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Structured Approach for Evaluating Strategies for Cancer Ascertainment Using Large-Scale Electronic Health Record Data

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abstract

Purpose Cancer ascertainment using large-scale electronic health records is a challenge. Our aim was to propose and apply a structured approach for evaluating multiple candidate approaches for cancer ascertainment using colorectal cancer (CRC) ascertainment within the US Department of Veterans Affairs (VA) as a use case.

Methods The proposed approach for evaluating cancer ascertainment strategies includes assessment of individual strategy performance, comparison of agreement across strategies, and review of discordant diagnoses. We applied this approach to compare three strategies for CRC ascertainment within the VA: administrative claims data consisting of International Classification of Diseases, Ninth Revision (ICD9) diagnosis codes; the VA Central Cancer Registry (VACCR); and the newly accessible Oncology Domain, consisting of cases abstracted by local cancer registrars. The study sample consisted of 1,839,043 veterans with index colonoscopy performed from 1999 to 2014. Strategy-specific performance was estimated based on manual record review of 100 candidate CRC cases and 100 colonoscopy controls. Strategies were further compared using Cohen's κ and focused review of discordant CRC diagnoses.

Results A total of 92,197 individuals met at least one CRC definition. All three strategies had high sensitivity and specificity for incident CRC. However, the ICD9-based strategy demonstrated poor positive predictive value (58%). VACCR and Oncology Domain had almost perfect agreement with each other (κ, 0.87) but only moderate agreement with ICD9-based diagnoses (κ, 0.51 and 0.57, respectively). Among discordant cases reviewed, 15% of ICD9-positive but VACCR- or Oncology Domain–negative cases had incident CRC.

Conclusion Evaluating novel strategies for identifying cancer requires a structured approach, including validation against manual record review, agreement among candidate strategies, and focused review of discordant findings. Without careful assessment of ascertainment methods, analyses may be subject to bias and limited in clinical impact.

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INTRODUCTION

Increasing availability of large-scale electronic health records (EHRs) has great promise for enabling groundbreaking epidemiologic and quality improvement work and is particularly important for cancer research. Indeed, a recent report issued by the President's Cancer Panel called for development of health information technologies (including through leveraging EHRs) to use learning health care systems to support continuous improvement in care across the cancer continuum and to use health information technologies to enhance cancer surveillance.[1]

The first steps in any initiative to leverage EHRs for epidemiologic research and quality improvement must include identifying a robust approach to cancer ascertainment. However, ascertainment of incident cancer derived from usual health care resources is a major challenge. Administrative claims data have been widely used for cancer ascertainment, but these may be subject to misclassification.[2-4] For example, an International Classification of Diseases, Ninth Revision (ICD9) diagnosis code for colorectal

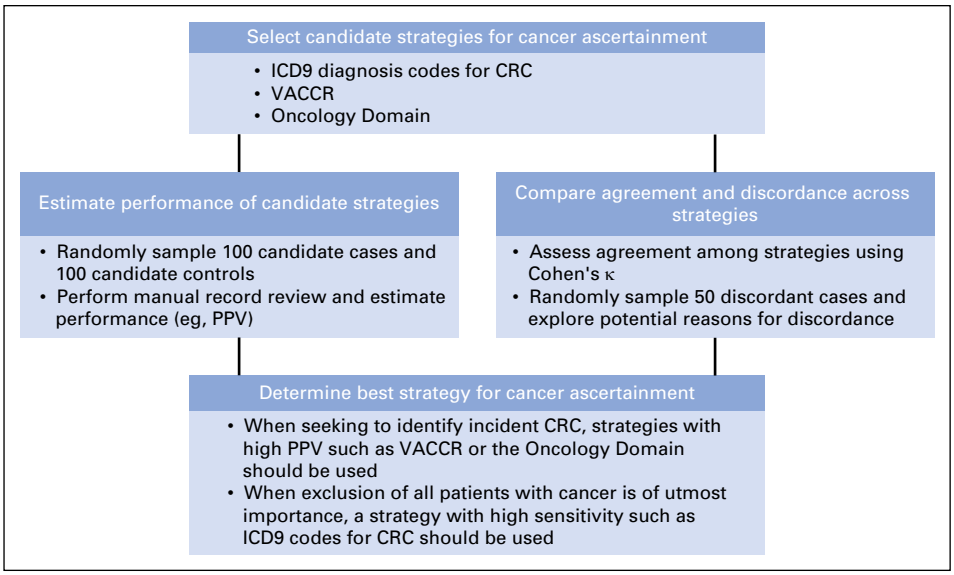

Fig 1. Structured approach for evaluating strategies for cancer ascertainment. A structured approach to evaluate cancer ascertainment strategies, as well as specific application of the approach to the use case of colorectal cancer (CRC) ascertainment within the Department of Veterans Affairs are presented. ICD9, International Classification of Diseases, Ninth Revision; PPV, positive predictive value; VACCR, Veterans Affairs Central Cancer Registry.

cancer (CRC) may be associated with a colonoscopy performed for a patient based on clinical suspicion of cancer, even though CRC was excluded during the same evaluation episode.[5] Sensitivity of administrative claims data for incident CRC has been reported to be as low as 72%.[6,7] Cancer registries may also be considered, but data are not usually linked to usual health care data and are under-reported from non–hospital-based settings.[1] Novel approaches that leverage information collected as part of usual care, such as pathology data, cases abstracted by local registrars, or cases identified through application of natural language processing algorithms, offer exciting potential but require careful validation and assessment.[8] Realizing the full promise of novel strategies requires such methodologic work because large sample size cannot immunize against potential bias. A structured approach must be taken to validate approaches used to ascertain cancer, because failing to do so may result in biased epidemiologic research and incomplete quality improvement efforts.

Herein we propose a structured approach for evaluating cancer ascertainment strategies derived from large-scale EHR data, including: assessment of individual strategy performance (eg, positive predictive value [PPV]), comparison of agreement across strategies, and review of discordant diagnoses (Fig 1). In this report, we apply this approach to compare three candidate strategies for CRC ascertainment within the US Department of Veterans Affairs (VA) as a use case. The approach may serve as a model for evaluating cancer ascertainment strategies derived from EHRs for epidemiologic research and quality improvement initiatives.

METHODS

Overview

We conducted a retrospective comparison of CRC diagnoses ascertained by the three data sources. The study sample consisted of veterans who had undergone colonoscopy in the VA. Performance of each strategy was determined by manual record review of a subsample of 100 candidate CRC cases and 100 candidate controls for which colonoscopy was performed in the VA and summarized. Agreement among strategies and careful review of discordant findings were conducted to determine etiology of discordance. The primary outcome was CRC diagnosis within 30 days of index colonoscopy.

Study Setting and Data Sources

The VA is the largest integrated health care system in the United States. A wide array of usual care data have been collected since 1999 and reflect care of almost 6 million veterans annually.[9] Available data include EHRs as well as complimentary sources such as cancer registries.[10] As such, the VA offers one of the largest resources for cancer research in the United States. Data are housed within the VA Informatics and Computing Infrastructure, which allows

secure access to national VA data. The Corporate Data Warehouse (CDW) is a large data repository and contains both clinical data (medications, laboratory tests, and pathology results) and administrative claims (diagnoses and procedure codes).[11] Within the CDW, ICD9 diagnosis codes recorded during any inpatient or outpatient setting represent one potential source for cancer ascertainment.

The VA Central Cancer Registry (VACCR) has served as the gold standard of cancer ascertainment for the last decade.[12] However, because of constrained resources, a significant time lag exists between case abstraction at local VA sites and final inclusion within the registry. Furthermore, data requests place a significant burden on already limited registry resources and are associated with significant time from request to data provision.

The Oncology Domain has recently become available to researchers within the CDW (Appendix Fig A1). Oncology Domain files represent data abstracted at the local level by cancer registrars. These data are used by VACCR for creation of finalized registry data. Data available within the Oncology Domain have not been previously cleaned or aggregated, but we postulate that restricting analyses of Oncology Domain data to those marked as having complete abstract status at the local level may result in data that mimic the quality of VACCR data, particularly for ascertainment of incident cancer, because local registrars have abstracted cases. Because these data are more easily accessible to VA researchers and quality improvement leaders, are immediately available after local registrar abstraction, and contain detail similar to VACCR data, the Oncology Domain may be a promising, practical resource for cancer ascertainment.

Study Sample and Candidate Case Ascertainment

The study sample consisted of veterans with at least one Current Procedural Terminology code for colonoscopy performed in an inpatient or outpatient setting from January 1, 1999, to December 31, 2014 (Appendix Table A1 lists codes used). To identify candidate cases, we created three algorithms for CRC diagnosis based on VACCR, the Oncology Domain, and ICD9 diagnosis codes (Appendix Table A2 lists algorithms used). Cases from VACCR and the Oncology Domain were defined by International Classification of Diseases for Oncology, Third Revision site codes. For each CRC definition, we selected the first instance recorded. Prevalent CRC was defined as occurring up to 6 months before or after the index colonoscopy. Additional exclusion criteria, including abstract status, class of case, cancer stage, and histology, are summarized in Table 1.

Statistical Analysis

For individuals who fit under each definition of CRC, patient characteristics and features of cancer presentation were abstracted and summarized. Demographics (sex, race/ethnicity) were ascertained from the CDW. Age at diagnosis was calculated as the difference between date of birth and date of presumed cancer diagnosis. Features of cancer presentation (primary site, cancer stage) were obtained from VACCR and the Oncology Domain. Primary site was split into proximal (C18.0, C18.2 to C18.5), distal (C18.6 to C18.7), rectal (C19.9, C20.9), and other (C18.8 to C18.9). Cancer stage was characterized as in situ, localized, regional, distant, or unknown.

Validation of candidate strategies. We developed a structured approach to independently validate each cancer ascertainment strategy in which we created an algorithm for each potential resource, applied the algorithm to our study sample, and estimated CRC prevalence based on each ascertainment strategy. For each CRC algorithm, we randomly sampled 100 candidate CRC cases and 100 candidate controls from our study sample of individuals who had undergone colonoscopy but did not meet criteria for CRC diagnosis. As such, our sampling resulted in three independent sample sets: 100 VACCR-based cases and 100 colonoscopy controls, 100 Oncology Domain–based cases and 100 controls, and 100 ICD9-based cases and 100 controls. For each sample set, reviewers (A.E. and R.B.) were blinded to whether each patient was a case or control and searched records for evidence of CRC diagnosis within the EHR.[13]

Performance of each algorithm was estimated by PPV and negative predictive value (NPV) using manual record review as the gold standard. Sample size was based on the $100(1 - \alpha/2)\%$ one-sided confidence lower bounds for PPV and NPV. Bonferroni correction was used for

Table 1. Criteria for VACCR-, Oncology Domain–, and ICD9 Code–Based Diagnoses

Criterion	VACCR and Oncology Domain	ICD9 Code
Cancer site*	C18.0 Cecum	153.0 Hepatic flexure
	C18.2 Ascending colon	153.1 Transverse colon
	C18.3 Hepatic flexure	153.2 Descending colon
	C18.4 Transverse colon	153.3 Sigmoid colon
	C18.5 Splenic flexure	153.4 Cecum
	C18.6 Descending colon	153.6 Ascending colon
	C18.7 Sigmoid colon	153.7 Splenic flexure
	C18.8 Overlapping lesion	153.8 Other specified site
	C18.9 Colon, not otherwise specified	153.9 Colon, unspecified
	C19.9 Rectosigmoid junction	154.0 Rectosigmoid junction
	C20.9 Rectum, not otherwise specified	154.1 Rectum
Abstract status†	Complete	—
Class of case‡	Analytic	—
Cancer stage§	In situ	—
	Localized	—
	Regional	—
	Distant	—
	Unknown	—
Histology‖	81403 Adenocarcinoma	—
	84803 Mucinous adenocarcinoma	—
	84903 Signet ring cell carcinoma	—
	85103 Medullary carcinoma	—
	80203 Undifferentiated carcinoma	—
	82013 Cribriform carcinoma	—
	82133 Serrated adenocarcinoma	—
	82103 Adenocarcinoma adenomatous in polyp	—
	82203 Adenocarcinoma in adenomatous polyposis coli	—
	82613 Adenocarcinoma in villous adenoma	—
	82633 Adenocarcinoma in tubulovillous adenoma	—

Abbreviations: ICD9, International Classification of Diseases, Ninth Revision; VACCR, Veterans Affairs Central Cancer Registry.

*VACCR and Oncology Domain cases were defined by International Classification of Diseases for Oncology, Third Revision site codes.

†Oncology Domain cases were completely abstracted by local cancer registrars and transmitted to VACCR.

‡VACCR and Oncology Domain cases that were not diagnosed and/or treated at the Department of Veterans Affairs.

§VACCR and Oncology Domain cases with a valid stage (SEER summary stage could not be null).

‖VACCR and Oncology Domain cases with an International Classification of Diseases for Oncology, Third Revision histology code consistent with adenocarcinoma.

multiple comparison adjustment to ensure an overall confidence of 95%. We postulated that if estimated PPV and NPV reached ≥ 95%, the 97.5% one-sided confidence lower bounds for PPV and NPV would be > 0.90, and we could confidently conclude that the true PPV and NPV were > 90% (manuscript in preparation). PPV and NPV for each algorithm were then combined with estimated prevalence to calculate sensitivity and specificity.

Agreement and discordance across candidate strategies. To assess whether multiple strategies could improve accuracy, we estimated agreement across strategies and randomly sampled discordant findings to explore potential reasons for discordance. Agreement was evaluated by Cohen's κ[14,15] and defined as (Po – Pe)/(1 – Pe), where Po is the observed proportion of individuals for which two methods agree and Pe is the probability that two methods agree by chance, based on the observed case and control classifications of each method. κ is > 0 if the observed agreement exceeds the proportion expected by chance and reaches its maximum value of 1 when two methods reach perfect agreement. CIs were calculated for κ, and Bonferroni correction was applied for three agreement measures with an overall confidence of 95%. $\kappa > 0.80$ represents almost perfect agreement, 0.61 to 0.80 represents substantial agreement, and 0.41 to 0.60 represents moderate agreement.[14]

There were six types of discordance: VACCR positive versus Oncology Domain negative, Oncology Domain positive versus VACCR negative, VACCR positive versus ICD9 negative, Oncology Domain positive versus ICD9 negative, ICD9 positive versus VACCR negative, and ICD9 positive versus Oncology Domain negative. We randomly sampled 50 cases for each type of discordance and conducted focused record reviews to determine presence or absence of CRC and potential reason for discrepancy.

RESULTS

From a study sample of 1,839,043 veterans with index colonoscopy from 1999 to 2014, 92,197 met criteria for CRC diagnosis based on one or more of our candidate strategies. Figure 2 depicts the overlap in candidate CRC diagnoses across strategies. VACCR and the Oncology Domain had high overlap, such that a small proportion were identified as candidate

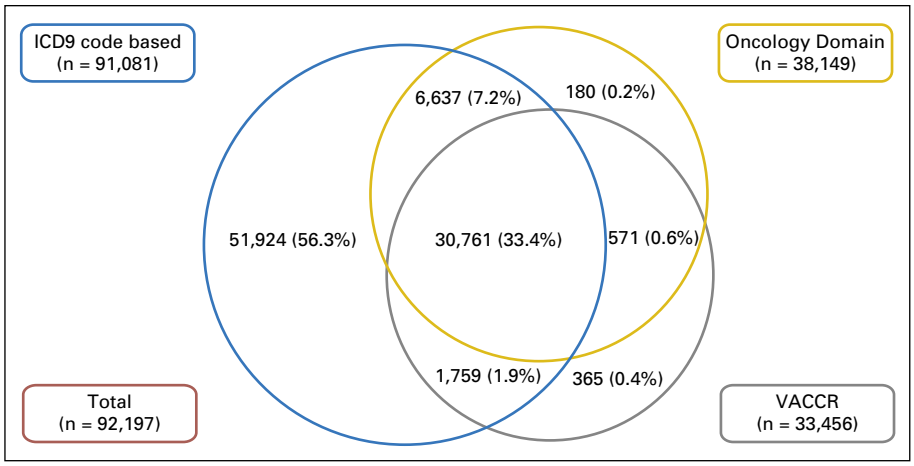

Fig 2. Overlap in candidate colorectal cancer (CRC) diagnoses across ascertainment strategies. A total of 92,197 individuals met at least one CRC definition. Veterans Affairs Central Cancer Registry (VACCR) and the Oncology Domain had high overlap, such that a small proportion of all individuals were identified as candidate CRC cases by one but not the other source. Although International Classification of Diseases, Ninth Revision (ICD9) –based ascertainment of candidate cases captured nearly all cases in VACCR or the Oncology Domain, 56.3% of ICD9-based candidate cases were not found in VACCR or the Oncology Domain. NOTE. Proportions are not to scale for ease of presentation.

cases by one but not the other source. Although ICD9-based ascertainment of candidate cases captured nearly all cases in VACCR or the Oncology Domain, a high proportion (56.3%) of ICD9-based candidate cases were not found in VACCR or the Oncology Domain. Table 2 lists summary statistics for individuals with suspected CRC. Most patients were white men with a median age of 68 years. On the basis of VACCR and the Oncology Domain, CRC cases most commonly originated in the proximal colon (VACCR, 36.9%; Oncology Domain, 37.1%) and were localized (VACCR, 46.3%; Oncology Domain, 44.8%).

Validation of CRC Ascertainment Strategies

Both VACCR- and Oncology Domain–based methods were estimated to have near perfect PPV, NPV, sensitivity, and specificity when compared against manual record review as the gold standard (Table 3). The ICD9 code–based strategy was less robust. Although sensitivity, specificity, and NPV were high, PPV was suboptimal at 58%. Among the ICD9-based cases that did not have evidence of CRC upon manual record review (n = 42), 27 were issued the code for suspicion of CRC that was later ruled out by colonoscopy, and 15 reflected prior history of CRC rather than diagnosis around the time of the colonoscopy procedure.

Agreement Among Ascertainment Strategies and Evaluation of Discordant Findings

Table 4 summarizes the level of agreement among our three CRC ascertainment strategies, using all data available (N = 1,839,043 with colonoscopy). Although VACCR- and Oncology Domain–based diagnoses demonstrated almost perfect agreement (κ, 0.87), the ICD9-based strategy had only moderate agreement with VACCR (κ, 0.51) and the Oncology Domain (κ, 0.57). The main reason for this discordance was that there were many more ICD9 code–based diagnoses than VACCR- or Oncology Domain–based diagnoses (Fig 2). For example, although 32,520 cases (35.7%) were consistent with CRC based on both VACCR and ICD9 criteria, the remaining 58,561 cases (64.3%) did not have VACCR data consistent with the ICD9-based approach.

To assess accuracy of each strategy for identifying CRC, we reviewed a random sample of discordant cases across strategies to determine presence or absence of CRC and etiology of discordance. All cases that were in VACCR but not in the Oncology Domain (or vice versa) had evidence of a CRC diagnosis at time of index colonoscopy. Similarly, all cases that were in VACCR or the Oncology Domain but did not have an ICD9 code–based diagnosis were confirmed to have incident CRC as well. However, only 15% of cases that had an ICD9 code but not a VACCR- or Oncology Domain–based diagnosis had evidence of CRC at index colonoscopy. The remaining cases were issued either the code for suspicion of CRC that was later ruled out by colonoscopy (38%) or the code reflecting prior history of CRC rather than diagnosis around the time of the colonoscopy procedure (47%).

DISCUSSION

Cancer ascertainment using large-scale EHRs is a challenge. Methods for ascertainment should

Table 2. Characteristics of Individuals With CRC as Defined by VACCR, Oncology Domain, and ICD9 Codes

Characteristic	VACCR (n = 33,456)		Oncology Domain (n = 38,149)		ICD9 Code* (n = 91,081)	
	No.	%	No.	%	No.	%
Sex						
Male	32,825	98.1	37,413	98.1	88,958	97.7
Female	631	1.9	736	1.9	2,123	2.3
Age, years, median, Q1-Q3	68	61-76	68	61-76	67	60-76
Race/ethnicity						
White	22,818	68.2	26,414	69.2	62,987	69.2
Black	5,740	17.2	6,313	16.5	14,928	16.4
Hispanic	1,565	4.7	1,798	4.7	4,150	4.6
Asian	270	0.8	297	0.8	847	0.9
American Indian	159	0.5	172	0.5	394	0.4
Other	588	1.8	643	1.7	1,552	1.7
Unknown	2,316	6.9	2,512	6.6	6,223	6.8
Primary site						
Proximal	12,353	36.9	14,152	37.1	—	—
Distal	10,007	29.9	11,368	29.8	—	—
Rectal	10,068	30.1	11,523	30.2	—	—
Other	1,028	3.1	1,106	2.9	—	—
Cancer stage						
In situ	1	0.0	55	0.1	—	—
Localized	15,497	46.3	17,076	44.8	—	—
Regional	12,041	36.0	14,586	38.2	—	—
Distant	4,705	14.1	5,141	13.5	—	—
Unknown	1,212	3.6	1,291	3.4	—	—

Abbreviations: CRC, colorectal cancer; ICD9, International Classification of Diseases, Ninth Revision; Q, quartile; VACCR, Veterans Affairs Central Cancer Registry.
*Based on first instance of ICD9 code recorded.

be chosen based on accuracy, accessibility, research questions under study, and purpose of ascertaining diagnoses. In this work, we proposed a structured approach for evaluating cancer ascertainment strategies using large-scale EHR data and subsequently implemented our approach to compare three candidate strategies for ascertainment of CRC within the VA as a use case.

All three strategies showed high sensitivity and specificity for incident CRC. However, the ICD9 code–based approach had a much lower PPV than the approaches based on VACCR or the newly accessible Oncology Domain. Specifically,

Table 3. Validation of VACCR-, Oncology Domain–, and ICD9 Code–Based Diagnoses

Definition	Estimated Prevalence (%)	PPV (%)		NPV (%)		Estimated Sensitivity (%)	Estimated Specificity (%)
		Estimated Value	Lower Bound*	Estimated Value	Lower Bound*		
VACCR	1.76	100	96.4	100	96.4	100	100
Oncology Domain	2.07	100	96.4	100	96.4	100	100
ICD9 code	4.95	58.0	47.7	100	96.4	100	97.9

Abbreviations: ICD9, International Classification of Diseases, Ninth Revision; NPV, negative predictive value; PPV, positive predictive value; VACCR, Veterans Affairs Central Cancer Registry.
*The lower bound was calculated based on exact binomial test.

Table 4. Agreement Among VACCR-, Oncology Domain–, and ICD9 Code–Based Diagnoses

Agreement	Positive	Negative	Total	κ (CI)
VACCR *v* Oncology Domain	Oncology			0.873 (0.869 to 0.876)
VACCR positive	31,332	2,124	33,456	
VACCR negative	6,817	1,798,770	1,805,587	
Total	38,149	1,800,894	1,839,043	
VACCR *v* ICD9 Codes	ICD9			0.509 (0.505 to 0.513)
VACCR positive	32,520	936	33,456	
VACCR negative	58,561	1,747,026	1,805,587	
Total	91,081	1,747,962	1,839,043	
Oncology Domain *v* ICD9 codes	ICD9			0.566 (0.562 to 0.570)
Oncology positive	37,398	751	38,149	
Oncology negative	53,683	1,747,211	1,800,894	
Total	91,081	1,747,962	1,839,043	

Abbreviations: ICD9, International Classification of Diseases, Ninth Revision; VACCR, Veterans Affairs Central Cancer Registry.

PPV for ICD9 code–based strategy was just 58% in comparison with 100% for VACCR and the Oncology Domain. In contrast, our evaluation of the agreement of VACCR-, Oncology Domain–, and ICD9 code–based diagnoses suggests that VACCR and the Oncology Domain do have limitations. Specifically, 15% of ICD9-positive but VACCR- or Oncology Domain–negative cases were confirmed to have CRC at index colonoscopy.

Application of multiple approaches for evaluating cancer ascertainment strategies allows us to carefully assess the strengths and weaknesses of candidate approaches (Fig 1). For example, our data suggest that for research questions seeking to identify incident CRC with high PPV, VACCR or the Oncology Domain should be used preferentially over ICD9-based criteria. In contrast, in situations where exclusion of all patients with baseline presence or history of CRC is of paramount importance, ICD9 codes should be considered as an adjunct to VACCR or the Oncology Domain. Our results also provide a cautionary example of why multiple approaches must be taken toward validating the accuracy of rare predictors or outcomes of interest. If we had only relied on a random sample of cases and controls, we would have assumed near-perfect sensitivity for VACCR and the Oncology Domain. Indeed, our finding that 15% of ICD9-positive but VACCR- or Oncology Domain–negative cases had a cancer diagnosis suggest that the sensitivity of these sources for cancer ascertainment can still be improved.

Our findings support the use of a structured, hybrid approach to evaluating candidate strategies implemented for EHR data (Fig 1). Specifically, by considering multiple strategies and comparing outputs using a structured approach including validation and agreement as well as record review of discordant cases, the strengths and limitations of each strategy can be well understood. We postulate that using large data sets from EHRs without such work might risk incorrect or underascertainment that could go unrecognized.

Several limitations should be considered when interpreting our work. First, we used a relatively simple ICD9 code–based strategy (first instance recorded). Others have considered other approaches (eg, multiple codes over time) to improve specificity.[2,3] Development and validation of a more complex strategy were beyond the scope of this work. Second, we focused on validating approaches for identifying CRC found at the time of index colonoscopy. Indeed, some of the ICD9-based positive diagnoses were in individuals who had a history of CRC. This speaks to the importance of validating the diagnostic approach for the purpose of the research under way; in our case, we were mainly interested in identification of individuals with incident cancer

at time of index colonoscopy. Third, caution should be taken in generalizing our findings to other cancer diagnoses. Future work should test whether our approach can be applied in other cancer types, in addition to using other data resources. Fourth, VACCR and Oncology Domain data are nonindependent, because in our system, Oncology Domain data inform final VACCR data. Although we validated each ascertainment strategy separately with independent random samples, potential for data correlation does exist. Strengths of this work include use of multiple approaches to assess strengths and weakness of each strategy and use of data from the largest integrated health system in the United States.

For researchers and quality improvement leaders interested in cancer research within the VA, our findings suggest that the Oncology Domain may be considered as an alternative source for cancer ascertainment. Indeed, we found 6,637 additional CRC cases in the Oncology Domain that were not in VACCR. This is the first report to our knowledge that has validated this newly accessible resource. Our results suggest that the Oncology Domain may continue to provide a valid resource for ascertaining cancer diagnoses.

Beyond the VA, our work suggests that a structured approach must be taken to evaluate strategies for identifying cancer outcomes and recommends considering validation using random sample record review, as well as evaluating agreement among candidate strategies. Additionally, we postulate that strategic sampling and manual record review of cases where definitions offer discordant conclusions in particular may be helpful in understanding the strengths and limitations of novel approaches, particularly those designed to identify rare predictors and outcomes.

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Appendix

Table A1. CPT Procedure Codes Used to Create Study Sample

Code	Definition
44388	Colonoscopy through stoma; diagnostic, including collection of specimen(s) by brushing or washing, when performed (separate procedure)
44389	Colonoscopy through stoma; with biopsy, single or multiple
44390	Colonoscopy through stoma; with removal of foreign body
44391	Colonoscopy through stoma; with control of bleeding (eg, injection, bipolar cautery, unipolar cautery, laser, heater probe, stapler, plasma coagulator)
44392	Colonoscopy through stoma; with removal of tumor(s), polyp(s), or other lesion(s) by hot biopsy forceps or bipolar cautery
44393	Colonoscopy through stoma; with ablation of tumor(s), polyp(s), or other lesion(s) not amenable to removal by hot biopsy forceps, bipolar cautery, or snare technique
44394	Colonoscopy through stoma; with removal of tumor(s), polyp(s), or other lesion(s) by snare technique
44397	Colonoscopy through stoma; with transendoscopic stent placement (includes predilation)
44401	Colonoscopy through stoma; with ablation of tumor(s), polyp(s), or other lesion(s) (includes pre- and postdilation and guide wire passage, when performed)
44402	Colonoscopy through stoma; with endoscopic stent placement (including pre- and postdilation and guide wire passage, when performed)
44403	Colonoscopy through stoma; with endoscopic mucosal resection
44404	Colonoscopy through stoma; with directed submucosal injection(s), any substance
44405	Colonoscopy through stoma; with transendoscopic balloon dilation
44406	Colonoscopy through stoma; with endoscopic ultrasound examination, limited to the sigmoid, descending, transverse, or ascending colon, cecum, and adjacent structures
44407	Colonoscopy through stoma; with transendoscopic ultrasound guided intramural/transmural fine-needle aspiration/biopsies, includes endoscopic ultrasound examination
45355	Colonoscopy, rigid or flexible, transabdominal via colotomy, single or multiple
45378	Colonoscopy, flexible, proximal to splenic flexure; diagnostic, with or without collection of specimen(s) by brushing or washing, with or without colon decompression
45379	Colonoscopy, flexible, proximal to splenic flexure; with removal of foreign body
45380	Colonoscopy, flexible, proximal to splenic flexure; with biopsy, single or multiple
45381	Colonoscopy, flexible; with directed submucosal injection(s), any substance submucosal injection(s), any substance
45382	Colonoscopy, flexible; with control of bleeding, any method bleeding (eg, injection, bipolar cautery, unipolar cautery, laser, heater probe, stapler, plasma coagulator)
45383	Colonoscopy, flexible, proximal to splenic flexure; with ablation of tumor(s), polyp(s), or other lesion(s) not amenable to removal by forceps, cautery or snare
45384	Colonoscopy, flexible; with removal of tumor(s), polyp(s), or other lesion(s) by hot biopsy forceps cautery
45385	Colonoscopy, flexible; with removal of tumor(s), polyp(s), or other lesion(s) by snare technique
45386	Colonoscopy, flexible; with transendoscopic balloon dilation balloon, one or more strictures

(Continued on following page)

Table A1. CPT Procedure Codes Used to Create Study Sample (Continued)

Code	Definition
45387	Colonoscopy, flexible, proximal to splenic flexure; with transendoscopic stent placement (includes predilation)
45388	Colonoscopy, flexible; with ablation of tumor(s), polyp(s), or other lesion(s) (includes pre- and postdilation and guide wire passage, when performed)
45389	Colonoscopy, flexible; with endoscopic stent placement (includes pre- and postdilation and guide wire passage, when performed)
45390	Colonoscopy, flexible; with endoscopic mucosal resection
45391	Colonoscopy, flexible, proximal to splenic flexure; with endoscopic ultrasound examination
45392	Colonoscopy, flexible, proximal to splenic flexure; with transendoscopic ultrasound guided intramural or transmural fine-needle aspiration/biopsy(s)
45393	Colonoscopy, flexible; with decompression (for pathologic distention) (eg, volvulus, megacolon), including placement of decompression tube, when performed
45398	Colonoscopy, flexible; with band ligation(s) (eg, hemorrhoids)
45399	Unlisted procedure, colon
G0105	Colorectal cancer screening; colonoscopy on individual at high risk
G0121	Colorectal cancer screening; colonoscopy on individual not meeting criteria for high risk
G6019	Colonoscopy through stoma; with ablation of tumor(s), polyp(s), or other lesion(s) not amenable to removal by hot biopsy forceps, bipolar cautery, or snare technique
G6020	Colonoscopy through stoma; with transendoscopic stent placement (includes predilation)
G6021	Unlisted procedure, intestine
G6024	Colonoscopy, flexible; proximal to splenic flexure; with ablation of tumor(s), polyp(s), or other lesion(s) not amenable to removal by forceps, cautery, or snare
G6025	Colonoscopy, flexible, proximal to splenic flexure; with transendoscopic stent placement (includes predilation)

Abbreviation: CPT, Current Procedural Terminology.

Table A2. Algorithms Used to Identify Candidate CRC Cases

Data Source	Case Selection Criteria
VACCR-based diagnosis*	where [primary site] in ('C180','C182','C183','C184','C185','C186','C187','C188','C189','C199','C209')
	and [class of case #1] in ('0','10','11','12','13','14','20','21','22')
	and [seer summary stage best] in ('1','2','3','4','5','7')
	and ([histology – best] in ('81403','84803','84903','85103','80203','82013','82133','82103', '82203', '82613','82633') or [histology – best] is null)
Oncology Domain–based diagnosis*	where [primarysiteien] in ('67180','67182','67183','67184','67185','67186','67187','67188','67189','67199','67209')
	and [abstractstatus] = 'complete'
	and [classcategory] = 'analytic'
	and [seersummarystage2000] is not null
	and ([histologyicdo3ien] in ('81403','84803','84903','85103','80203','82013','82133','82103','82203','82613','8263 3') or [histologyicdo3ien] is null)
ICD9 code–based diagnosis	where [ICD9code] in ('153.0','153.1','153.2','153.3','153.4','153.6','153.7','153.8','153.9','154.0','154.1')

Abbreviations: CRC, colorectal cancer; ICD9, International Classification of Diseases, Ninth Revision; VACCR, Veterans Affairs Central Cancer Registry.
*Defined by Facility Oncology Registry Data Standard.

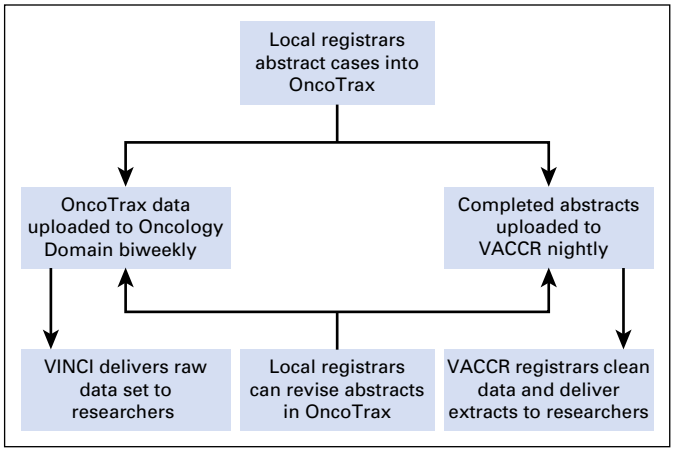

Fig A1. Overview of the Veterans Affairs (VA) cancer data abstraction process. Local registrars from VA medical centers across the country manually abstract cases into OncoTrax. Completed abstracts are transmitted to the VA Central Cancer Registry (VACCR) nightly. VACCR registrars clean and aggregate the data and deliver research-grade extracts to researchers upon request. OncoTrax data have recently become available through tables known as the Oncology Domain. OncoTrax data are uploaded to the Oncology Domain biweekly. The VA Informatics and Computing Infrastructure (VINCI) delivers static data sets to researchers upon request.