TITLE: Validation of 5 key colonoscopy-related data elements from Ontario health administrative databases compared to the clinical record: A cross-sectional study.

Short Title: Validation of 5 key colonoscopy data elements

AUTHORS: Jill Tinmouth MD PhD[1,2,3], Rinku Sutradhar PhD[1,9], Ning Liu MSc[1], Nancy N. Baxter MD PhD[1,2,4] , Lawrence Paszat MD MS[1,3,9], Linda Rabeneck MD MPH[1,2]

[1]Institute for Clinical Evaluative Sciences, Toronto, Ontario, Canada
[2]Prevention & Cancer Control, Cancer Care Ontario, Toronto, Ontario, Canada
[3]Sunnybrook Research Institute, Toronto, Ontario, Canada
[4]Li Ka Shing Knowledge Institute, St. Michael's Hospital
[9]Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada.

Word counts: Main text 2499, Abstract 247

Authorship criteria
Conception and design: Tinmouth, Paszat, Rabeneck
Analysis and interpretation of the data: Tinmouth, Sutradhar, Liu, Baxter, Paszat, Rabeneck
Drafting of the article: Tinmouth
Critical revision of the article for important intellectual content: Sutradhar, Liu, Baxter, Paszat, Rabeneck
Final approval of the article: Tinmouth, Sutradhar, Liu, Baxter, Paszat, Rabeneck

ABSTRACT

Background: Colonoscopy is widely used but its quality is highly variable, which may adversely affect patients. Research and quality improvement initiatives in a variety of jurisdictions have sought to address this issue, often supported by the use of health administrative data. As these data are generally not collected for these purposes, it is critical to measure their validity prior to use. The aim of this study is to validate health administrative data definitions for 5 key colonoscopy elements compared to the clinical record.

Methods: We randomly sampled 1,962 colonoscopy and non-colonoscopy procedures from 28 hospitals and non-hospital endoscopy clinics between April 2008 and March 2009 in Ontario, Canada. Definitions for 5 key colonoscopy elements derived from the health administrative data were compared to the clinical record. Weighted and unweighted sensitivity and specificity, adjusted for clustering of patients within physicians, were calculated for each definition relative to the reference standard.

Findings: We abstracted 1,845 records; in 1,282, colonoscopy was intended or performed. The weighted sensitivity and specificity of colonoscopy case, non-hospital colonoscopy setting and anesthesiologist-assistance exceeded 95%. Weighted sensitivity for colonoscopy completeness and polypectomy exceeded 95% but specificity was less than 90%.

Interpretation: Ontario health administrative data definitions for 5 key colonoscopy data elements performed well, with acceptable sensitivities and specificities for use in research and quality improvement initiatives. In other jurisdictions where health administrative data are used for research or quality improvement, similar studies should be performed to ensure that these data are valid for these purposes.

INTRODUCTION

Colonoscopy is common, essential for the management of gastrointestinal diseases. Colonoscopy has important risks, including perforation, bleeding and death.[1] Furthermore, there is considerable variation in the quality of colonoscopy.[2, 3] Patients are adversely affected by poor quality colonoscopy; such procedures are associated with missed colorectal cancers and cancer-related death.[4]

Colonoscopy practice standards[5, 6], research[7, 8] and policy[9, 10] initiatives have been implemented to improve quality. The use of "routinely collected data"[11] such as health administrative data for these purposes is highly attractive as they are inexpensive to use, readily available, and can be captured uniformly across a health care payer or health system. These data are being used for funding, accountability and to measure performance and quality of care by government agencies.[12] However, as these data are often collected for other reasons,[13, 14] it is critical to ensure their validity when using them for these purposes. Thus far, colonoscopy validation studies have generally focused on procedure indication[15-17] and other aspects of colonoscopy have not been widely evaluated.

In Ontario, the Institute for Clinical Evaluative Sciences (ICES) houses health administrative databases containing the health care records for the population of Ontario. These databases have been used extensively in colonoscopy research[1, 18-20] and quality improvement[21] but to date, they have not been validated. The objective of this study was to validate health administrative data definitions for 5 key colonoscopy elements: colonoscopy case, colonoscopy setting, colonoscopy completeness, anesthesiologist-assistance and polypectomy.

METHODS

Overview: In this multi-site chart abstraction study, we created health administrative definitions of 5 colonoscopy data elements: a 'colonoscopy case', colonoscopy setting, colonoscopy completeness, anesthesiologist-assistance and polypectomy. We compared these definitions to reference standards: clinical data obtained via chart abstraction at 23 hospitals and 5 non-hospital endoscopy clinics in Ontario, Canada. For some data elements, we included more than one health administrative definition and/or more than one reference standard. The clinical data largely comprised medical records of complete and incomplete colonoscopies but also included a number of gastroscopies and flexible sigmoidoscopies in order to allow estimation of the "true negative" rate for the case definition of colonoscopy. Ethics approval was obtained from Sunnybrook Health Sciences Centre Research Ethics Board as well as from the research ethics boards at the 23 hospitals where chart abstraction was performed.

Sources of Administrative Data: The Ontario Health Insurance Plan (OHIP) and the Canadian Institute for Health Information (CIHI) databases housed at ICES were used. OHIP contains physician billing data on inpatient and outpatient visits and procedures including colonoscopy since 1991. CIHI comprises diagnosis and procedure (both inpatient and 'same day') codes for all hospital admissions in Canada since 1988.

Hospital and non-hospital endoscopy clinic sites: We randomly selected 23 hospital and 5 non-hospital facilities in Ontario to participate in the study. The hospital sites were selected in a stratified fashion based on teaching/community status, size, and urban/rural status from hospitals performing more than 200 colonoscopies in the prior year (n=115) in the province. With the assistance of endoscopy equipment manufacturers, we identified 34 non-hospital clinics active during the study period. We randomly selected from among those who performed more than 200 colonoscopies in the prior year and indicated willingness to participate in the study (N=21 of 34 clinics). The non-hospital facilities were almost all located in urban areas and none are academic, therefore selection was stratified by high and low annual colonoscopy volumes only.

Medical Record Abstraction: All outpatient procedure visits for gastroscopy, flexible sigmoidoscopy and colonoscopy at the 28 facilities from April 1 2008 to March 31 2009 were identified using health administrative data (hospitals) or using self-reported billing data (clinics) and comprised the sampling frame (Figure 1). From the 144,078 procedures in the sampling frame, we then randomly selected 1,968 medical records for abstraction (the "sample") using a stratified sampling strategy

previously used by others [22]. The sample included complete colonoscopies (n=794), incomplete colonoscopies (n=806), gastroscopies (n=128), and flexible sigmoidoscopies (n= 240). The sampling strategy ensured adequate inclusion of less common events, such as incomplete colonoscopy, while maintaining a sample size feasible for medical record abstraction.

At the 28 sites, trained ICES medical record abstractors, blinded to the administrative data, abstracted from 3 pre-specified sources, the endoscopist's procedure note, the anesthesiologist's record, and the pathologist's record using a standardized data collection protocol. The data were collected in a standardized fashion by the abstractors using a customized data collection platform residing on encrypted laptops. The data were then transmitted from each site to ICES via secure virtual private network. If the endoscopist's procedure note could not be found at the sites or if the dates for the procedure found in the medical record at abstraction did not agree with those in the administrative data, the case was excluded.

Cohort creation: Three cohorts were created for the analyses:
(1) All successfully abstracted medical records – used to assess the health administrative data definition for colonoscopy case.
(2) Medical records where either colonoscopy or flexible sigmoidoscopy was intended and colonoscopy codes were billed – used to evaluate the definition for colonoscopy completeness. Ontario physicians bill colonoscopy per segment reached; this data structure allows measurement of colonoscopy completeness.[18] Although there is a separate code for flexible sigmoidoscopy, anecdotally, colonoscopy codes are often used to bill this procedure as remuneration is better. As this practice may result in misclassification of incomplete colonoscopies when using the Ontario administrative data, flexible sigmoidoscopies billed with colonoscopy codes were included in the cohort. Individuals with prior total colectomy or right hemicolectomy were excluded.
(3) Medical records where colonoscopy was intended or performed – used to test the remaining 3 colonoscopy data elements, colonoscopy setting, anesthesiologist-assistance and polypectomy.

Administrative data definitions and reference standards for colonoscopy data elements: See Table 1 for definitions and reference standards for each data element. There were 14 alternative definitions for colonoscopy case because of the structure of OHIP colonoscopy codes: a base code (Z555A) must be used indicating that the scope was inserted to the level of the descending colon. Up to 4 additional "E" codes are then used for every additional segment of colon visualized. We evaluated colonoscopy completeness using 2 definitions of colonoscopy case: achieving either

the cecum or terminal ileum among (1) colonoscopies identified using the most sensitive definition and (2) those identified using the most accurate definition, based on the analyses described below.

Health administrative data definitions were compared to relevant reference standards. There were 2 reference standards for anesthesiologist-assistance (presence of anesthesiologist record, indicating an anesthesiologist attended the procedure; and propofol use documented in anesthetic record or endoscopist's procedure note) and polypectomy (polyp documented by endoscopist; and histology confirmation of adenoma, including advanced adenoma, or sessile serrated adenoma/polyp documented). See Supplementary Tables for a list of specific codes used and their definitions.

Sample size: We performed a sample size calculation a priori for the key data elements of colonoscopy case and colonoscopy completeness. Using methods for two-sided binomial tests,[23] we estimated that we would need at least 600 complete colonoscopy cases, 600 incomplete colonoscopy cases and 200 non-colonoscopy cases to have over 80% power (alpha = 0.05) to detect at least a 4% absolute difference in coding accuracy (assuming a coding accuracy proportion, determined by comparing the medical record data with the administrative data, of 0.85) within each group.

Analysis: Sensitivity and specificity with 95% confidence intervals were calculated for each administrative data definition relative to the relevant reference standard. The 95% confidence limits were adjusted for clustering of patients within physicians using the Taylor Series Expansion method.[24] Because we oversampled incomplete colonoscopy procedures, we performed both unweighted and weighted analyses, where the weights reflected the distribution of procedures in the sampling frame relative to those in the sample. Weighted results are presented unless there was important variation between weighted and unweighted results. For the colonoscopy case data element, we created a receiver operating curve by plotting the sensitivity (on the y-axis) and 1-specificity (on the x-axis) for the 14 definitions. The definition located in the upper left hand corner of this curve was defined as the most accurate as per the Youden method.[25]

RESULTS

Of the 1,968 randomly selected endoscopy procedures, 1845 were successfully abstracted (see Figure 1 for exclusions). Of these, colonoscopy was intended or performed in 1282 cases. Approximately 25% of patients undergoing included procedures were under age 50, over half were women and 15% were performed in non-hospital endoscopy clinics (Table 2). In the 23 hospitals, 7 to 153 charts were abstracted per hospital while in the 5 non-hospital clinics 31 to 86 were abstracted per clinic.

Fourteen definitions of a colonoscopy case were evaluated (Figure 2 and Figure 3). The most sensitive definition was the base colonoscopy code, Z555A, with or without one or more additional E codes. However, this definition was also the least specific. The most accurate definition was base code plus the code "to hepatic flexure" (Z555A + E741A) with or without additional E codes.

All 3 administrative data definitions for non-hospital clinic setting were found to have sensitivities and specificities in excess of 95% (Figure 4). The first two applied criteria using either OHIP codes alone or using CIHI codes alone; when used simultaneously, there was minor loss of sensitivity.

The sensitivity and specificity for colonoscopy completeness differed depending on the definition of colonoscopy case and whether they were weighted or unweighted (Figure 4). Regardless of the colonoscopy case definition, the weighted sensitivity exceeded 95% and the weighted specificity was poor (<80%). All unweighted estimates were approximately 95% or higher with one exception - the unweighted sensitivity using the most sensitive colonoscopy definition was 70.2%.

The sensitivity and specificity of the administrative data definition for anaesthesiologist-assisted colonoscopy exceeded 95% using either presence of anesthesiologist record (indicating an anesthesiologist attended the procedure) or the use of propofol as a sedating agent (Figure 4) as the reference standard.

Three administrative data definitions of polypectomy were evaluated compared to 2 reference standards, polyp seen/removed or histology (Figure 4). Using more codes improved the sensitivity but worsened specificity. These definitions were more sensitive but less specific when the reference standard was histology vs. polyp seen/removed.

DISCUSSION

We have demonstrated that health administrative data definitions of colonoscopy case, colonoscopy setting and anesthesiologist-assistance perform well when compared to the medical record. The weighted definitions of colonoscopy completeness were sensitive but not specific. The definitions of polypectomy performed less well for the identification of the more clinically relevant reference standard, histologically significant polyps (adenomas and sessile serrated adenomas/polyps), than they did for 'polyp seen or removed'.

Many health administrative colonoscopy data validation studies to date have focused on colonoscopy indication.[15-17] However, health administrative data are being used to evaluate and measure other aspects of colonoscopy, including completeness,[18] type of setting,[19, 26] polypectomy rate/adenoma detection rate,[4, 27] anesthesiologist-assistance,[19, 20, 28, 29] complications[1, 29] and missed cancers.[4, 26] As such, our study validates the use of health administrative data for many of these other aspects of colonoscopy.

In our study, we found that the most accurate definition of colonoscopy incorporates codes indicating that the endoscopist reached the hepatic flexure. However, in practice, other definitions may be used depending on context, e.g., for studies on perforation (as the procedure may be aborted if perforation is recognized)[30]. One other study also found that the health administrative data identified colonoscopy procedures accurately.[31] Accurate ascertainment of colonoscopy cases is important for research and performance measurement using health administrative data. For example, low volume endoscopists have been shown to have higher rates of complications.[1]

Our results for colonoscopy completeness must be interpreted in light of the differences in the weighted and unweighted results. Given the stratified sampling procedure used, we would expect the weighted results to be more valid than the unweighted results as long as the distribution of procedures in our sampling frame is representative of the distribution in the underlying population. The weighted results indicate that the administrative data definitions for colonoscopy completeness are sensitive but less specific, which would occur if the endoscopist billed for a complete colonoscopy but in fact it was not complete. In a study of 15,168 colonoscopies where Medicare claims were matched to records in the Clinical Outcomes Research Initiative (CORI) database, the Medicare data also failed to identify incomplete colonoscopies accurately.[32]

We found that the administrative data definition comprising codes for removal of a polyp 3 mm or larger, for fulguration, and for removal of large polyps greater than 3 cm was highly specific but the sensitivity was 76.9%. This specificity is comparable to that reported in the study of Medicare data described above[32] and to a second study [33] from Quebec, Canada, however the sensitivities reported in the Medicare and Quebec studies were better (92% and 86% respectively). We found that the administrative data definition described above performed reasonably well for the more clinically relevant reference standard of adenoma or sessile serrated adenoma/polyp, although the false negative and false positive rates were 20% and 13%, respectively. While others have shown a strong correlation between endosocopist polypectomy rate and adenoma detection rate,[34] ours is the first to report the test characteristics of using polypectomy codes as a surrogate for histologically significant polyps.

Routinely collected data, such as health administrative data, are widely used for research but also by health care systems and funders in North America and Europe to allocate funds and monitor quality.[12, 13, 35, 36] However, data inaccuracies can lead to disease or exposure misclassification,[37] to the inability to identify sources of bias and to inaccurate conclusions.[11, 38] There are examples of such data issues in the colonoscopy literature.[39] For these reasons, recent guidelines for the reporting of studies conducted using "routinely collected data", such as health administrative data, recommend that the validation of codes or algorithms used be described.[11] Validation enhances credibility and transparency of studies using health administrative data, which is important for uptake of findings[40] by scientific and policy consumers and application of algorithms by other scientists. [38]

The research approach maximizes the internal and external validity. We employed trained, blinded, chart abstractors who used a standardized data collection tool. The sample was large and representative of regional and facility differences. We used a rigorous sampling strategy that randomly selected institutions and procedures and ensured adequate inclusion of rare events. However, this approach, which necessitates the use of weighted cases, also introduces a potential limitation as inaccuracies may occur if the selected cases are not representative of the underlying sampling frame. While we validated Ontario data sources specifically, our methods and our central message - the importance of validating health administrative data - are broadly applicable to other jurisdictions.

In sum, we have rigorously validated 5 colonoscopy data elements that are routinely used in health administrative data studies of colonoscopy, for quality assurance purposes and to guide health policy. The methods described here are reproducible

and should be replicated for routinely collected data for colonoscopy used in other jurisdictions. It is paramount to ensure that these sources of "big data" are sufficiently accurate given their increasingly influential role in research and the delivery of health care globally.

ACKNOWLEDGEMENTS

This study was funded by the Canadian Cancer Society Research Institute and Cancer Care Ontario. The opinions, results and conclusions reported in this paper are those of the authors and are independent from the funding sources. This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health and Long-Term Care. The opinions, results and conclusions reported in this paper are those of the authors and are independent from the funding sources. No endorsement by ICES or the Ontario MOHLTC is intended or should be inferred. Parts of this material are based on data and information compiled and provided by CIHI. However, the analyses, conclusions, opinions and statements expressed herein are those of the author, and not necessarily those of CIHI. Dr. Tinmouth is the recipient of a Canadian Institutes of Health Research Embedded Clinician Researcher Award.

DECLARATION OF INTERESTS

Cancer Care Ontario is a provincial government agency that acts as primary advisory on matters related to cancer to the Ontario Ministry of Health and Long-Term Care. Dr. Tinmouth is employed by Cancer Care Ontario as the Lead Scientist of Ontario's colorectal cancer screening program, ColonCancerCheck. Dr. Baxter is employed by Cancer Care Ontario as the Provincial Lead for the Gastrointestinal Endoscopy Quality Based Procedures program. Dr. Rabeneck is employed by Cancer Care Ontario as the Vice-President of Prevention and Cancer Control. The remaining authors have no conflicts of interest to report.

Table 1. Description of the cohorts, administrative data definitions and the reference standards for 5 colonoscopy data elements.

Colonoscopy Data Element	Cohort, size	Administrative Data Definition	Reference Standard
Colonoscopy case	All successfully abstracted charts, n=1845	OHIP codes: Z555A alone or in combination with any of: E740A, E741A, E747A OR E705A. 14 of the most clinically plausible combinations were evaluated (see Figure 3 for specifics).	Performed or intended to perform colonoscopy according to endoscopist's procedure note
Non-hospital clinic	Charts where colonoscopy was intended or performed, n=1282	1. OHIP code E649A billed on date of colonoscopy 2. No record in CIHI overlapping with date of colonoscopy according to OHIP (i.e., no record of the procedure being done in hospital) 3. E649A AND no overlapping record in CIHI	Presence of endoscopist's procedure note in non-hospital facility chart
Anesthesiologist-assistance	Charts where colonoscopy was intended or performed, n=1282	OHIP codes for anesthesia (003C or procedure code with "C" suffix, see Supplementary Tables) billed on date as colonoscopy on same patient	1. Presence of anesthesiologist record on chart, regardless of type of sedating agent 2. Use of propofol as sedating agent according to anesthesiologist's record

Colonoscopy Data Element	Cohort, size	Administrative Data Definition	Reference Standard
Colonoscopy completeness*	Charts where procedure billed with colonoscopy codes and colonoscopy or flexible sigmoidoscopy was intended**, n=1477 (administrative data def'n 1), n=1016 (administrative data def'n 2)	1. OHIP codes E747A (to cecum) OR E705A (to terminal ileum) billed among colonoscopies defined using most sensitive definition (Z555A +/- other E codes) 2. OHIP codes E747A (to cecum) OR E705A (to terminal ileum) billed among colonoscopies defined using most accurate definition (Z555A +E741 +/- other E codes)	Colonoscopy 'intended' and 'complete' according to the endoscopist's procedure note
Polypectomy#	Charts where colonoscopy was intended or performed%, n= 1256 (reference standard 1), n=1252 (reference standard 2)	1. OHIP code Z571A alone 2. OHIP codes Z571A OR Z570A or E685A 3. OHIP codes Z571A OR Z570A or E685A OR E717A	1. Polyp visualized or polypectomy described according to endoscopist's procedure note 2. Adenoma, advanced adenoma or sessile serrated polyp according the pathologist's report

*Procedures intended as a flexible sigmoidoscopy where E747A or E705A was billed were classified as "false positive". Procedures intended as a flexible sigmoidoscopy where E747A and E705A were not billed were classified as "false negative".
**Excluding those with prior total or right hemicolectomy.
#Histology of the polyp is not available in administrative databases, therefore cannot define adenoma using these data
%Excluding those with missing data for reference standard.
OHIP = Ontario Health Insurance Plan (physician billing database).
CIHI = Canadian Institute for Health Information (hospital billing database).
Endoscopist's procedure note: completed by the endoscopist, includes a description of the procedure including findings
Anesthesiologist's record: completed by the anesthesiologist, record of anesthetic administered during procedure
Pathologist's report: report on the histology of specimens, such as polyps, obtained at colonoscopy.

Table 2. Patient and procedure characteristics, for 2 cohorts: (1) all abstracted charts and (2) charts where a colonoscopy was intended or performed.

Characteristic	All successfully abstracted charts (N=1,845)	Charts where colonoscopy was intended or performed (N=1,282)
Age group, in years		
<50	469 (25.4%)	251 (19.6%)
50-59	517 (28.0%)	395 (30.8%)
60-69	430 (23.3%)	327 (25.5%)
70-74	174 (9.4%)	134 (10.4%)
>74	255 (13.8%)	175 (13.7%)
Sex		
Female	986 (53.4%)	709 (55.3%)
Male	859 (46.6%)	573 (44.7%)
Procedures performed*		
CS only	1,143 (62.0%)	1,125 (87.8%)
EGD only	45 (2.4%)	≤ 5
FS only	432 (23.4%)	≤ 5
CS & EGD	200 (10.8%)	151 (11.8%)
FS & EGD	12 (0.7%)	≤ 5
CS & other procedure	≤ 5	≤ 5
FS & other procedure	≤ 5	0
Other procedure only	6 (0.3%)	0
Neighbourhood income quintile		
Low	300 (16.3%)	205 (16.0%)
2	331 (17.9%)	225 (17.6%)
3	337 (18.3%)	233 (18.2%)
4	393 (21.3%)	265 (20.7%)
High	474 (25.7%)	348 (27.1%)
Missing	10 (0.5%)	6 (0.5%)
Setting		
Non-hospital clinic	284 (15.4%)	216 (16.8%)
Hospital	1561 (84.6%)	1,066 (83.2%)

*Based on findings at chart abstraction
CS = colonoscopy
EGD = esophagogastroduodenoscopy
FS = flexible sigmoidoscopy

FIGURE LEGENDS

Figure 1. Flow chart describing sampling of facilities and procedures

Figure 2. Weighted sensitivity and specificity of 14 administrative data definitions using Ontario Health Insurance Plan (OHIP) codes of colonoscopy case compared to the reference standard of colonoscopy intended or performed according to the medical record.

Figure 3. Receiver operating curve of the 14 definitions for colonoscopy case.

Figure 4. Sensitivity and specificity of non-hospital setting, colonoscopy completeness, anesthesiologist-assistance and polypectomy compared to reference standards.

REFERENCES

1. Rabeneck L, Paszat LF, Hilsden RJ, Saskin R, Leddin D, Grunfeld E, et al. Bleeding and perforation after outpatient colonoscopy and their risk factors in usual clinical practice. Gastroenterology. 2008;135(6):1899-906.
2. Hilsden RJ, Dube C, Heitman SJ, Bridges R, McGregor SE, Rostom A. The association of colonoscopy quality indicators with the detection of screen-relevant lesions, adverse events, and postcolonoscopy cancers in an asymptomatic Canadian colorectal cancer screening population. Gastrointest Endosc. 2015;82(5):887-94.
3. Bowles CJ, Leicester R, Romaya C, Swarbrick E, Williams CB, Epstein O, et al. A prospective study of colonoscopy practice in the UK today: are we adequately prepared for national colorectal cancer screening tomorrow? Gut. 2004;53(2):277-83.
4. Corley DA, Jensen CD, Marks AR, Zhao WK, Lee JK, Doubeni CA, et al. Adenoma detection rate and risk of colorectal cancer and death. N Engl J Med. 2014;370(14):1298-306.
5. Rees CJ, Thomas Gibson S, Rutter MD, Baragwanath P, Pullan R, Feeney M, et al. UK key performance indicators and quality assurance standards for colonoscopy. Gut. 2016.
6. Tinmouth J, Kennedy E, Baron D, Burke M, Feinberg S, Gould M, et al. Colonoscopy quality assurance in Ontario: Systematic review and clinical practice guideline. Can J Gastroenterol Hepatol. 2014;28(5):251-74.
7. Kaminski MF, Anderson J, Valori R, Kraszewska E, Rupinski M, Pachlewski J, et al. Leadership training to improve adenoma detection rate in screening colonoscopy: a randomised trial. Gut. 2016;65:616-24.
8. Coe SG, Crook JE, Diehl NN, Wallace MB. An endoscopic quality improvement program improves detection of colorectal adenomas. Am J Gastroenterol. 2013;08(2):219-26.
9. Alberta Health Services. Forzani & MacPhail Colon Cancer Screening Centre: Quality Assurance 2016 [Available from: http://www.albertahealthservices.ca/info/Page8336.aspx.
10. Quality Management Partnership. Quality Management Partnership: Colonoscopy [Available from: https://www.qmpontario.ca/colonoscopy/.
11. Benchimol EI, Smeeth L, Guttmann A, Harron K, Moher D, Petersen I, et al. The REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statement. PLoS Med. 2015;12(10):e1001885.
12. Rothbard A. Quality Issues in the Use of Administrative Data Records. In: Fantuzzo J, Culhane DP, editors. Actionable intelligence: Using integrated data systems to achieve a more effective, efficient, and ethical government. New York: Palgrave Macmillan US; 2015. p. 77-103.
13. Logan JR, Lieberman DA. The use of databases and registries to enhance colonoscopy quality. Gastrointest Endosc Clin N Am. 2010;20(4):717-34.
14. De Coster C, Li B, Quan H. Comparison and validity of procedures coded With ICD-9-CM and ICD-10-CA/CCI. Med Care. 2008;46(6):627-34.

15. Groenen MJ, van Buuren HR, van Berge Henegouwen GP, Fockens P, van der Lei J, Stuifbergen WN, et al. Validation study of automatically generated codes in colonoscopy using the endoscopic report system Endobase. Scand J Gastroenterol. 2010;45(9):1121-6.
16. Lee JK, Jensen CD, Lee A, Doubeni CA, Zauber AG, Levin TR, et al. Development and validation of an algorithm for classifying colonoscopy indication. Gastrointest Endosc. 2015;81(3):575-82.e4.
17. Fisher DA, Grubber JM, Castor JM, Coffman CJ. Ascertainment of colonoscopy indication using administrative data. Dig Dis Sci. 2010;55(6):1721-5.
18. Baxter NN, Goldwasser MA, Paszat LF, Saskin R, Urbach DR, Rabeneck L. Association of colonoscopy and death from colorectal cancer. Ann Intern Med. 2009;150(1):1-8.
19. Alharbi O, Rabeneck L, Sutradhar R, Wijeysundera D, Yun L, Paszat L, et al. A population-based analysis of outpatient colonoscopy in adults assisted by an anesthesiologist. Anesthesiology. 2009;111(4):734-40.
20. Bielawska B, Hookey LC, Sutradhar R, Whitehead M, Xu J, Paszat LF, et al. Anesthesia Assistance in Outpatient Colonoscopy and Risk of Aspiration Pneumonia, Bowel Perforation, and Splenic Injury. Gastroenterology. 2018;154(1):77-85.e3.
21. Quality Management Partnership. Building on strong foundations: Inaugural report on quality in colonoscopy, mammography and pathology. 2015 November 2015. Report No.
22. Steele LS, Glazier RH, Lin E, Evans M. Using administrative data to measure ambulatory mental health service provision in primary care. Med Care. 2004;42:960-5.
23. Rosner B. Fundamentals of biostatistics 6th ed. Boston, MA: Duxbury Press; 2006.
24. Casella G, Berger RL. Statistical Inference. Belmont, CA: Duxbury Press; 1990.
25. Youden WJ. Index for rating diagnostic tests. Cancer. 1950;3(1):32-5.
26. Bressler B, Paszat LF, Chen Z, Rothwell DM, Vinden C, Rabeneck L. Rates of new or missed colorectal cancers after colonoscopy and their risk factors: a population-based analysis. Gastroenterology. 2007;132:96-102.
27. Baxter NN, Sutradhar R, Forbes SS, Paszat LF, Saskin R, Rabeneck L. Analysis of administrative data finds endoscopist quality measures associated with postcolonoscopy colorectal cancer. Gastroenterology. 2011;140(1):65-72.
28. Dominitz JA, Baldwin LM, Green P, Kreuter WI, Ko CW. Regional variation in anesthesia assistance during outpatient colonoscopy is not associated with differences in polyp detection or complication rates. Gastroenterology. 2013;144(2):298-306.
29. Wernli KJ, Brenner AT, Rutter CM, Inadomi JM. Risks Associated With Anesthesia Services During Colonoscopy. Gastroenterology. 2016;150(4):888-94; quiz e18.
30. Cancer Quality Council of Ontario. Technical Information. Colorectal Cancer Screening Follow-Up Toronto, ON: Cancer Care Ontario; 2016 [Available from: http://www.csqi.on.ca/by_patient_journey/screening/colorectal_screening_follow_up/technical_info/.

31. Li X, Hilsden R, Hossain S, Fleming J, Winget M. Validation of administrative data sources for endoscopy utilization in colorectal cancer diagnosis. BMC Health Serv Res. 2012;12:358.
32. Ko CW, Dominitz JA, Green P, Kreuter W, Baldwin LM. Accuracy of Medicare claims for identifying findings and procedures performed during colonoscopy. Gastrointest Endosc. 2011;73(3):447-53.e1.
33. Wyse JM, Joseph L, Barkun AN, Sewitch MJ. Accuracy of administrative claims data for polypectomy. CMAJ. 2011;183(11):E743-7.
34. Patel NC, Islam RS, Wu Q, Gurudu SR, Ramirez FC, Crowell MD, et al. Measurement of polypectomy rate by using administrative claims data with validation against the adenoma detection rate. Gastrointest Endosc. 2013;77(3):390-4.
35. Rahal R, Chadder J, DeCaria K, G. L, Bryant H, for the System Performance Steering Committee and the Technical Working Group. How different is cancer control across Canada? Comparing performance indicators for prevention, screening, diagnosis, and treatment. Curr Oncol. 2017;24(2):124-8.
36. Smith PC, Mossialos E, Papanicolas I. Performance measurement for healthsystem improvement:experiences, challenges and prospects. Copenhagen: 2008.
37. Manuel DG, Lim JJ, Tanuseputro P, Stukel TA. How many people have had a myocardial infarction? Prevalence estimated using historical hospital data. BMC Public Health. 2007;7:174.
38. Benchimol EI, Manuel DG, To T, Griffiths AM, Rabeneck L, Guttmann A. Development and use of reporting guidelines for assessing the quality of validation studies of health administrative data. J Clin Epidemiol. 2011;64(8):821-9.
39. Gotfried J, Bernstein M, Ehrlich AC, Friedenberg FK. Administrative database research overestimates the rate of interval colon cancer. J Clin Gastroenterol. 2015;49(6):483-90.
40. Morrato EH, Elias M, Gericke CA. Using population-based routine data for evidence-based health policy decisions: lessons from three examples of setting and evaluating national health policy in Australia, the UK and the USA. J Public Health. 2007;29(4):463-71.

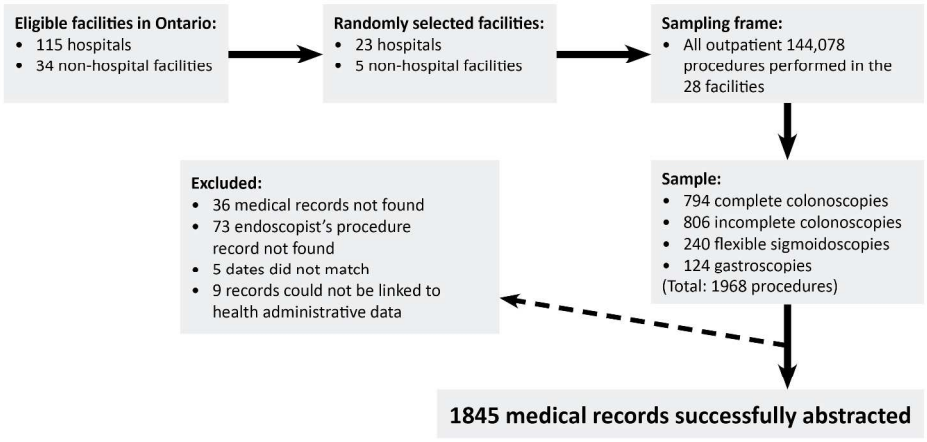


Figure 1. Flow chart describing sampling of facilities and procedures

279x146mm (300 x 300 DPI)

OHIP Definition	Sensitivity (95% CI)	Specificity (95% CI)
1. Z555A +/- other E codes	98.6 (97.4 - 99.8)	81.6 (76.3 - 86.9)
2. Z555A + E740A +/- other E codes	97.0 (95.4 - 98.5)	88.6 (83.5 - 93.7)
3. Z555A + E740A + E741A +/- other E codes	95.9 (94.3 - 97.5)	95.5 (90.7 - 100)
4. Z555A + E740A + E741A + E747A +/- other E codes	93.3 (91.5 - 95.1)	96.0 (91.2 - 100)
5. Z555A + E740A + E741A + E747A + E705A	40.9 (34.1 - 47.8)	96.5 (91.6 - 100)
6. Z555A + E741A +/- other E codes	96.3 (94.9 - 97.7)	95.5 (90.7 - 100)
7. Z555A + E747A +/- other E codes	93.7 (92.0 - 95.3)	96.0 (91.2 - 100)
8. Z555A + E705A +/- other E codes	41.4 (34.6 - 48.2)	96.5 (91.6 - 100)
9. Z555A + E740A + E747A +/- other E codes	93.3 (91.5 - 95.1)	96.0 (91.2 - 100)
10. Z555A + E740A + E705A +/- other E codes	41.0 (34.2 - 47.8)	96.5 (91.6 - 100)
11. Z555A + E741A + E747A +/- other E codes	93.7 (92.0 - 95.3)	96.0 (91.2 - 100)
12. Z555A + E741A + E705A +/- other E codes	41.4 (34.6 - 48.2)	96.5 (91.6 - 100)
13. Z555A + E747A + E705A +/- other E codes	41.3 (34.5 - 48.1)	96.5 (91.6 - 100)
14. Z555A + at least one of E740A, E741A, E747A, or E705A	97.3 (96.0 - 98.7)	88.6 (83.5 - 93.7)

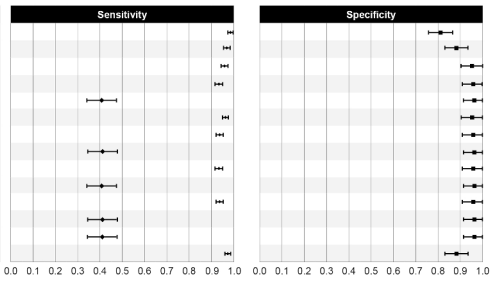
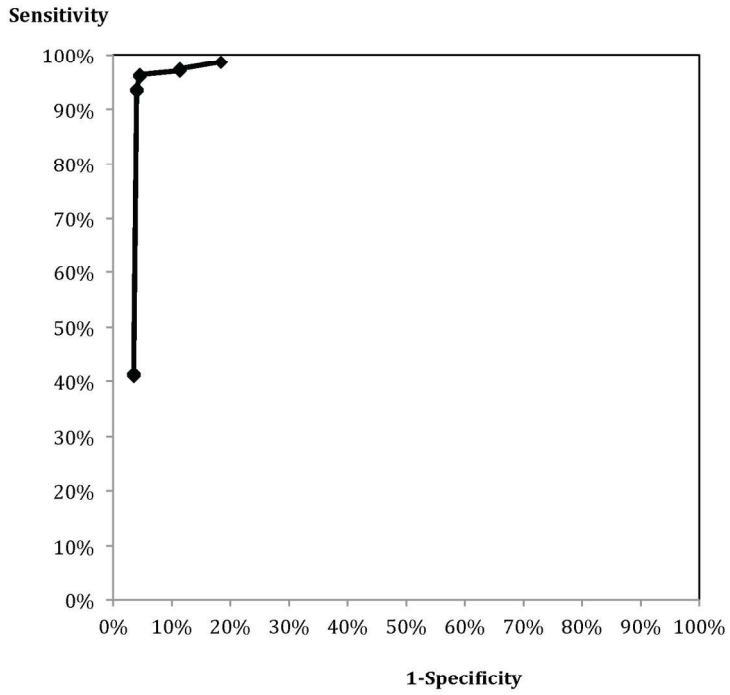


Figure 2. Weighted sensitivity and specificity of 14 administrative data definitions using Ontario Health Insurance Plan (OHIP) codes of colonoscopy case compared to the reference standard of colonoscopy intended or performed according to the medical record.

285x82mm (300 x 300 DPI)



*Upper left point of curve corresponds to OHIP definition #6: Z555A + E741A +/- other E codes

Figure 3. Receiver operating curve of the 14 definitions for colonoscopy case.

171x158mm (300 x 300 DPI)

	Sensitivity (95% CI)	Specificity (95% CI)
Non-hospital setting		
1. OHIP code E649A billed on date of colonoscopy	99 (97.5 - 100)	100 (100 - 100)
2. No record in CIHI overlapping with date of colonoscopy according to OHIP	99.9 (99.5 - 100)	100 (100 - 100)
3. E649A AND no overlapping record in CIHI	98.8 (97.3 - 100)	100 (100 - 100)
Completeness, using most sensitive colonoscopy defn		
Weighted analysis results	95.9 (95.1 - 96.7)	79.6 (78.1 - 81.1)
Unweighted analysis results	70.2 (66.1 - 74.4)	97.5 (97.3 - 97.7)
Completeness, using most accurate colonoscopy defn		
Weighted analysis results	99.5 (99.4 - 99.6)	64.2 (60.6 - 67.7)
Unweighted analysis results	94.6 (93.8 - 95.5)	94.9 (94.2 - 95.7)
Anesthiologist assistance		
vs. Anaesthesiologist record	99.8 (99.6 - 100)	96.9 (94.9 - 98.9)
vs. Use of propofol	99.8 (99.5 - 100)	95.7 (93.6 - 97.9)
Polypectomy		
vs. Polyp seen or removed		
1. Z571A alone	67.2 (60.1 - 73.8)	99.7 (99.1 - 100)
2. Z571A, Z570A, or E685A	76.9 (71.7 - 82.0)	99.5 (98.9 - 100)
3. Z571A, Z570A, E717A or E685A	92.8 (89.9 - 95.6)	86.5 (82.6 - 90.3)
vs. Histology		
1. Z571A alone	74.4 (66.9 - 81.9)	90.2 (87.7 - 92.7)
2. Z571A, Z570A, or E685A	80.5 (74.6 - 86.4)	87.3 (84.5 - 90.1)
3. Z571A, Z570A, E717A or E685A	94.0 (90.6 - 97.4)	73.1 (68.8 - 77.4)

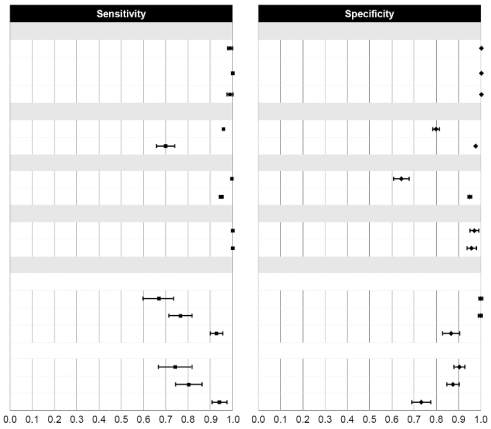


Figure 4. Sensitivity and specificity of non-hospital setting, colonoscopy completeness, anesthesiologist-assistance and polypectomy compared to reference standards.

285x124mm (300 x 300 DPI)

Supplementary Table 1. Description of OHIP codes used in the current study.

OHIP Billing Code	OHIP Billing Code Description
Colonoscopy and related codes	
Z555A	INTESTINES-ENDOSCOPY-COLONOSCOPY INTO DESCENDING COLON
E740A	INTESTINE ENDO SIGMOID TO SPLENIC FLEXURE ADD
E741A	INTESTINE END SIGMOID TO HEPATIC FLEXURE ADD
E747A	INTESTINE-ENDOSCOPY-SIGMOID.TO CAECUM ADD TO Z512/Z555
E705A	DIGEST.SYST.INTEST.ENDOSC.INTO TERMINAL ILEUM,ADD.
E749A	DIGEST SYST.-WHEN Z512,555,580 PERFORMED OUT HOSP....ADD
Z570A	INTESTINES-EXCISION-FULGURATION OF POLYPS THRO.COLONOSCOPE
Z571A	INTESTINES-EXC.-POLYPS THRO. COLONOSCOPE
E685A	INTESTINES,ENDOSCOPY TOTAL EXCISION >3CM SESSILE POLYPS
Gastroscopy and flexible sigmoidoscopy codes	
Z399A	OESOPHAGUS-OESOPHAGO/GASTRO. WITH/OUT DUODENOSCOPY
Z515A	DIGEST.SYST.OESOPHAGOSCOPY WITH/OUT BIOPSY(S)
Z523A	OESOPHAGUS-DILATION OF OESOPHAGUS-GUIDED(STRING,WIRE)
Z525A	OESOPHAGUS-DILATION-OESOPH.-PNEUMATIC
Z527A	STOMACH-ENDOSCOPY-GASTROSCOPY
Z528A	STOMACH-ENDOSCOPY-GASTROSCOPY-SUBSEQ.
Z532A	PERCUT ENDOSCOPC GASTROSTMY-REV Z CD & INCR FEE TO 1/2 S118
Z547A	STOMACH-ENDOSCOPY GASTROSCOPY WITH REMOVAL FOREIGN BODY
Z580A	INTESTINE-ENDOSCOPY-USING 60C.M. FLEXIBLE ENDOSCOPE.
Colectomy codes	
S166A	INTESTINE-EXC.-SML+LGE INTESTINE-TERM.ILEUM-CAECUM ASC.COLON
S168A	INTESTINE-EXC.-ILEOSTOMY.SUBTOTAL COLECTOMY
S169A	INTESTINE-EXC-TOTAL COLECTOMY W/ILEO-RECTAL ANASTOMOSIS.
S170A	INTESTINE-EXC.-ILEOSTOMY+TTLCOLECTOMY+ABDOM-PERIN.RESECTION
S172A	INTESTINE-EXC.-TOTAL COLECTOMY WITH LOOP ILEOSTOMY.
S214A	RECTUM-EXC.-PROCTECTOMY-ABDOMINO-PERINEAL RESEC/PULL THRU

S215A	RECTUM-EXC.PROCTECTOMY-2 SURG. TEAM ABDOMINAL SURGEON
S216A	RECTUM-EXC.-PROCTECTOMY-2 SURG. TEAM PERINEAL SURGEON

Supplementary Table 2. OHIP billing codes used in analysis to identify anaesthesia assistance. This list was empirically derived from Ontario health administrative data by identifying endoscopy-related and anesthesia codes with "C" suffix billed +/- 1 day of a colonoscopy from 1993-2005.*

OHIP Billing Code	OHIP Billing Code Description
E003C	ASST./ANAES. ATTEND. - MONITORING/CARE
E747C	ENDOSC SIGMOID TO CAECUM, ADD TO Z512/Z555
S119C	PERCUTANEOUS ENDOSCOPIC GASTROSTOMY
S236C	ESOPHAGUS - ENDOSCOPIC ULTRASOUND USING LINEAR OR RADIAL ECHO-ENDOSCOPE - EXCLUDING BILIARY OR PANCREATIC EXAM.
S237C	ESOPHAGUS - ENDOSCOPIC ULTRASOUND USING LINEAR OR RADIAL ECHO-ENDOSCOPE - INCLUDING BILIARY AND/OR PANCREATIC EXAM.
Z399C	OESOPHAGOSCOPY-GASTROCOPY W/OUT DUDENOSCOPY - ELECTIVE
Z400C	OESOPHAGUS - FOR ACTIVE BLEEDING
Z512C	INTESTINES - ENDOSCOPY ILEOSTOMY OR COLOSTOMY
Z514C	INTESTINES - ENDOSCOPY ILEOSTOMY OR COLOSTOMY WITH BIOPSY
Z515C	OESOPHAGOSCOPY WITH/OUT BIOPSY
Z527C	STOMACH - ENDOSCOP - GASTROSCOPY (W/OUT BIOPSY/PHOTO)
Z528C	SUBSEQ (WITHIN 3 MONTHS FOLLOWING PREV GASTROSCOPY
Z535C	RECTUM - SIGMOIDOSCOPY W/OUT ANOSCOPY (NOT WITH Z555/Z580)
Z536C	RECTUM - SIGMOIDOSCOPY W/OUT ANOSCOPY - W/BIOPSY
Z544C	ANUS - INC. BIOPSY
Z547C	STOMACH - GASTROSCOPY WITH REMOVAL OF FOREIGN BODY
Z551C	LIVER - INC - BIOPSY, NEEDLE
Z555C	ENDOSCOPY - SIGMOID/DESCENDING COLON
Z558C	BILIARY TRACT - ENDO MANIP &/OR REM DUCT STONES W/OUT SPHINCTEROTOMY
Z560C	INTESTINES - ENDOSCOPY - DUODENOSCOPY (NOT WITH Z399/Z400)
Z561C	INTESTINES - DUODENOSCOPY - CANN. PANCR. DUCT
Z567C	SUBSEQ PROC (WITHIN 3 MON. FOLL PREV ENDOSCOPIC PROC)
Z568C	SUBSEQ PROC SAME PHYS (WITHIN 3 MON. PREV ENDOSCOPIC PROC)
Z570C	FULG POLYP THROUGH COLONOSCOPE
Z571C	EXC POLYP, THROUGH COLONSCOPE
Z576C	INTRO - INJECTIONS ANAL FISSURE

Z580C	ENDOSCOPY (USING 60CM. FLEX SCOPE)
Z592C	RECTUM - SIGMOIDOSCOPY - DECOMPRESSION/VOLVULUS
Z749C	INTEST - ENDOSCOPY - SUBSEQ PROC (WITHIN 3 MONTHS)
Z753C	RECTUM - POLYPS/TUMOURS ELECTROCOAG - UNDER 2 CMS
Z754C	RECTUM - POLYPS/TUMOURS EXC - UNDER 2 CMS
Z755C	RECTUM - POLYPS/TUMOURS ELECTROCOAG/EXC - OVER 2 CMS
Z757C	EXC BENIGN ANAL LESION(S)
Z761C	RECTUM POLYPS WITH ELECTROCOAGULATION OR EXCISION BASE 5 CM.+

* Alharbi O, Rabeneck L, Sutradhar R, et al. A population-based analysis of outpatient colonoscopy in adults assisted by an anesthesiologist. Anesthesiology 2009;111:734-740.

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Title page
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4-5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Table 1
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Table 1
Bias	9	Describe any efforts to address potential sources of bias	6
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	n/a
		(*c*) Explain how missing data were addressed	Figure 1
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	4-5
		(*e*) Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	Figure 1
		(b) Give reasons for non-participation at each stage	Figure 1
		(c) Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential	Table 2

		confounders	
		(b) Indicate number of participants with missing data for each variable of interest	n/a
Outcome data	15*	Report numbers of outcome events or summary measures	Figure 2,3
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Figure 2,3
		(*b*) Report category boundaries when continuous variables were categorized	n/a
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	9
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	9-10
Generalisability	21	Discuss the generalisability (external validity) of the study results	9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	11

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.