ORIGINAL RESEARCH

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Validation of abdominal aortic aneurysm repair codes in Ontario administrative data

Abstract

Purpose: To determine the positive predictive values (PPV) of Ontario administrative data codes for the identification of open (OSR) and endovascular (EVAR) repairs of elective (eAAA) and ruptured (rAAA) abdominal aortic aneurysms.

Methods: We randomly identified 319 eAAA and rAAA repairs at two Toronto hospitals between April 2003 and March 2015, using administrative health data in Ontario, Canada. International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) codes I71.3 and I71.4, were used to identify rAAA and eAAA patients, respectively. A blinded retrospective chart review was conducted and served as the gold standard comparator. Re-abstracted records were compared to Canadian Classification of Health Interventions (CCI) and Ontario Health Insurance Plan (OHIP) codes in the Canadian Institute for Health Information Discharge Abstract Database (CIHI-DAD) and OHIP databases. We calculated the PPV and 95% confidence intervals (95% CI) of individual and combined procedure and billing codes for elective and ruptured OSR and EVAR (eOSR, eEVAR, rOSR, and rEVAR).

Results: Permutation of codes allowed identification of eOSR with 95% PPV (95% CI 88, 98), eEVAR with 96% PPV (95% CI 90, 99), rOSR with 87% PPV (95% CI 79, 93) and rEVAR with 91% PPV (95% CI 59, 100).

Conclusions: Diagnostic, procedure and billing code combinations allow identification of eOSR, eEVAR, rOSR and rEVAR patients in Ontario administrative data with a high degree of certainty.

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Abdominal aortic aneurysms (AAAs) are focal dilatations of the abdominal aorta measuring greater than 3 cm in diameter, with a natural history of growth and eventual rupture. Conventionally, AAAs were repaired using an open surgical approach (OSR) through a long midline incision; however, in the early 1990's, endovascular aortic repair (EVAR), a minimally invasive technique employing wires and covered stents, was introduced as an alternative treatment approach. Early trials demonstrated the superiority of EVAR in the peri-operative period in terms of morbidity, mortality and length of stay, among other outcomes [1-3]; however, mid and long-term follow-up studies showed an eventual loss of this mortality benefit, as well as higher re-intervention rates and secondary rupture rates among EVAR patients [4-8]. Despite the use of now obsolete, first generation grafts, the profound short term benefits demonstrated by these studies have made clinical equipoise difficult to argue for subsequent study of modern endovascular grafts. Fortunately, analysis of large sample population-based observational data can supplement data from randomized trials and significantly add to best available evidence; however, the use of such observational data relies on the accuracy of the coding to define diagnoses, procedures and outcomes of interest.

The province of Ontario (Canada) maintains several comprehensive, deterministically-linked administrative health databases that are frequently used to conduct epidemiological research. The completeness and accuracy of these data have been demonstrated across a range of diagnoses and procedures [9-19]; however, the sheer number of medical conditions and surgical procedures in existence requires continued efforts to define the operating characteristics of the diagnostic, procedure, and billing codes within Ontario administrative data. The procedure and billing codes for elective (eAAA) and ruptured (rAAA) abdominal aortic aneurysm repair have not been comprehensively validated in Ontario administrative data.

The primary objective of the present study was to determine the positive predictive value (PPV) of ICD-10, Canadian Classification of Health Interventions (CCI) and Ontario Health Insurance Plan (OHIP) codes for the identification of OSR and EVAR repairs of eAAAs and rAAAs within Ontario administrative data. Our secondary objective was to define the optimal combination of codes to support a study of the comparative effectiveness of OSR and EVAR outcomes in eAAA and rAAA settings.

Methods

Study design and data sources

Following institutional research ethics board approval at St. Michael's (SMH) and Sunnybrook (SBK) Hospitals, which are academic tertiary hospitals in Toronto, Ontario, Canada, we conducted a retrospective cross-sectional chart reabstraction study. We used a combination of Ontario linked administrative healthcare data obtained through the Institute for Clinical and Evaluative Sciences (ICES) and corresponding chart data from the participating hospital sites. ICES managed databases are routinely used for health services research, and frequently yield high impact research with policy implications [20-26]. The specific datasets that we used included the Canadian Institutes for Health Information Discharge Abstract Database (CIHI-DAD), a national database containing admission, procedure, and demographic information for all acute hospitalizations in Canada since 1982. The CIHI-DAD has used 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10-CA) and Canadian Classification of Health Intervention (CCI) codes to designate admission diagnoses and procedures since 2002, respectively. The National Ambulatory Care Reporting System Database (NACRS), which contains information on all ambulatory care visits since 2001, was used to capture ambulatory diagnoses of AAA according to ICD-10-CA codes. In addition, we used the Ontario Health Insurance Plan (OHIP) database, a dataset collected by the Ministry of Health and Long-Term Care (MOHLTC) of Ontario, that contains information on all physician billing claims for insured services for the province of Ontario. Finally, we also used the Registered Persons Database, another MOHLTC database that contains basic demographic and geographic information for all Ontario persons with a health card number. The information contained within each database was linked together using a unique encrypted identification number issued by ICES.

Cohort identification and data collection

We first identified all patients with possible AAA repairs in Ontario from April 1, 2003 to March 31, 2015, using the described ICES datasets. Candidate patients were identified based on the first occurrence of a CCI or OHIP code of interest within the study period (data available upon request from the corresponding author). We then sub-selected all patients that had their repairs conducted at SMH or SBK, and split the cohort into eAAA and rAAA sub-cohorts based on the presence of preceding diagnoses of eAAA (ICD-10-CA

code I71.4) or rAAA (ICD-10-CA code I71.3) in the CIHI-DAD or NACRS databases. Two hundred patients were randomly selected from the eAAA sub-cohort, balancing hospital site and associated repair approach candidate codes (OSR vs EVAR), while all patients within the rAAA sub-cohort were selected because fewer than 200 cases were conducted between the hospital sites within the study period. A unique provincial patient identifier number, patient age, biological sex and admission date for the associated repair codes were then abstracted from ICES records for each patient.

Hospital charts for the patients identified in the ICES cohort, were then reviewed by a blinded abstractor who collected patient age, sex, admission date of repair, gold standard repair approach and indication for repair (eAAA, rAAA or other non-AAA). Repairs of inflammatory and mycotic aneurysms, graft explants and repairs of abdominal components of thoracoabdominal aortic aneurysms were considered “other” indications for repair as the risks and challenges associated with repairing these types of aneurysms are not identical with those of ruptured aneurysms. Symptomatic aneurysms, aneurysms with contained ruptures that were repaired after work-up and aneurysms without hemodynamic instability were coded as eAAA. Open surgical repair was defined as any infrarenal, pararenal or juxtarenal AAA repair involving the use of prosthetic graft terminating at any distal site. Endovascular aortic repair was defined as any infrarenal EVAR, excluding fenestrated (fEVAR) and branched (bEVAR) repairs due to added repair complexity, time and additional associated risks. The re-abstracted data were collected and stored on an encrypted laptop, and uploaded to the ICES secure server environment for analysis.

Data analysis

We used SAS Enterprise Guide 7.1 (SAS Institute, Cary, NC, USA) within the ICES Central secure server environment to conduct all our statistical analyses. In addition to the unique patient identifier number, patient age, sex and admission date for repair were used to verify patient identity. All patients with any discordant values between administrative and chart data were excluded from the validation analysis. We calculated positive predictive values (PPV) and corresponding 95% confidence intervals (95% CI) for each code separately for the eAAA and rAAA subgroups. We then permuted CCI and OHIP codes to determine the code combinations with the best PPV for the identification of elective OSR (eOSR) and EVAR (eEVAR) and ruptured OSR (rOSR) and EVAR (rEVAR).

Results

We identified a total of 327 records from administrative data for chart validation. Following chart review and data upload, eight records were removed for non-matching patient age, biological sex, procedure date or missing values. Of the remaining 319 records, 179 were from SMH and 140 from SBK. Fourteen records used AAA repair codes for other conditions and procedures including thoracic endovascular aortic repairs (TEVARs), inflammatory and symptomatic aneurysm repairs and primary and secondary aortic fistula repairs, among others, according to gold-standard chart abstraction. The study sample included 200 eAAA and 105 rAAA repair records (Figure 1). Of these patients, six underwent procedures other than OSR or EVAR, resulting in a 93.7% (299/319) AAA repair rate.

The most commonly occurring CCI code for OSR was 1.KA.80.LA-XX-N in both the eAAA and rAAA sub-groups, with frequencies of 73.2% (71/97) and 72.1% (63/85), respectively. Of the OHIP codes, R802 occurred most commonly, with frequencies of 65.0% (63/97 eOSR) and 84.7% (72/85 rOSR) (Table 1). The most common CCI codes for EVAR were 1.KA.80.GQ-NR-N which occurred in 97.0% (98/101) of eEVARs, and 95.0% (19/20) of rEVARs, and the OHIP code R875 occurred in all abstracted eEVARs and rEVARs (Table 1).

The use of ICD-10-CA codes for the identification of eAAA and rAAA demonstrated high PPVs (Table 2). Code I71.4 identified eAAA repairs with 96% PPV (95% CI 93, 99), while code I71.3 identified rAAA repairs with 83% PPV (95% CI 75, 89). The OHIP add-on billing code for repair of rAAA (E627) identified rAAA repairs with 90% PPV (95% CI 83-96). Combination of codes I71.3 and E627 with operators “AND” or “OR” did not improve on the PPV for rAAA identification.

Use of individual codes for the identification of OSR demonstrated high PPVs among both CCI and OHIP codes (Table 2). Combination of ICD-10-CA diagnosis codes and CCI codes for eOSR demonstrated similar characteristics, when individual CCI or OHIP codes were combined with the diagnosis code. Permutation of multiple CCI codes in conjunction with OHIP codes significantly narrowed the 95% confidence intervals of the identification algorithm with maximal 95% PPV (95% CI 88, 98). A combination of code I71.3 and individual OSR codes to identify rOSR demonstrated poorer performance, which was ameliorated by the combination of multiple CCI codes with OHIP codes to identify rOSR with 87% PPV (95% CI 79, 93). Table 3 lists the proposed optimized code combinations and their

TABLE 1. Individual OSR and EVAR code frequency, by indication (%)

Approach	Code Type	Code	Repair Indication		
			eAAA	rAAA	Other
OSR	CCI	1.KA.80.LA	2.1	5.9	11.1
		1.KA.80.LA-XX-A	5.2	3.5	0
		1.KA.80.LA-XX-K	0	1.2	0
		1.KA.80.LA-XX-N	73.2	74.1	88.9
		1.KA.80.LA-XX-Q	4.1	4.7	0
		1.KA.76.MZ-XXN	9.3	3.5	0
		1.KA.76.NB-XXN	6.2	7.1	0
	OHIP	R802	65.0	84.7	0
		R817	20.6	4.7	0
		R877	14.4	10.6	0
EVAR	CCI	1.KA.80.GQ-NR-N	97.0	95.0	100
		1.KA.50.GQ-OA	2.0	0	0
		1.KE.50.GQ-OA	1.0	5.0	0
	OHIP	R875	100	100	100

Abbreviations: CCI=Canadian Classification of Health Interventions; eAAA=Elective Abdominal Aortic Aneurysm; EVAR=Endovascular Aortic Repair; OHIP=Ontario Health Insurance Plan; OSR=Open Surgical Repair; rAAA=Ruptured Abdominal Aortic Aneurysm

FIGURE 1. Abbreviations: eAAA=Elective Abdominal Aortic Aneurysm; EVAR=Endovascular Aortic Repair; OHIP=Ontario Health Insurance Plan; OSR=Open Surgical Repair; rAAA=Ruptured Abdominal Aortic Aneurysm

TABLE 2. Positive predictive value of individual diagnosis, procedure and billing code

Diagnosis/ Procedure	Code Type	Code	Positive Predictive Value % (95% CI)
eAAA	ICD-10-CA	I71.4	96 (93,99)
rAAA	ICD-10-CA	I71.3	83 (75,89)
	OHIP	E627	90 (83,96)
OSR	CCI	1.KA.80.LA	100 (63,100)
		1.KA.80.LA-XX-A	100 (63,100)
		1.KA.80.LA-XX-K	100 (3,100)
		1.KA.80.LA-XX-N	100 (97,100)
		1.KA.80.LA-XX-Q	100 (63,100)
		1.KA.76.MZ-XXN	100 (74,100)
		1.KA.76.NB-XXN	100 (74,100)
	OHIP	R802	100 (97,100)
		R817	100 (97,100)
		R877	100 (88,100)
EVAR	CCI	1.KA.80.GQ-NR-N	98 (94,100)
		1.KA.50.GQ-OA	0 (0,0)
		1.KE.50.GQ-OA	0 (0,0)
	OHIP	R875	98 (94,100)

Abbreviations: CCI=Canadian Classification of Health Interventions; CI=Confidence Interval; eAAA=Elective Abdominal Aortic Aneurysm; EVAR=Endovascular Aortic Repair; ICD-10-CA= International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Canada; OHIP=Ontario Health Insurance Plan; OSR=Open Surgical Repair; rAAA=Ruptured Abdominal Aortic Aneurysm

TABLE 3. Positive predictive value of optimized code combinations for identification of OSR and EVAR in eAAA and rAAA patients

Indication and repair	Code Combination	Positive Predictive Value % (95% CI)
eOSR	I71.4 AND (1.KA.80.LA-XX-N OR 1.KA.76.MZ-XX-N OR 1.KA.76.NB-XX-N OR R802)	95 (88,98)
eEVAR	I71.4 AND (1.KA.80.GQ-NR-N OR R875)	96 (90,99)
rOSR	I71.3 AND (1.KA.80.LA-XX-N OR 1.KA.76.MZ-XX-N OR 1.KA.76.NB-XX-N OR R802)_	87 (79,93)
rEVAR	I71.3 AND E627 AND (1.KA.80.GQ-NR-N OR R875)	91 (59,100)

Abbreviations: CI=Confidence Interval; eAAA=Elective Abdominal Aortic Aneurysm; eEVAR=Elective Endovascular Aortic Repair; eOSR=Elective Open Surgical Repair; EVAR=Endovascular Aortic Repair; OSR=Open Surgical Repair; rAAA=Ruptured Abdominal Aortic Aneurysm; rEVAR= Ruptured Endovascular Aortic Repair; rOSR=Ruptured Open Surgical Repair

performance identifying OSR and EVAR in both eAAA and rAAA patients. A complete list of code permutations and associated PPVs is available upon request from the corresponding author.

Use of individual codes for the identification of EVAR demonstrated excellent PPV for both CCI and OHIP codes, and combination of code I71.4 with individual proposed EVAR codes did not change the PPV for the identification of eEVAR (Table 2). This was also the case when code I71.4 was used in conjunction with multiple CCI and OHIP codes (data available upon request from the corresponding author). Similarly, identification of rEVAR using ICD-10-CA code I71.3 and individual procedure and billing codes had excellent PPV, but wide confidence intervals. The highest PPV achieved using code I71.3 with single procedure or billing codes was 100% (95% CI 3, 100). The use of OHIP add-on code E627 in combination with individual CCI or OHIP codes demonstrated a similar pattern of high PPVs with wide confidence intervals. Permutation of codes I71.3, E627, and CCI and OHIP codes identified rEVAR with high PPV, and significantly narrowed the 95% confidence interval for the PPV estimate. See Table 3 for proposed administrative data definitions for eEVAR and rEVAR patients, and the PPVs and associated 95% confidence intervals for these definitions.

Discussion

In the present chart abstraction study, we determined the PPV of ICD-10-CA, CCI, and OHIP diagnosis, procedure and billing codes for the identification of patients following eOSR, eEVAR, rOSR and rEVAR, in Ontario administrative health data. We demonstrated high PPVs for ICD-10-CA code identification of eAAA and rAAA patients, and high performance of individual CCI and OHIP codes for identification of eOSR, eEVAR, rOSR and rEVAR repairs. Combination and permutation of codes maintained the PPV of eOSR, eEVAR, rOSR and rEVAR repairs, and significantly narrowed the 95% confidence intervals for the associated PPV estimates.

The findings of our study are consistent with the limited data available regarding the validity of aneurysm diagnosis coding in Ontario administrative data. In one of the largest abstraction studies conducted internationally, Juurlink *et al.* examined the accuracy of diagnosis and procedure coding in 14,500 patient discharges from 18 hospitals in Ontario [15]. They found high agreement within the CIHI-DAD for diagnosis of aortic aneurysms and dissections between coders and re-abstractors ($\kappa=0.94$, 95% CI 90, 97), and similarly high PPV (94%, 95% CI 87, 98) when the parent ICD-10-CA code

I71 for aortic aneurysm and dissection was considered. Due to the use of only the parent code (first three characters), their findings could not parse out the performance of specific diagnosis codes for eAAA and rAAA diagnosis. Our findings confirmed similarly high performance of these specific codes for the identification of eAAA and rAAA diagnoses.

Elsewhere, Jetty *et al.* are responsible for the only other investigation of ICD-10-CA and CCI codes for the identification of eOSR and eEVAR in Ontario administrative data [27]. They used primary hospital data for 514 patients undergoing eAAA repair from a single tertiary centre, and demonstrated poor coding accuracy for identification of eOSR and eEVAR using ICD-10-CA and individual CCI codes related to AAA repair only. Specifically, these single CCI repair code algorithms were challenged by 48.1 % (95% CI 43.3, 53.0) and 58.2% (95% CI 46.5, 69.2) sensitivities for eOSR and eEVAR repairs, respectively, and a negative predictive value of 22.6% (95% CI 17.9, 27.8) for eOSR; however, they demonstrated significant increases in eOSR (98.1%) and eEVAR (72.2%) sensitivity when procedure codes were combined. Furthermore, the authors defined a coding algorithm using additional anesthesia codes to identify eOSR and eEVAR patients with high accuracy (95.9%, 95% CI 93.8, 97.4, and 97.3%, 95% CI 95.4, 98.5, respectively). Our abstraction methodology did not permit us to measure the sensitivity of our proposed coding algorithms; however, our analysis yielded similar PPV optimizing code combinations for the identification of eOSR and eEVAR repairs, presumably retaining the sensitivity benefits of these combinations demonstrated by Jetty *et al.* In contrast, we did not use anesthesia modifiers to help further refine our algorithms. Although eEVARs can be conducted under local or regional anesthesia, general anesthesia is used for EVAR in approximately 90% of cases, according to a large Vascular Quality Initiative study [28]. This is likely attributable to conflicting reports regarding the superior safety of loco-regional anesthetic techniques for EVAR [29, 30]. Instead, we tested the PPV of OHIP billing codes, which are submitted by the operating physician, and thus less likely to be mistakenly miscoded. The addition of these codes to our definitions maintained high PPVs for eOSR, eEVAR, rOSR and rEVAR identification, and narrowed the 95% confidence intervals associated with these estimates.

Previously, no validation studies have considered the identification of rAAA repairs and approaches in Ontario administrative data. Although we demonstrated high PPVs for the identification of both rOSRs and rEVARs, the proposed algorithms should be used with caution for several reasons.

First, the limited number of rAAA patients (n=105) that were available for code validation, and the fewer still (n=20) that underwent rEVAR according to gold standard chart review, limited the power to measure the operating characteristics of candidate rEVAR code combinations. Furthermore, the moderate PPV for many of the tested rEVAR algorithms may be attributed to improper coding of non-ruptured aneurysms with code I71.3, due to similarity between rupture and other high risk aneurysm patients, including symptomatic, inflammatory and ruptured patients, and lack of knowledge regarding the differences between these AAA repair indications among coders. Elsewhere, following the introduction of EVAR in Ontario, code E627 was not initially eligible to be billed in conjunction with R875 for endovascular repair for several years, and rEVARs would have been billed without the rupture modifier. As such, although the use of code E627 in our proposed definition should increase the sensitivity of our algorithm, we were again, unable to test this parameter owing to our methodology. Finally, it is not uncommon to conduct unilateral rEVAR repairs followed by femoro-femoral bypass, with the latter associated with higher remuneration. Since the MOHLTC imposes mandatory audit of billing claims involving more than two surgical billing codes, resulting in significant payment delay, operators might be incentivized to forego billing the rupture code (E627) in lieu of the more lucrative femoro-femoral bypass code (R933), in addition to the base EVAR code. This practice could also reduce the sensitivity of our rEVAR definition.

In addition to the cautions noted above, the results of our study should be interpreted keeping several additional limitations in mind. First, our validation work utilizes Ontario administrative data, and may not be applicable to other administrative datasets due to differences in coder training and coding practices, despite the use of similar coding systems. Furthermore, our validation study employed data from two urban, academic, tertiary referral centres where coding practices may differ from those at community or rural hospitals, potentially limiting generalizability to the remainder of Ontario administrative data. Finally, as already alluded to, our use of reabstraction methodology limits us to being able to make meaningful conclusions only about the PPV of the codes and combinations assessed. The high PPV of the assessed codes and combinations permit the identification of patients with each type of repair with high certainty, ensuring that the population of interest is being studied. This is particularly true of rAAA patients, given the additional fact that no previous attempts at validating repair codes in these patients have been made. These findings are specific to the current data set, and

the proposed coding definitions should be used keeping these generalizability limitations in mind, or should be further externally validated in the specific data sets used in subsequent work.

In conclusion, this chart reabstraction study of 319 patients from two urban, tertiary academic centres in Ontario demonstrates the ability to identify eOSR, eEVAR, rOSR and rEVAR patients in Ontario administrative data with a high degree of certainty. We propose the use of ICD-10-CA, CCI and OHIP codes in combination, to identify these patients in future studies using Ontario administrative data. Future work to completely define the operating characteristics of the codes used for AAA repairs should include more comprehensive validation approaches, including rural and community hospitals, or province-wide approaches using primary data, particularly in rAAA patients.

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