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RESEARCH ARTICLE

Case Definitions for Acute Myocardial Infarction in Administrative Databases and Their Impact on In-Hospital Mortality Rates

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Objective. To identify validated ICD-9-CM/ICD-10 coded case definitions for acute myocardial infarction (AMI).

Data Sources. Ovid Medline (1950–2010) was searched to identify studies that validated acute myocardial infarction (AMI) case definitions. Hospital discharge abstract data and chart data were linked to validate identified AMI definitions.

Study Design. Systematic literature review, chart review, and administrative data analysis.

Data Collection/Extraction Methods. Data on sensitivity/specificity/positive and negative predictive values (PPV and NPV) were extracted from previous studies to identify validated case definitions for AMI. These case definitions were validated in administrative data through chart review and applied to hospital discharge data to assess in-hospital mortality.

Principal Findings. Of the eight ICD-9-CM definitions validated in the literature, use of ICD-9-CM code 410 to define AMI had the highest sensitivity (94 percent) and specificity (99 percent). In our data, ICD-9-CM/ICD-10 codes 410/I21-I22 in all available coding fields had high sensitivity (83.3 percent/82.8 percent) and PPV (82.8 percent/82.2 percent). The in-hospital mortality among AMI patients identified using this case definition was 7.6 percent in ICD-9-CM data and 6.6 percent in ICD-10 data.

Conclusions. We recommend that ICD-9-CM 410 or ICD-10 I21-I22 in the primary diagnosis coding field should be used to define AMI. The use of a consistent validated case definition would improve comparability across studies

Key Words. Administrative data, acute myocardial infarction, validation studies, international classification of disease (ICD) codes, mortality

Acute myocardial infarction (AMI) is an important health issue that has been widely studied in the literature both in terms of its clinical impact on the population and its inclusion as part of performance indicators (Yeh and Go 2010).

However, the essential question of what constitutes an AMI clinically remains unaddressed, resulting in heterogeneity between study findings (Thygesen et al. 2007; Yeh and Go 2010). The lack of a common clinical definition further complicates population-based studies that rely on administrative data that are coded from this heterogeneous pool of clinical definitions.

Administrative data such as hospital discharge abstract data, physician billing data, health insurance plan registries, and vital statistics repositories are employed for many different purposes in part due to their wide population-coverage, their cost-effectiveness, and the fact that they are often a readily available source of data. Administrative health databases typically code medical conditions using the World Health Organization International Classification of Diseases and Related Disorders (ICD) codes, and as such are very useful tool for research. Today, most countries use ICD-9 (first released in 1975), ICD-9-CM (Clinical Modification), or ICD-10 (first released in 1990) to classify their national morbidity and mortality data, making these coding systems the most widely used classification systems underlying health care data internationally (Jette et al. 2010; World Health Organization 2010).

Although administrative data are used to estimate the incidence and prevalence of acute conditions requiring hospital admission, administrative data were not originally intended to be collected for disease surveillance (Tu et al. 1999; Austin, Daly, and Tu 2002). As a result, it is important to assess disease coding validity from administrative databases for conditions such as AMI before proceeding with any outcome analysis or epidemiological studies. A case definition for a disease can simply consist of the appearance of a single disease code at any point in time in any administrative data source (i.e., if a patient has one physician visit for the condition of interest, he or she is classified as having the disease), or it can use an algorithm to identify patients with the disease (i.e., a patient is only classified as having the disease if he or she had two physician visits and one emergency room visit coded with the condition of interest within a 2-year period) (Quan et al. 2009). Numerous

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studies have been published using administrative hospitalization data to study various AMI outcomes; however, the case definitions used have often not been validated prior to their implementation and are inconsistent across studies, which may lead to incomparable findings.

The objectives of this study were to (1) perform a systematic review of hospital-based studies to identify validated ICD-9-, ICD-9-CM-, or ICD-10-based AMI case definitions; (2) identify what case definitions have been used in the literature; (3) validate previously validated case definitions in dually coded ICD-9-CM and ICD-10 data through medical chart review; and (4) apply validated AMI case definitions to Canadian hospital discharge abstract data to assess the impact of various case definitions on estimates of AMI admissions and in-hospital mortality.

METHODS

Literature Review of Validated AMI Case Definitions

A systematic literature search was conducted in July 2010 using Ovid Medline (1950 to present) for the following terms: myocardial infarction or cardiac infarct or heart infarct or myocardial infarct or acute myocardial infarction; AND case definition or admin data or administrative data or algorithms or computer algorithms or registries or International Classification of Diseases or ICD-9 or ICD-9CM or ICD-10 or ICD code or patient coding or patient classification or disease classification or disease coding or international classification disease. The search was limited to English language articles only. All abstracts were reviewed independently by two authors, and full-text articles were reviewed if one of the two reviewers thought the article may be relevant at the abstract review stage. Full-text articles were included if both reviewers agreed that the article met all eligibility criteria: validated AMI ICD-9 or ICD-10 codes (including any country-specific modification in these coding frameworks); specified the ICD codes used in hospital discharge abstract data; and reported sensitivity, specificity, positive predictive value (PPV), or negative predictive value (NPV) or provided the data required to calculate these values. Reference lists were also hand searched to ensure no additional studies were missed. Disagreements between reviewers were resolved by consensus.

Data on sensitivity, specificity, PPV, and NPV (when available) were abstracted by two reviewers from validated case definitions and summarized in tabular form. In addition, data were also abstracted on study characteristics (such as sample size, years of data collection, validation database, and gold standard) and the specific ICD codes used in the validation.

Literature Review of Case Definitions Used in AMI studies

Due to the high volume of publications on AMI, we searched high-impact general medical journals (i.e., *British Medical Journal, Canadian Medical Association Journal, Journal of the American Medical Association, Lancet, New England Journal of Medicine*) and high-impact cardiovascular journals (i.e., *American Journal of Cardiology, Circulation, Heart, Journal of the American College of Cardiology*) and determined what ICD-based case definitions for AMI were most commonly used in the scientific literature. A literature search of these journals using Ovid Medline (2007–2012) was conducted in February 2012 using the following terms: myocardial infarction or acute myocardial infarction; and medical records or health services or health services research or insurance, hospitalization, or length of stay or risk adjustment or hospitals or databases, factual. Journal articles were included if they used an ICD-9- or ICD-10-based case definition for AMI and reported the ICD codes used.

Validating AMI Case Definitions in Dually Coded ICD-9-CM and ICD-10 Hospital Discharge Data

We randomly selected 4,008 inpatients records from hospital discharge abstract data who were admitted between January 1 and June 30, 2003, for any indication. Up to 25 diagnoses per encounter were coded using ICD-10. Trained health coders recoded these inpatient charts using ICD-9-CM using standard coding methodology. Charts were then independently reviewed by trained reviewers with nursing backgrounds. Reviewers were instructed to examine the entire chart, including the cover page, admission notes, laboratory results, and discharge summaries. A chart was coded as indicating the presence of AMI based on all available documentation and if the AMI was not present on admission. Thus, for 4,008 inpatients, three datasets were created: ICD-9-CM, ICD-10, and chart review datasets. Details were reported elsewhere (Quan et al. 2008). Sensitivity, specificity, PPV, and NPV were calculated for ICD-9-CM and ICD-10 data (found in any coding position), respectively, accepting the chart data as a reference standard for each AMI case definition.

AMI Case Volume and In-Hospital Mortality in Hospital Discharge Data

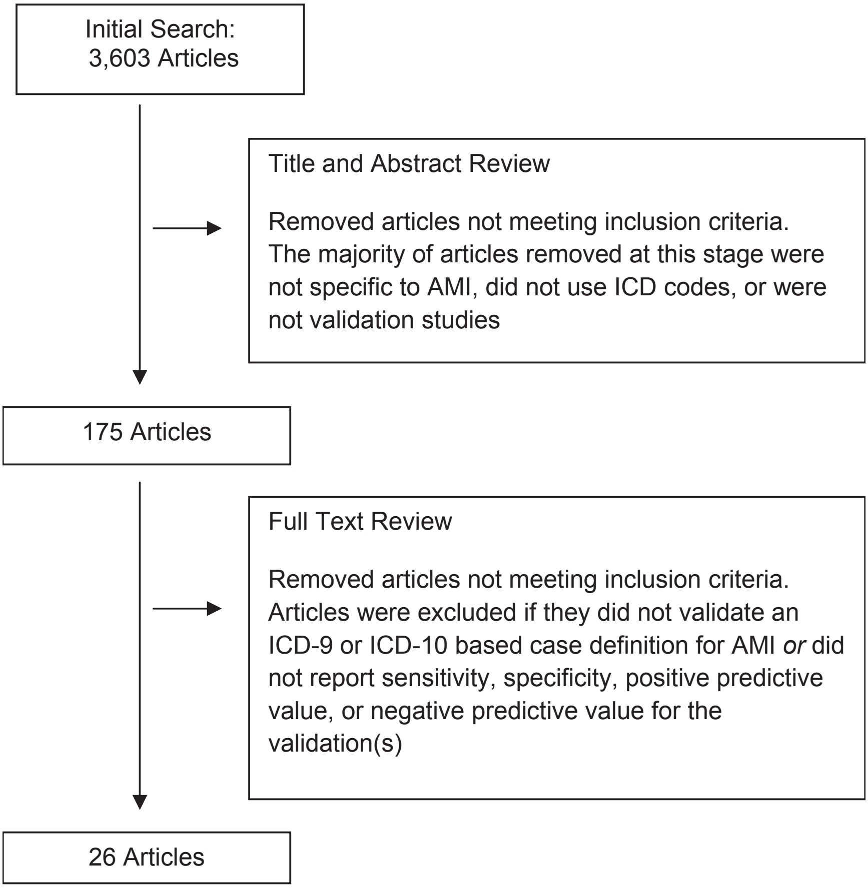
AMI case definitions were applied to the hospital discharge abstract data from Calgary, Alberta, Canada, from April 2001 to March 2002 (ICD-9 coded data) and April 2006 to March 2007 (ICD-10 coded data). Hospitals in Calgary serve a population of 1.4 million individuals. These data encompass all patients who were admitted to hospital and include numerous variables such as length of stay, diagnoses, interventions, and in-hospital mortality. Up to 50 diagnoses per case are recorded in this database. AMI patients were defined using the primary diagnosis alone and then using primary and secondary diagnoses (i.e., conditions were coded in any coding field). Patients were included in this analysis if they were 18 years of age or older at the time of admission. For patients with multiple admissions, only the first admission in the fiscal year was used in the analysis. For each case definition, the number of patients identified and the in-hospital mortality rate was assessed among those identified.

RESULTS

Literature Review of Validated AMI Case Definitions

Of 3,603 articles identified, 26 articles from nine countries, including Australia, Canada, Finland, Korea, the Netherlands, New Zealand, Scotland, Sweden, and United States, met all inclusion criteria (Figure 1). Nine ICD-9 and two ICD-10 codes were used in these studies in eight combinations (see Tables 1 and 2). All these studies included ICD-9 code 410 (AMI) in either the primary (major reason for admission or resource consumption) or one of the secondary diagnostic code positions (co-existing condition) to identify patients with AMI. The second most frequently used code was ICD-9 411 (other acute and subacute forms of ischemic heart disease). Only one study validated ICD-10 codes, I21 (acute myocardial infarction, disregarding any ICD-10 subgroups) and I22 (subsequent myocardial infarction, disregarding any ICD-10 subgroups), and combined these codes with ICD-9 code 410 (Pajunen et al. 2005). Most studies did not differentiate whether a particular code of interest was in the primary position or in one of the secondary positions. Of the 26 studies reviewed, 17 used medical records and 9 used registry data as the gold standard to validate AMI diagnosis in hospital discharge data. ICD-9 codes 410–414 had the highest reported sensitivity (range: 79–95 percent), whereas ICD-9 code 410 used in isolation had the highest reported specificity (range: 89–99 percent) (see Table 2).

Figure 1: Flow Chart of Systematic Literature Review to Identify Studies That Validated Case Definitions for Acute Myocardial Infarction



PPV was reported in 22 studies (range: 5.6–98.7 percent). The ICD-9 code 410 used in isolation had the highest reported PPV (range: 54.6–98.7 percent) but PPV decreased when ICD-9 410 was used in combination with other codes (range: 19–90 percent) that were not specific to AMI. NPV was only calculated in four studies (Kennedy, Stern, and Crawford 1984; Palomaki et al. 1994; Pladevall et al. 1996; Heckbert et al. 2004), where values ranged from 68.8 to 100 percent for ICD-9 410 in isolation, and from 45.8 to 98.3 percent for ICD-9 410–411.

Table 1: International Classification of Disease (ICD) Codes Used as Part of Validated Acute Myocardial Infarction Case Definitions

ICD-9-CM Code	*Definition*	*ICD-10-CA Code*	*Definition*
410	Acute myocardial infarction	I21	Acute myocardial infarction
410.x0	Acute myocardial infarction: episode of care unspecified	I22	Subsequent myocardial infarction
410.x1	Acute myocardial infarction: initial episode of care	–	–
410.0	Acute myocardial infarction of anterolateral wall	–	–
410.1	Acute myocardial infarction of other anterior wall	–	–
410.2	Acute myocardial infarction of inferolateral wall	–	–
410.3	Acute myocardial infarction of inferoposterior wall	–	–
410.4	Acute myocardial infarction of other inferior wall	–	–
410.5	Acute myocardial infarction of other lateral wall	–	–
410.6	True posterior wall infarction	–	–
410.7	Subendocardial infarction	–	–
410.8	Acute myocardial infarction of other specified sites (infarction of atrium, papillary muscle, septum alone)	–	–
410.9	Acute myocardial infarction: unspecified site	–	–
411	Other acute and subacute forms of ischemic heart disease	–	–
412	Old myocardial infarction	–	–
413	Angina pectoris	–	–
414	Other forms of chronic ischemic heart disease	–	–
427.4	Ventricular fibrillation and flutter	–	–
427.5	Cardiac arrest	–	–

Table 2: Validation Studies and Results until July 2010

Author	Country	N	Year of Data Collection	Administrative Database	Gold Standard	ICD Code*	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Austin, Daly, and Tu (2002)	Canada	58,816	Jan 1996–Mar 2000	Hospital discharge	Registry data	410	MRD: 88.8 Any: 92.8	MRD: 92.8 Any: 89.2	MRD: 88.5 Any: 84.2	
Beaglehole, Stewart, and Walker (1987)	New Zealand	858	1983	Hospital discharge	Registry data	410 410–414	86.0 95.1	– –	67.1 25.6†	– –
Boyle and Dobson (1995)	Australia	5,283	Aug 1986–Dec 1991	Hospital discharge	Registry data	410	78.9	–	65.6	–
Dobson et al. (1988)	Australia	2,947	1979, 1984–1985	Hospital discharge	Registry data	410 410–414	84.8 (1979) 84.8 (1984) 78.6 (1979) 91.6 (1984)	– –	79.3 (1979) 70.2 (1984) 67.9 (1979) 42.7 (1984)	– –
Ellerbeck et al. (1995)	USA	14,108	June 1992–Feb 1993	Hospital discharge	Chart review	410	–	–	87.4	–
Fisher et al. (1992)	USA	Any: 271 Principle: 204	Oct 1984–Mar 1985	Hospital discharge	Chart review	410	Any diagnostic field: 90.0 Primary diagnostic field: 94.0	–	Any diagnostic field: 87.0 Primary diagnostic field: 92.0	–
Hammar et al. (2001)	Sweden	713	1987–1995	Hospital discharge	Chart review	410	94.0	–	86.0	–
Heckbert et al. (2004)	USA	1,042	Jan 1994–Nov 2000	Hospital discharge	Chart review	410, 427.4, 427.5	80.0	99.4†	77.7	99.5†

continued

Table 2. *Continued*

Author	Country	N	Year of Data Collection	Administrative Database	Gold Standard	ICD Code*	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Kennedy, Stern, and Crawford (1984)	USA	20,386	12-month period before 1984	Hospital discharge	Registry data	410	94.3	99.8	60.9	100.0
Kiyota et al. (2004)	USA	2,022	1999, 2000	Hospital discharge	Chart review	410.x0 410.x1	–	–	Any diagnostic field: 94.1 Primary diagnostic field: 95.1	–
Levy et al. (1999)	Canada	234	1994	Hospital discharge	Chart review	410	–	–	96.0	–
Lindblad et al. (1993)	Sweden	432	1977–1987	Hospital admissions	Chart review	410–411	–	–	91.4[†]	–
Mahonen et al. (1997)	Finland	397	1983–1990	Hospital discharge	Registry data	410	Men: 86.0 Women: 81.3	–	Men: 85.9 Women: 80.7	–
						410–411	Men: 79.6 Women: 73.9	–	Men: 84.8 Women: 79.0	–
Mascioli, Jacobs, and Kottke (1989)	USA	1,845	Jan–June 1979	Hospital discharge	Chart review	410–411	84.7	92.8	94.6	–
						412–414	–	–	18.8	–
McAlpine et al. (1998)	Scotland	154	Oct 1993–Oct 1995	Hospital discharge	Chart review	410	67.0	100.0	100.0	–
						411	5.6	99.0	50.0	–
						413	5.6	94.0	9.1	–
						414	5.6	86.0	4.5	–

continued

Table 2. *Continued*

Author	Country	N	Year of Data Collection	Administrative Database	Gold Standard	ICD Code*	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Merry et al. (2009)	The Netherlands	21,110	1987–1997	Hospital discharge	Registry data	410	84.0	-	97.0	–
Newton et al. (1999)	USA	121	Jan 1992–Mar 1996	Hospital data	Chart review	410, 427.4, 427.5	94.4	86.4	56.8	–
Nova Scotia-Saskatchewan Cardiovascular Disease Epidemiology Group (1992)	Canada	410: 1,810 411–414: 1,059	1977–1985	Hospital discharge	Chart review	410 411–414	– –	– –	85.5† 7.1†	– –
Pajunen et al. (2005)	Finland	37,062 CHD events	1988–2002	Hospital discharge	Chart review	410, I21, I22	83.0	–	90.0	–
Palomaki et al. (1994)	Finland	1,565	1987–1990	Hospital discharge	Registry data	410.0 410.0–410.9 410, 411	88.7† 72.3† 71.0†	93.8† 90.6† 74.9†	86.4† 92.0† 89.6†	92.4† 68.8† 45.8†
Petersen et al. (1999)	USA	4,565	Jan 1994–Sep 1995	Hospital discharge	Chart review	410	–	–	96.9	–
Pladevall et al. (1996)	USA	734	May 1988–Apr 1990	Hospital discharge	Registry data	410 410–411	80.9 86.5	93.1 80.2	54.6 31.0	97.9 98.3
Rosamond et al. (2004)	USA	17,900	1987–2000	Hospital Discharge	Chart review	410	Men: 69.0 Women: 66.0	–	Men: 58.0 Women: 52.0	–
Ryu et al. (2000)	Korea	258	1993–1997	Hospital discharge	Chart review	410	–	–	76.0	–

continued

Table 2. *Continued*

Author	Country	N	Year of Data Collection	Administrative Database	Gold Standard	ICD Code*	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Varas-Lorenzo et al. (2008)	Canada	ICD-9 code 410:193 ICD-9 code 411:763	Nov 1999–Dec 2001	Hospital discharge	Chart review	410 411	– –	– –	94.8[†] 8.7[†]	– –
Yeh et al. (2010)	USA	640	1999–2007	Hospital discharge	Chart review	410.x0, 410.x1	–	–	96.7	–

*All are ICD-9 codes except for I21 and I22, which are ICD-10 codes.
[†]Derived values.
AMI, acute myocardial infarction; CHD, coronary heart disease; MRD, most responsible diagnosis; NPV, negative predictive value; PPV, positive predictive value.

Literature Review of Case Definitions Used in AMI Studies

Sixty-three articles were identified, including eight studies from Canada, six from Denmark, one from Italy, two from the Netherlands, one from New Zealand, two from Scotland, two from Sweden, one from the United Kingdom, and forty-one from the United States. Fifty-three studies used ICD-9 coding, all of which used some variation in ICD-9 code 410 to identify cases of AMI (see Table 3). Fifteen studies used ICD-10 codes, all of which used some variation in ICD-10 code I21 to identify cases of AMI (see Table 3).

Validating AMI Case Definitions in Dually Coded ICD-9-CM and ICD-10 Hospital Discharge Data

Of the 4,008 charts reviewed, 169 indicated that the patient had AMI resulting in a prevalence of 4.2 percent. All previously validated case definitions had specificity values of at least 99 percent and NPV 86 percent or above; however, sensitivity ranged from 20.9 percent (ICD-9 411) to 84.0 percent (ICD 9 410.x0, 410.x1) and PPV ranged from 13.6 percent (ICD-9 411) to 97.6 percent (ICD 9 410–414) (see Table 4). Use of either ICD-9 410 or ICD-10 I21–I22 resulted in similar validity.

AMI Case Volume and In-Hospital Mortality in Hospital Discharge Data

The eight previously validated case definitions were applied to hospital discharge abstract data (n = 94,937 for ICD-9-CM, 2001/2002 and n = 118,839 for ICD-10, 2006/2007) to assess their impact on number of AMI cases and in-hospital mortality (Table 5). The ICD-9 code combination 410–414 identified the greatest number of AMI cases in any diagnostic field (n = 14,645) and in the primary diagnostic field (n = 3,581). The ICD-9 code 410, the most commonly validated AMI code in the literature, identified 1,958 cases using all diagnostic fields and 1,488 cases using only the primary diagnostic field. In-hospital mortality from validated case definitions ranged from 0 percent (ICD-9 411 used in isolation and found in either the primary diagnostic field or any diagnostic field) to 10.3 percent (ICD-9 410.0 used in isolation and found in the primary diagnostic field). The mortality was 6.1 percent (n = 91 deaths) among AMI cases identified using ICD-9 code 410 on the primary diagnosis coding field, and 6.6 percent (n = 129 deaths) among AMI cases using ICD-9 code 410 in any diagnostic coding fields.

Table 3: Case Definitions of Acute Myocardial Infarction Commonly Used in the Literature (2007–2012)

Author	*Country*	*Study Years*	*ICD-9 Case Definition*	*ICD-10 Case Definition*
Agyemang et al. (2009)	The Netherlands	1995	410	
Berger et al. (2008)	USA	2001	410	
Brown, Xie, and Mensah (2007)	USA	2003–2004	410	
Buch et al. (2007)	Denmark	1994–2002		I21, I22
Chan et al. (2008)	New Zealand	1993–2005	410	I21
Chen et al. (2010)	USA	2002–2007	410.x0, 410.x1	
Curtis et al. (2009)	USA	2005	410.x0, 410.x1	
Dudas et al. (2011)	Sweden	1991–2006	410	I21
Ezekowitz et al. (2009)	Canada	1994–2005	410	
Fazel et al. (2009)	USA	2000–2006	410.x1	
Friberg et al. (2009)	Sweden	2002		I21
Garg et al. (2008)	USA	2003–2004	410.x1	
Habel et al. (2011)	USA	1986–2005	410	I21, I22
Hammill et al. (2009)	USA	1999–2006	410.x1	
Ho et al. (2008)	USA	2003–2005	410	
Hvelplund et al. (2010)	Denmark	2005–2007		I21, I22
Jackevicius, Li, and Tu (2008)	Canada	1999–2001	410	
Jensen et al. (2010)	Denmark	2002–2005		I21
Joynt et al. (2011a)	USA	2009	410.x0, 410.x1	
Joynt, Orav, and Jha (2011b)	USA	2006–2009	410.x0, 410.x1	
Khan et al. (2010)	Canada	1994–2003	410	
King, Khan, and Quan (2009)	Canada	2002–2006		I21, I22
Ko et al. (2007)	Canada and USA	1998–1999	410	
Ko et al. (2008)	USA	1998–2001	410	
Kosiborod et al. (2008)	USA	2000–2005	410.x0, 410.x1	
Kosiborod et al. (2009)	USA	2000–2005	410.x0, 410.x1	
Kostis et al. (2007)	USA	1987–2005	410	
Krumholz et al. (2009)	USA	1995–2006	410.x0, 410.x1	
Kulik et al. (2010)	USA	1995–2004	410.x1, 411	
Lambert et al. (2010)	Canada	2006–2007	410	
Lipscombe et al. (2007)	Canada	2002–2005	I21, I24, I25.4	
Mauri et al. (2008)	USA	2003–2004	410.x1	
Mazzini et al. (2008)	USA	2002–2003	410	
McAlister et al. (2008)	Canada	1994–2000	410	
McNamara et al. (2007)	USA	1999–2002	410.x1	
Mehta et al. (2010)	USA	Not stated	410	
Mehta et al. (2008)	USA	2000–2008	410	

continued

Table 3. *Continued*

Author	*Country*	*Study Years*	*ICD-9 Case Definition*	*ICD-10 Case Definition*
Movahed et al. (2009)	USA	1998–2004	410.01, 410.11, 410.21, 410.31, 410.41, 410.51, 410.61, 410.81	
Nallamothu et al. (2007a)	USA	2003	410.x0, 410.x1	
Nallamothu et al. (2007b)	USA	2002–2005	410.x1	
Pearte et al. (2008)	USA	1987–2001	402, 410–414, 427, 428, 518.4	
Popescu, Cram, and Vaughan-Sarrazin (2011)	USA	2005	410	
Popescu, Vaughan-Sarrazin, and Rosenthal (2007)	USA	2000–2005	410	
Roger et al. (2010)	USA	1987–2006	410	
Ross et al. (2010)	USA	2004–2006	410.x0, 410.x1	
Saia et al. (2009)	Italy	2002, 2004	410	
Schjerning Olsen et al. (2011)	Denmark	1997–2006		I21, I22
Sekhri et al. (2007)	United Kingdom	2003–2005		I21–I23
Setoguchi et al. (2007)	USA	1995–2004	410	
Setoguchi et al. (2008a)	USA	1995–2004	410	
Setoguchi et al. (2008b)	USA	1999–2000	410	
Shen and Hsia (2011)	USA	2000–2006	410.x0, 410.x1	
Shreibati, Baker, and Hlatky (2011)	USA	2005–2008	410.x	
Sorensen et al. (2011)	Denmark	2002–2008		I21, I22
Sorensen et al. (2009)	Denmark	2000–2005		I21, I22
Suaya et al. (2007)	USA	1997	410	
Taylor et al. (2008)	Scotland	1996–2000	410	I21, I22
Towfighi, Markovic, and Ovbiagele (2011)	USA	1997–2006	410.x0, 410.x1	
van der Elst et al. (2007)	The Netherlands	1991–2000	410	
Volpp et al. (2007a)	USA	2000–2005	410.00–410.19, 410.20–410.69, 410.7x, 410.80–410.99	
Volpp et al. (2007b)	USA	2000–2005	410.00–410.19, 410.20–410.69, 410.7x, 410.80–410.99	
Wei et al. (2008)	Scotland	1994–2003	410	I21
Yeh et al. (2010)	USA	1999–2008	410.x0, 410.x1	

Table 4: Validation of International Disease Classification (ICD) Hospital Discharge Abstract Data Based on Chart Review Data for Acute Myocardial Infarction

Case Definition	*Sensitivity (%)*	*Specificity (%)*	*Positive Predictive Value (%)*	*Negative Predictive Value (%)*
ICD-9-CM				
410	83.3	99.2	82.8	99.3
410.x0, 410.x1	84.0	99.2	81.1	99.3
410, 411	56.5	99.4	87.0	97.1
410–414	24.2	99.9	97.6	86.5
410, 427.4, 427.5	73.1	99.3	83.4	98.6
411	20.9	96.3	13.6	97.7
411–414	22.7	99.4	87.6	86.8
ICD-10				
I21, I22	81.8	99.2	82.2	99.2

Some component parts of various case definitions identified few cases, but they had very high mortality rates. For example, when used in the primary position, the ICD-9 code 427.5 (cardiac arrest) identified nine hospitalized patients, but it was associated with a mortality rate of 66.7 percent; the mortality rate for this code dropped to 19.2 percent when found in any diagnostic coding field. In other instances, specific codes contributed very little to case definitions. For example, the validated case definition ICD-10 I21 or I22 identified 1,425 admissions when either code was found in the primarily position, and 2,450 admissions when either code was found in any diagnostic coding field; however, the ICD-10 code I22 only identified three admissions if it was coded in the primary diagnostic coding field and seven admissions if it was coded in any diagnostic coding field and no deaths (regardless of coding field).

DISCUSSION

Through a systematic review of the literature, this study identified eight validated AMI case definitions using hospital discharge abstract data. These validated case definitions had varying ranges of validity. Based on reported values for sensitivity, specificity, PPV, and NPV, it appears that the three-digit ICD-9 code 410 (acute myocardial infarction) used in isolation had the highest validity. When these eight case definitions were validated in one dataset, ICD-9 410 still had high validity. Although a substantial amount of heterogeneity was noted in the content of case definitions, which is reflected in the variability of

Table 5: Acute Myocardial Infarction (AMI) Case Volume and In-Hospital Deaths by Case Definition

ICD Codes		*AMI Defined Using Primary Diagnosis (A)*	*Number of Death (B)*	*Death Rate (A/B%)*	*AMI Defined Using Primary and Secondary Diagnosis (C)*	*Number of Death (D)*	*Death Rate (C/D%)*
Year 2001/2002 (ICD-9-CM)							
	410	1,488	91	6.1	1,958	129	6.6
ICD-9-CM case definitions	410.x0, 410,x1	1,477	91	7.0	1,855	129	7.0
	410, 411	1,621	91	5.6	3,352	129	3.8
	410–414	3,581	111	3.1	14,645	219	1.5
	410, 427.4, 427.5	1,515	100	6.6	2,322	143	6.2
	411	130	0	0.0	1,306	0	0.0
	411–414	1,961	20	1.0	11,974	88	0.7
Relative contribution of each code to ICD-9-CM case definitions	410.x0	11	2	18.2	17	2	11.8
	410.x1	1,466	89	6.1	1,838	127	6.9
	410.0	68	7	10.3	75	7	9.3
	410.1	249	23	9.2	303	24	7.9
	410.2	57	7	12.3	65	7	10.8
	410.3	65	3	4.6	77	3	3.9
	410.4	285	8	2.8	331	14	4.2
	410.5	26	1	3.8	41	2	4.8
	410.6	7	0	0.0	12	0	0.0
	410.7	566	19	3.4	744	29	3.9
	410.8	14	3	21.4	26	3	11.5
	410.9	53	14	26.4	167	33	19.8
	412	0	0	0.0	2,637	9	0.3
	413	76	0	0.0	1,271	3	0.2
	414	1,755	20	1.1	6,760	76	1.1
	427.4	17	3	17.6	119	0	0.0
	427.5	9	6	66.7	224	43	19.2
Year 2006/2007 (ICD-10)							
ICD-10 case definition	I21, I22	1,425	94	6.6	2,450	186	7.6
Relative contribution of each code to ICD-10 case definition	I21	1,422	94	6.6	2,443	186	7.6
	I22	3	0	0.0	7	0	0.0

their performance characteristics, there is a substantial amount of agreement with regard to case definitions that are used in the published literature. An examination of ICD-9 and ICD-10 codes used in the published literature revealed very few differences in the codes used—all studies that used ICD-9 used some variation in code 410, while all studies that used ICD-10 used some variation in ICD-10 code I21, thus allowing for meaningful comparisons across studies. However, as more countries transition from ICD-9 to ICD-10, the ICD-10-based case definitions for AMI codes should be validated.

While the reasoning for the variation in reported values of sensitivity and specificity for the same case definition is unclear, it could be due to the underlying definition of AMI. Many studies included ICD-9 code 411 (other acute and subacute forms of ischemic heart disease) in their definition. As this code is not the correct assignment of true AMI cases, its inclusion reduces the specificity of the case definition. Inclusion of ICD-9 codes 412 (old myocardial infarction) and 413 (angina pectoris) in the case definition further reduces the specificity of a case definition that aims to identify cases of *acute* myocardial infarction as it mixes symptoms with disease and includes conditions that are clinically distinct from AMI. Limiting the administrative data case definition to codes found in the primary diagnostic coding field can also impact the sensitivity and specificity of reported definitions as codes in this position merely represent the main reason for hospitalization or resource consumption, but they cannot capture all health events that occurred in hospital or that motivated hospital admission. Searching secondary code positions for codes of interest will increase the sensitivity of a case definition. The heterogeneity in the codes used to identify AMI may also reflect underlying clinical uncertainty in the definition of AMI. Multiple clinical diagnostics such as imaging, biochemistry, electrocardiography, and pathology are used to clinically establish whether a patient experienced an AMI (Thygesen et al. 2007). As the science of each of these fields has advanced, clinicians have been able to more accurately diagnosis AMI events; this is particularly true for biochemistry, as the rapid introduction of new biomarkers in recent years, such as the introduction of troponin as a biochemical marker of AMI, has increased the clinical sensitivity and specificity of AMI diagnoses (Thygesen et al. 2007). While changing clinical definitions of AMI are not currently reflected in ICD codes, any clinical changes that improve the accuracy of AMI diagnoses will impact the incidence and prevalence of this condition when studied using administrative data.

Differences in the predictive ability of case definitions could also be related to the gold standard used to confirm the AMI diagnosis and the population studied. Studies have shown that accepting the diagnosis coded in the chart at face value is not always valid (Iezzoni et al. 1988; Hennessy et al. 2010). The use of clinical parameters in the chart to assess for the presence or absence of AMI instead of accepting the diagnosis as written in the chart likely increases the sensitivity of the case definition. In addition, the source population captured by the gold standard will influence the predictive ability of case definitions. Patient registries will typically capture a different population than that identified by general medical record review as registries tend to focus on higher risk populations, thus artificially increasing the sensitivity of a case definition as only the sickest individuals are captured in the reference standard. The reporting of PPV, in addition to sensitivity, can help overcome this limitation.

Also of note is the variation in health care systems across countries with regard to coder variation (trained health coders vs. physician coders) (Hennessy et al. 2010), the number of secondary diagnoses allowed (World Health Organization 2010), and country-specific modifications to ICD coding manuals (Jette et al. 2010; World Health Organization 2010); all of these factors may impact the validity of case definitions.

This study draws to light the differences in reporting practices for validation studies and indicates the need for reporting guidelines for this body of literature to enhance comparability between studies. This study also calls into question what values of sensitivity and specificity are required to call a case definition "validated". While sensitivity and specificity values of greater than 80 percent are considered excellent, sensitivity values as low as 66 percent for AMI are found in the literature (Rosamond et al. 2004). While a specificity value below 80 percent was only found in one study included in the review (Palomaki et al. 1994), only eight (Kennedy, Stern, and Crawford 1984; Mascioli, Jacobs, and Kottke 1989; Palomaki et al. 1994; Pladevall et al. 1996; McAlpine et al. 1998; Newton et al. 1999; Austin, Daly, and Tu 2002; Heckbert et al. 2004) of the 26 studies reported data on specificity.

While ICD-10 has been available for over 20 years (World Health Organization 2010) and its coding descriptions dramatically changed compared with ICD-9, no studies could be found that exclusively validated ICD-10 codes for AMI. ICD-10 and ICD-9 specified AMI using inconsistent duration from onset; the longer duration in ICD-9 than ICD-10 (8 weeks or less vs. 4 weeks or less) might result in more AMIs being coded in ICD-9 than ICD-10. In addition, the ICD-9 code 410 and ICD-10 code I21 (AMI) are subdivided into transmural AMI and nontransmural AMI; however, this subdivision is not defined by ST segment elevation. Although modified versions of

ICD-9-CM (Steinberg et al. 2008) and ICD-10 Canadian modification have been developed to distinguish between ST segment elevation myocardial infarction (STEMI) and non-ST segment elevation myocardial infarction (NSTEMI), not all countries make use of these modifications. The ICD-11 will specify STEMI and NSTEMI.

This study has some limitations. The literature review was limited to papers written in English only and validation studies published in the gray literature were not included. Publication bias was not specifically assessed; however, as several studies were identified with low sensitivity, specificity, positive, and negative predictive values, this is not believed to have substantially influenced the results. It is possible that individual authors selectively reported only their best case definition as opposed to all case definitions tested. As inter-country differences exist in administrative coding practices (Hennessy et al. 2010; Jette et al. 2010), it is also possible that the results generated by applying the validated case definitions to Alberta data may not be generalizable to other regions. Furthermore, as 2001–2002 was in the early phases of troponin use as a clinical biomarker of AMI, the comparison of results from 2001/02 to 2006/07 is likely to be influenced by changing clinical practices in addition to changes in administrative data coding practices.

In conclusion, a variety of case definitions for AMI using administrative data have been found in the literature, with variable validity. While reporting guidelines for validation studies have recently been released (Benchimol et al. 2011), their application is essential to ensure comparability between studies and to ensure adequate reporting of results. In addition, international consensus on what constitutes an AMI and validation of ICD-10 codes for AMI is critically needed as more countries introduce this coding framework for epidemiological and outcomes study of AMI. We recommend ICD-9-CM code 410 and ICD-10 codes I21 and I22 in the primary diagnosis coding field should be used to define AMI.

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Appendix SA1: Author Matrix.

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