Black	9131 (94.3%)	1155 (12.6%)	7976 (87.4%)	

*Percentages are calculated as the proportion of each subgroup within the entire average-risk screening population (column percentage).

†Percentages are calculated as the proportion of overuse within each subgroup (row percentage).

‡Percentages are calculated as the proportion of high-value use within each subgroup (row percentage).

§P values were obtained from χ^2 test comparing the overuse rates by patient characteristic.

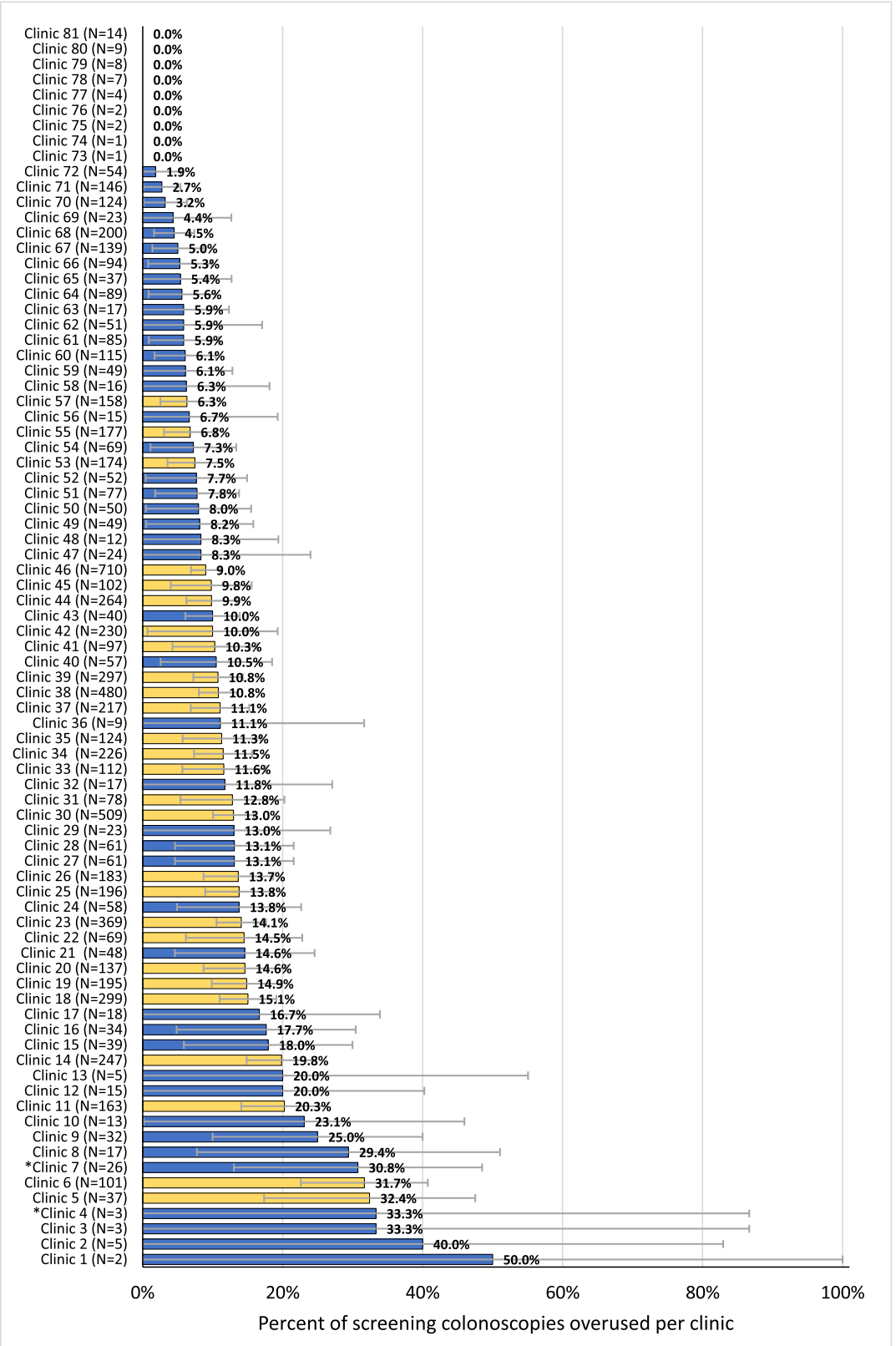

Figure 2 Distribution of screening colonoscopy overuse prevalence by primary care clinic, n = 72 clinics.

screening colonoscopy overuse. During our validation of the e-measure, we found that approximately one-third of overuse colonoscopies were attributed to screening prior to the age of eligibility and nearly two-thirds were due to screening sooner than the recommended interval after prior fecal immunochemical testing or colonoscopy. The e-measure estimated that 1 in 8 colonoscopies ordered within the health system represented overuse, and overuse was concentrated among a small subset of primary care practices.

Although our adjusted sensitivity was modest, it remains a substantial improvement compared to the sensitivity (~20%) of the e-measure previously developed at the VA on which our algorithm was based. Although this measure may potentially miss cases of overuse, when it does detect cases we can be more confident in the probability that the case truly reflects overuse, which has important implications for quality improvement efforts. Specifically, by using a highly specific measure we are less likely to cause the unintended consequence of misclassifying appropriate care as medical overuse, such as discouraging medically appropriate care and impacting patient safety by potentially leading to delays in CRC detection.

Although the rate of screening colonoscopy overuse in our overall population (12.4%) is lower than rates previously reported in studies, our findings highlight important differences in utilization at the patient and clinic levels.[2,13-18] Overuse was more common in males and non-Black patients. Furthermore, overuse was unevenly distributed among primary care clinics. One-third of clinics contributed to the majority of overuse cases, and these clinics also ordered colonoscopies more frequently than other clinics when accounting for colonoscopy utilization volume. Notably, patient demographics were similar in high-utilization clinics compared with remaining clinics. As next steps, we intend to assess patient-, provider- and clinic-level factors that are associated with overuse. Interventions to encourage appropriate screening ordering behaviors in high-utilization clinics may significantly reduce unnecessary procedures, minimize risk for colonoscopy complications, improve overall quality of care in our health system, and help promote health care equity.

Although sensitivity was modest, our e-measure demonstrated improved overall performance compared to the study on which it was based.[13] A major limitation of the e-measure is its dependence on accurate ICD-9/10 and CPT coding of procedures and diagnoses. The e-measure made most errors while identifying average-risk screening colonoscopies in step 1, largely due to inaccurate or missing EHR codes for nonscreening indications. For example, procedures in patients age <40 (2% of study population) that were classified by the e-measure as overuse were often mislabeled due to inappropriate ICD-9/10 or CPT codes. Notably, few cases of overuse were missed in step 2, which relied on a discrete set of definitions rather than procedural codes for categorization. Improved provider documentation of procedure indications or combining the e-measure with machine learning techniques like natural language processing may help improve the measure's performance.[21] In addition, given that the e-measure focuses on screening colonoscopies and does not assess appropriateness of surveillance colonoscopies, we anticipate that there may also be overuse among individuals who undergo surveillance colonoscopy. Developing an automated method to determine appropriate surveillance intervals for patients at high-risk of CRC will help assess overall colonoscopy overuse at the health system level.

A major strength of our study is the e-measure's high specificity compared to existing performance measures. We believe the improved performance is likely due to updating the algorithm previously validated at the VA to use ICD-10 codes, which are more specific compared with ICD-9 codes. Additionally, e-measures are valuable tools for automated, regular quality monitoring in large health care systems, but have not yet been optimized as a mechanism to promote appropriate use of common medical interventions, including screening colonoscopy. The successful development of an e-measure for screening colonoscopy overuse in a large, nonfederal medical center is a critical step toward developing future quality improvement efforts to increase high-value care.

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SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjmed.2021.12.008.

APPENDIX A ICD-9, ICD-10, & CPT CODES USED BY THE E-MEASURE FOR EXCLUSIONS IN STEP 1

Exclusion Category	Code type	Codes
Referral Orders – Upper EGD co-referral	CPT CODE	00700, 00702, 00730, 00731, 00732, 00750, 00752, 00754, 00756, 00770, 00790, 00792, 00794, 00796, 00797, 43180, 43191, 43192, 43193, 43194, 43195, 43196, 43197, 43198, 43200, 43201, 43202, 43204, 43205, 43206, 43210, 43211, 43212, 43213, 43214, 43215, 43216, 43217, 43220, 43226, 43227, 43229, 43231, 43232, 43233, 43235, 43236, 43237, 43238, 43239, 43240, 43241, 43242, 43243, 43244, 43245, 43246, 43247, 43248, 43249, 43250, 43251, 43252, 43253, 43254, 43255, 43257, 43259, 43266, 43270
Diagnostic Colonoscopy: Symptomatic	ICD9 CODE: COLONOSCOPIES PERFORMED FOR NON-SCREENING INDICATIONS DIAGNOSES	280, 280.1, 280.8, 280.9, 285.1, 285.9, 558.1, 558.9, 560, 560.1, 560.9, 562.12, 562.13, 564, 564.1, 564.5, 564.7, 569.3, 569.42, 569.85, 578, 578.1, 578.9, 787.0, 787.01, 787.02, 787.03, 787.3, 783, 783.2, 787.6, 787.9, 789.0, 789.3, 792.1, V100.5, V100.6, V127.2
	ICD10 Code: COLONOSCOPIES PERFORMED FOR NON-SCREENING INDICATIONS DIAGNOSES	D50.0, D50.1, D50.8, D50.9, D62, D64.9, K50.00, K50.011, K50.012, K50.013, K50.014, K50.018, K50.019, K50.10, K50.111, K50.112, K50.113, K50.114, K50.118, K50.119, K50.80, K50.811, K50.812, K50.813, K50.814, K50.818, K50.819, K50.90, K50.911, K50.912, K50.913, K50.914, K50.918, K50.919, K51.00, K51.011, K51.012, K51.013, K51.014, K51.018, K51.019, K51.20, K51.211, K51.212, K51.213, K51.214, K51.218, K51.219, K51.30, K51.311, K51.312, K51.313, K51.314, K51.318, K51.319, K51.40, K51.411, K51.412, K51.413, K51.414, K51.418, K51.419, K51.50, K51.511, K51.512, K51.513, K51.514, K51.518, K51.519, K51.80, K51.811, K51.812, K51.813, K51.814, K51.818, K51.819, K51.90, K51.911, K51.912, K51.913, K51.914, K51.918, K51.919, K52.0, K52.29, K52.3, K52.831, K52.832, K52.838, K52.839, K52.89, K52.9, K55.21, K56.0, K56.1, K56.60, K56.7, K57.21, K57.31, K57.33, K57.41, K57.51, K57.53, K57.81, K57.91, K57.93, K58.0, K58.1, K58.2, K58.8, K58.9, K59.00, K59.01, K59.02, K59.03, K59.04, K59.09, K59.1, K59.31, K59.39, K62.5, K62.89, K92.0, K92.1, K92.2, R10.0, R10.10, R10.11, R10.12, R10.13, R10.2, R10.30, R10.31, R10.32, R10.33, R10.84, R10.9, R11.0, R11.10, R11.11, R11.12, R11.14, R11.2, R14.0, R14.1, R14.2, R14.3, R15.0, R15.1, R15.2, R15.9, R19.00, R19.01, R19.02, R19.03, R19.04, R19.05, R19.06, R19.07, R19.09, R19.4, R19.5, R19.7, R19.8, R63.0, R63.4, R63.6
High-Risk Screening or Surveillance: Increased risk of CRC	TOTAL COLECTOMY (AHRQ CPT)	44150, 44151, 44152, 44153, 44155, 44156, 44157, 44158, 44210, 44211, 44212
	COLORECTAL CANCER (HCPCS)	G0105, G0213, G0214, G0215, G0231
	ICD9 Code: COLORECTAL CANCER DIAGNOSES	153.0, 153.1, 153.2, 153.3, 153.4, 153.5, 153.6, 153.7, 153.8, 153.9, 154.0, 154.1, 154.8, V10.0, V10.05, V10.06
	ICD10 Code: COLORECTAL CANCER DIAGNOSES	C18.0, C18.1, C18.2, C18.3, C18.4, C18.5, C18.6, C18.7, C18.8, C18.9, C19, C20, C21.2, C21.8, Z85.00, Z85.01, Z85.028, Z85.038, Z85.048, Z85.05,
	ICD9 Code: INFLAMMATORY BOWEL DISEASE	555, 555.1, 555.2, 555.9, 556, 556.1, 556.2, 556.3, 556.4, 556.5, 556.6, 556.8, 556.9
	ICD10 Code: INFLAMMATORY BOWEL DISEASE	K50.00, K50.011, K50.012, K50.013, K50.014, K50.018, K50.019, K50.10, K50.111, K50.112, K50.113, K50.114, K50.118, K50.119, K50.80, K50.811,
	ICD9 Code: FAMILY HISTORY OF COLORECTAL CANCER DIAGNOSES	V16.0, V18.51
	ICD10 Code: FAMILY HISTORY OF COLORECTAL CANCER DIAGNOSES	Z80.0, Z83.71
	ICD9 COLON POLYPS DIAGNOSES	211.3, 211.4, 230.3, 230.4, V12.72
	ICD10 COLON POLYPS DIAGNOSES	D01.0, D01.1, D01.2, D12.0, D12.1, D12.2, D12.3, D12.4, D12.5, D12.6, D12.7, D12.8, D12.9, K63.5, Z86.010

APPENDIX B PERFORMANCE OF E-MEASURE COMPARED TO CHART REVIEW FOR IDENTIFICATION OF SCREENING PROCEDURES (STEP 1)

		E-measure		
		Average risk screening	Nonscreening procedure	Total
Manual chart review	Average risk screening	123	(FN) 3	126
	Nonscreening Procedure	(FP) 81	193	274
	Total	204	196	400

FN = false negative
FP = false positive

APPENDIX C PERFORMANCE OF E-MEASURE COMPARED TO CHART REVIEW FOR IDENTIFICATION SCREENING OVERUSE (STEP 2)

		E-measure		
		Possible or Probable Overuse	Other*	**Total**
Manual chart review	Possible or Probable Overuse	68	(FN) 5	73
	Other*	(FP) 70	257	327
	Total	138	262	400

FN = false negative
FP = false positive
*Colonoscopies designated as either a nonscreening procedure in step 1 or as high-value screening in step 2.