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"Health Surveillance for Acute Myocardial Infarction in Canada: A Comparison of Administrative and Laboratory Data Case Definitions"

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ABSTRACT

BACKGROUND: Health surveillance for acute myocardial infarction (AMI) requires a valid methodology to detect AMI cases in order to accurately measure AMI morbidity and mortality trends.

OBJECTIVE: To determine the validity of the ICD coding for AMI in adults discharged from Calgary hospitals against a reference standard of those individuals with positive cardiac troponin T results from the laboratory database during the same time period.

METHODS: A methodological comparison of AMI definitions were used to assess and validate ICD coding. Chart review was conducted to determine recurring explanations of discordant cases. Incidence rates by definition and period were calculated.

RESULTS: Sensitivity decreased across the periods (52.8% to 48.5%:p=ns). Incidence rates were not statistically different across the periods but varied significantly within periods depending on the surveillance definition used ($p<0.0001$).

CONCLUSION: This methodological comparison of approaches to identifying individuals with AMI found validity to be sub-optimal.

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DEDICATION

In loving memory of my father, Robert P Galbraith, “the smartest man I have ever known”. I only wish we could have walked and talked and shared this experience.

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List of Abbreviations

ACC – American College of Cardiology
AHA – American Heart Association
AMI – acute myocardial infarction
CCCDS – Coordinating Committee for Community Demonstration Studies
CDC – Centre for Disease Control
CHR – Calgary Health Region
CIHI – Canadian Institute for Health Information
CLS – Calgary Laboratory Services
cTnI – cardiac troponin I
cTnT – cardiac troponin T
DAD – discharge abstract database
ESC – European Society of Cardiology
ICD-9-CM – *International Classification of Diseases*, ninth edition, Clinical Modification
ICD-10-CA - *International Classification of Diseases*, tenth edition, Canadian
IHD – ischemic heart disease
MONICA – Multinational Monitoring of Trends and Determinants in Cardiovascular Disease
NHLBI – National Heart, Lung and Blood Institute
Period 1 – January 2002 – March 2002
Period 2 – April 2002 – September 2002
Period 3 – October 2002 – March 2003
PPV – positive predictive value
WHO – World Health Organization

CHAPTER 1: INTRODUCTION

Acute myocardial infarction is the leading cardiovascular cause of morbidity and mortality in adults in North America[1-3]. The human suffering and financial burden of acute myocardial infarction (AMI) are substantial. AMI impacts the individual by altering quality of life and return to work. Families often need to be caregivers when affected individuals can no longer fulfill normal roles. Societal costs are high due to both direct costs incurred in the provision of health care services to individuals suffering AMI, and also due to lost productivity of these individuals. Cardiovascular disease, including AMI is the leading economic burden of disease in Canada with a direct cost of $6.8 billion and indirect cost (relating to mortality and disability) of $11.6 billion in 1998[4]. Statistics Canada has recently reported one-year mortality rates of 24%, increasing to 49% in the elderly[5].

The burden of this disease will, unfortunately, continue to increase as Canada's baby boomers are at the prime age for cardiac events. Our population is aging and the number of elderly persons continues to increase significantly each year[6]. As the population continues to age, it is expected that the number of individuals with heart disease will increase as age is a dominant risk factor. AMI is a major public health concern and a high priority acute disease event that clearly requires surveillance.

Despite the widespread recognition of the importance of AMI as a cause of morbidity and mortality in Canada, we continue to have only sketchy information on the true incidence of AMI, because most reports document its occurrence using administrative hospital separation data. If the data used to derive incidence estimates are inaccurate and/or incomplete, the current impression of the magnitude of the health problem posed by AMI

may be erroneous. Adding to this problem is that even in clinical trials, the criteria for defining AMI vary from study to study[7]. In 2000, consensus guidelines from the European Society of Cardiology and the American College of Cardiology were developed and have published a new definition of AMI[8] to address this issue but its use in the epidemiological characterization of AMI to date is not yet widespread.

Population-based surveillance of AMI patients is needed to provide critical information essential to assess and analyze regional differences and trends over time in the incidence of AMI. As these differences and trends can be related to risk factors, this surveillance information can facilitate development of new guidelines for AMI management and appropriate interventions can be targeted to control this disease. Complete capture of individuals with AMI is thus a crucial first step in the conduct of representative health services research and decision-making relating to AMI.

CHAPTER 2: THESIS OVERVIEW

This thesis document describes a study assessing the performance of different methodologies for identifying individuals hospitalized with acute myocardial infarction (AMI) using passive surveillance of administrative hospital discharge data relative to an approach identifying individuals with AMI according to a centralized laboratory database. The laboratory database that we used for this research contains information on cardiac troponin T (cTnT) results, and serves as a reference standard for determining the validity of administrative data definitions of AMI.

Chapter 1 is the introduction and illustrates the burden of AMI. In Chapter 3 the literature review is presented. Section 3.1 focuses on disease surveillance and reviews the history in the development of surveillance, its definition, the uses of disease surveillance systems as well as the difference between surveillance and research. Section 3.2 reviews administrative discharge data and the *International Classification of Diseases* used to define the target codes for AMI. Earlier studies have questioned the validity of administrative data but the advantages of large sample size and low cost are attractive. Section 3.3 reviews biomarkers and the evolution to cardiac troponins. Cardiac troponin T became incorporated into routine clinical practice for patients presenting with chest pain in the Calgary Health Region in late September 2001. This thereby offered a unique opportunity to identify individuals with elevated cTnT.

Study objectives and hypotheses are explicitly stated in Chapter 4, and followed by a description of study methodology in Chapter 5. Study results are then presented for an initial period of study (January – March 2002) in Chapter 6, with presentation of the

sensitivity and positive predictive value (PPV) of administrative data definitions of AMI against the reference standard of cTnT. Descriptions of patient profiles, burden of illness, length of stay, and mortality rates are also provided in that chapter, along with a comparison of AMI incidence estimates according to four different AMI surveillance definitions that use one or both of administrative discharge data and/or laboratory data. The four definitions assessed are: 1) positive AMI-coding, 2) positive cTnT, 3) positive cTnT *and* positive AMI-coding 4) positive cTnT *or* positive AMI-coding.

Chapter 7 details the sensitivity and PPV for Periods 2 (April – September 2002) and Period 3 (October 2002 – March 2003). The description of patient profiles and burden of illness are compared over the 3 periods. Incidence calculations using the 4 different surveillance definitions are compared between the 3 periods. The rationale for studying three separate time periods is that the first period studied (described in Chapter 6) involved administrative data coding in the older 9th revision of the *International Classification of Diseases*, Clinical Modification (ICD-9-CM). Period 2 is a very early period after the switch to the 10th version of the *International Classification of Diseases* (ICD-10), and permits an early assessment of whether the sensitivity and positive predictive value of administrative data were better (or worse) in ICD-10 relative to ICD-9-CM. A later period (period 3) was also assessed, as it was recognized that there may be an early coding 'learning curve', during which the performance of administrative data may be suboptimal. Period 3 therefore allowed us to assess whether the capture of AMI cases changed over time, as the new coding system was implemented.

The final chapter is a discussion of study results and their implications. This section demonstrates that the findings of this research provide important information relating to: 1) the sensitivity and positive predictive value of administrative hospital discharge data coded in ICD-9-CM and ICD-10 for detection of AMI, 2) insights into the relative performance of these 2 coding systems 3) the clinical profiles of cTnT positive patients who do not have AMI coded, and 4) information on the AMI incidence estimates produced by different methodologies for disease surveillance for AMI. The latter has particularly important implications to our understanding of the global epidemiology of cardiovascular disease.

CHAPTER 3: BACKGROUND

3.1 Surveillance

The practice of surveillance dates back many years, possibly to the occurrence of the 'Black Death' in 1348 that resulted in governments appointing public health workers to detect and exclude ships that had infected persons aboard[(9)]. Years later, in the late 1600s, the parish Clerk of the Halls in London were given the responsibility of compiling and interpreting the statistics of death from burials to provide information of the extent of the plague and then this information was then disseminated in the Bills of Mortality. John Graunt was the first to quantify patterns of disease with some fundamental principles of surveillance by estimating the population of London and counting the number of births as well as deaths and cause of death. In the next century, Achenwall introduced the term 'statistics' in referring to surveillance data and during the next several decades 'vital statistics' became widespread in Europe. However, it was not until 1839-79, that William Farr, as superintendent of the statistical department of the Registrar's office of England and Wales, collected, assembled and evaluated more complete vital statistics[(10)]. These statistics in turn were reported to the health authorities and general public. He is therefore recognized as the founder of the modern concepts of surveillance. The term "surveillance" was restricted to infectious or communicable diseases until the 1950s, and at that time actually referred to close observation of exposed persons with the goal of prompt isolation and treatment.

The current concept of monitoring both infectious and non-infectious disease occurrence in populations was promoted by Dr. Alexander D. Langmuir in 1963 who defined disease surveillance as the:

> "continued watchfulness over the distribution and trends of incidence through the systematic collection, consolidation, evaluation of morbidity and mortality reports and other relevant data and regular dissemination of data to all who need to know." (11)

In 1968, the 21st World Health Assembly established that surveillance was an essential function of public health practice and identified the main features of surveillance that are still in use today: 1) the systematic collection of pertinent data; 2) the orderly consolidation and evaluation of these data; 3) the prompt dissemination of the results to those who need to know, particularly those who are in a position to take action.(9)

In 1976, the broadening of the definition of surveillance was demonstrated as manuscripts relating to a variety of surveillance activities including smallpox, TB, vaccinations, child growth, cancer and heart disease were published in a special issue of the *International Journal of Epidemiology*(12).

Dr. Langmuir was the chief epidemiologist at the Centre for Disease Control (CDC) and Prevention in the US for more than 20 years and made pivotal contributions to surveillance worldwide. In 1986, the CDC defined epidemiological surveillance as the:

> "ongoing systematic collection, analysis, and interpretation of health data essential to planning, implementation and evaluation of public health practice, closely integrated

with the timely dissemination of these data to those who need to know. The final link in the surveillance chain is the application of these data to prevention and control"[13].

Dr. Langmuir promoted the concept of surveillance and notably stated that good surveillance does not necessarily ensure the making of right decisions, but it reduces the chances of wrong ones[14].

Today, information from surveillance systems are used to assess health status and estimate the burden of disease or health problem/event, determine the geographic distribution of the disease/event, monitor changes in disease occurrence, portray the natural history of disease, detect outbreaks and epidemics, define health priorities and facilitate planning. Additionally, information from surveillance systems can generate hypotheses and stimulate research.

There are numerous characteristics of a surveillance system including: 1) acceptability by the stakeholders, 2) simplicity of compilation of data (ie large sample size and low cost), 3) flexibility and ability to respond to the changing information need, 4) optimal data quality, 5) positive predictive value, 6) sensitivity, 7) representativeness – accurately portrays the incidence, 8) ability to provide data that is timely enough to be acted upon, and 9) reliability, stability and compliance.

Furthermore, case definitions used in the surveillance systems must be clear and evolve over time. As our understanding of a disease and its associated laboratory testing improves, alterations in case definitions can lead to changes in sensitivity and specificity.

The ultimate goal for an 'ideal' surveillance program is to attain 100% sensitivity and specificity, (i.e., to correctly identify all disease cases and all non-diseased cases). However,

few if any perfect disease surveillance systems exists so tradeoffs must be made. Accordingly, the process of epidemiologic surveillance strives for timely access to information, with highest possible sensitivity and positive predictive value for priority health events, such as AMI.

The need for quality cardiac surveillance systems in Canada has been identified by Health Canada and a number of consensus groups[3;15]. Despite major advances in diagnosis and management, cardiovascular disease (CVD) is still the leading cause of death for both men and women in Canada and is a major public health problem. There is a growing burden of CVD and this will only be amplified by the aging of the population. As a result, CVD is clearly a high priority health event in need of surveillance.

Additionally, there are significant provincial and health region level differences in CVD morbidity and mortality in Canada[16;17]. Tu et al. recently published age- and sex-standardized in-hospital mortality rates post-AMI in Canada and showed a variance from 10.5% in Prince Edward Island to a high of 13.1% in Quebec[18]. One of the limitations of prior work, however, is that there is variation in the data quality of various provincial databases. These authors notably state that it is hoped that this study serves as a reminder of the importance and value of developing and refining national standards.

Surveillance drives the cycle for public health prevention by providing information for action. Surveillance provides information that is contemporary, timely, and for which there is ongoing and repetitive reporting, so that there is an increased probability of there being a link between surveillance and action.

Relationship of Surveillance to Research

It is important to understand the relationship between 'surveillance' and 'research'. The preceding description and definitions highlight the characteristics of surveillance systems, most notably that they are ongoing and timely. This is in contrast to research, which often occurs at a slower pace, without measures in place to provide ongoing and repetitive reporting of information. Surveillance activities aim to be practical and simple whereas research may be very expensive and complex particularly if large numbers are involved. Surveillance focuses on timeliness whereas research more typically focuses on accuracy and is the firm basis for statistical hypothesis testing.

Both surveillance and research safeguard the privacy of the individual and require adherence to relevant privacy laws and policy. Research requires approval from the Institutional Ethics Review Board while surveillance activities usually do not. Last defines research as a "class of activities to develop or contribute to generalizable knowledge; generalizable knowledge consist of theories, principles, or relationships or the accumulation of information on which these are based, that can be corroborated by acceptable scientific methods of observation, inference, and/or experiment."[19] Although generating data to monitor trends or to suggest research hypotheses is also an important purpose of surveillance, it is usually not the primary purpose. On the other hand, the main purpose of disease surveillance is to gather information that can help public health officials develop interventions to prevent and control disease. Nevertheless, the information generated by disease surveillance activities can identify regional "hot spots" and can lead to targeted research in these areas with aggressive heart health promotion and risk factor modification.

It is difficult or impossible for research to test an intervention that is already widely used whereas information gathered from surveillance activities can inform patients, physicians and policy-makers of the scope and impact and burden of the disease and thereby lead to public health programs that can in turn improve the health of the community.

Both surveillance and research involve data collection, integration, analysis and interpretation. However, they deliver different products. Surveillance typically is based on the dimensions of person, place and time and generates counts and rates that are formulated into reports whereas research typically is reported through manuscripts published in peer-reviewed journals.

Research and surveillance, while distinct, are also highly complementary. Results from surveillance activities help to prioritize and facilitate further research. Surveillance is ongoing and delivers information on the magnitude of the problem and the geographic distribution patterns. This in turn stimulates research. Research, meanwhile, can pick up on important surveillance findings to explore 'what would happen if' and delivers explanations for the questions arising from surveillance. Research is a structured process that proceeds in a systematic way to delineate a general strategy for gathering, analyzing and interpreting data to answer a question. These findings contribute to generalizable knowledge.

Given the uncertainty on optimal methodologies for surveillance, there is a strong need for research into surveillance methodologies. In that regard, this thesis research demonstrates yet another example of how research and surveillance are complementary, and in fact inter-related. This study focuses on AMI and contributes to generalizable knowledge in the establishment of optimal definitions and a framework for future AMI surveillance

initiatives that have the potential to be widely and officially applied in Canada, and internationally.

3.2 Administrative Data and the International Classification of Diseases.

The development of the 'International Classification of Diseases' (ICD) has been previously described[20] and has a history dating back to 1858 when the first International Statistical Congress requested an internationally applicable uniform nomenclature for causes of death. The ninth edition was issued in 1977 and was published in 1978 to be a worldwide source of taxonomy and with an extension developed in the US, called Clinical Modification (CM) to meet the following objectives: 1) to serve as a useful tool in the area of classification of morbidity data for indexing of medical records, medical care review, and ambulatory and other medical care programs as well as for basic statistics, and 2) to describe the clinical picture of the patient, the codes must be more precise than those needed for statistical grouping and trend analysis.[21]

In 1978, the Bethesda Conference on the decline of coronary heart disease mortality showed that better data were needed from more countries to explain changing mortality rates. Several small reports used discharge codes for AMI as a convenient proxy for incidence trends and suggested that changes in both the incidence of AMI and the improved survival post-AMI probably played a role in declining mortality rates[22]. On a larger scale the World Health Organization (WHO) cardiovascular disease unit recruited experts to collaborate on this critical issue and the MONICA (Multinational Monitoring of Trends and Determinants in Cardiovascular Disease) project was initiated. The WHO-MONICA project found that across 38 populations (21 countries) the percentage of definite MI cases derived from hospital separation data (ICD-9-CM code 410) was 74% (range 35-90%)[23]. Fourteen of the populations in this project used both "active" (pursuing admissions) and "passive"

(retrospective) surveillance of AMI cases so the percentage that would be documented from passive surveillance alone was probably lower. Information on Canadian AMI was limited from WHO-MONICA project as Halifax was the only participating Canadian site. Additionally the down side of the "active" method of data collection is that it is time-consuming and expensive.

In Canada, health care providers document what happens to the patient while in hospital in the health record chart. Once the patient is discharged, standardized summary information is retrieved from the chart by health record coders into a discharge abstract. Coders follow diagnostic coding rules to complete the discharge abstract. The discharge abstract contains: 1) demographic data – date-of-birth, gender, postal code; 2) administrative data – admission date and time, discharge date and time; 3) diagnostic data. There are up to 16 diagnosis fields that identify the most responsible diagnosis for the admission and other diagnoses of the condition of the patient using ICD codes. The ICD codes are abstracted to the administrative discharge abstract database. In Canada this database is maintained by the Canadian Institute for Health Information (CIHI). CIHI was established in 1994 by the federal, provincial and territorial ministers of health in response to the need to coordinate health information. CIHI's mandate is to provide accurate and timely information that is needed to establish sound health care policy and to effectively manage Canada's health care system[24]. Discharge abstracts are sent directly to CIHI from the hospitals throughout the year and CIHI receives approximately 4.3 million records annually. Currently about 75% of all hospital discharges are submitted directly to CIHI and are included in the discharge

abstract database(DAD)[25]. Unfortunately, at this time Quebec and Manitoba do not use this database, making provincial comparisons difficult.

Historically, health services researchers and epidemiologists have used the passive pursuit method of screening the discharge abstract for ICD-9-CM codes for the diagnosis of AMI. Unfortunately, early studies reported error rates in AMI coding ranging from 18 to 43%[26], leading many to question the validity of administrative data. Some studies have also suggested that there is a high false positive rate in coding AMI in administrative hospital discharge data[27-31]. In Canada, Cox et al found that 12% of coded AMIs in administrative data were actually false positives and suggested that administrative coding combined with a user-friendly checklist would improve the accuracy of Canadian hospital records[32]. However, adding more work to an already tight time-line for record coding may not be feasible on a large scale.

Coding accuracy is affected by diagnosis definitions, interpretation of the codes and coding practices that may vary across hospitals and regions. For example, in instances where the physician writes “rule-out MI”, this is sometimes subsequently coded as AMI[29]. When physician diagnoses of AMI are compared with registries or when the evidence in the medical chart was reviewed, 9-34% of patients were incorrectly diagnosed[33]. This may arise occasionally when the diagnosis is made solely on the basis of clinical features and not definitive lab values. There are also problems with the fifth digit sub-classification (ICD-9-CM code 410.xx) that designates the first episode of care and may lead to miscoding[34]. This miscoding of multiple AMI’s yields false positives.

The tenth revision of ICD (ICD-10) system was introduced in 1992 as an enhancement to ICD-9-CM[35]. The new ICD-10 system has more codes and is more comprehensive than ICD-9[36;37]. Specifically for AMI, attempts have been made to improve inconsistencies by shortening the latitude in the timeframe of the AMI from 8 to 4 weeks and by denoting a specific code (I22) for subsequent MI-related care. The Canadian ICD-10-CA system is being implemented in an attempt to keep up with medical advancements and establish national standards[38]. This system has been in place in Alberta since April 2002 and currently, all provinces use this new system of coding. The ICD-10-CA modification has added more levels of codes but maintains the same definitions for MI as the ICD-10 used in other countries, allowing for international comparability of AMI statistics across studies.

There is recent data from Japan that reported sensitivity, positive predictive value, specificity and negative predictive value for ischemic heart disease (IHD) as the cause of death using ICD-10 coding and the MONICA criteria as the reference standard[39]. Sensitivity, PPV and specificity for IHD certified as the cause of death were 86.5% (95% Cl:77.6-92.3), 50.3% (42.5-58.1), and 64.7% (58.1-70.7), respectively. Multivariate logistic models revealed out-of-hospital deaths and being aged 25-54 years to be significant predictors of false positive cases and resulted in decreased PPV and specificity percentages.

Administrative data also provides the codes for patient clinical characteristics and co-morbidities. There are two widely used co-morbidity measurement tools developed by Charlson et al.[40] and Elixhauser et al.[41]. These tools measure burden of disease using administrative data. Deyo developed ICD-9-CM coding algorithms for the 17 Charlson defined co-morbidities[42]. Elixhauser et al defined 30 co-morbidities using distinctive ICD-9-

CM codes. Southern et al recently reported a head to head comparison of the Charlson/Deyo and Elixhauser co-morbidity measurement methods using ICD-9-CM codes[43]. In this Canadian AMI cohort the Elixhauser method performed better in predicting in-hospital mortality than the Charlson/Deyo method. Quan conducted a multi-step process to develop ICD-10 coding algorithms using a consensual approach among international coding experts and research leaders. During this process Charlson and Elixhauser co-morbidities were defined and performance assessed. The new ICD-10 and the enhanced ICD-9 coding algorithms outperformed the original coding algorithms in predicting in-hospital mortality[44].

Using administrative hospital discharge data for studies of AMI patients has the advantages of large sample size, computer readable and low cost, but these advantages must be weighed against the quality of the data. Interestingly, Pine et al have suggested that adding laboratory data to administrative data can enhance the utility of administrative data and provide accurate predictions of inpatient death from AMI and reduce the misclassification that tends to arise when administrative data are used alone[45].

3.3 Cardiac Troponin T

The use of serum enzymes as a means of diagnosing AMI began many years ago. These enzymes are released into the circulation upon injury. In 1954, aspartate aminotransferase (AST) was used in the diagnosis of MI. Later lactate dehydrogenase (LD) and creatine kinase (CK) were used[46]. However, these enzymes are not specific to cardiac tissue so can be misleading in the diagnostic process. In 1975, an isoenzyme of CK, CK-MB was recognized as an acceptable and more specific test for the diagnosis of MI[47].

In 1989, it was recommended by the National Heart Lung and Blood Institute that to define AMI, either the standard CCCDS (Coordinating Committee for Community Demonstration Studies) algorithm should be used including MI pain, ECG findings and hospital discharge ICD-9 code, or that the CCCDS algorithm should be enhanced with the use of cardiac enzymes, specifically creatinine kinase (CK)[48]. In studies of disease prevalence by the World Health Organization (WHO), AMI was defined by the presence of a triad of typical characteristics including symptoms, enzymes and electrocardiogram. Although biochemical enzymes have better sensitivity and specificity than ECG, this latter definition has been problematic with frequent false positives because CK is not cardiac specific and its values rise with skeletal muscle damage. As our understanding of this disease and its associated laboratory testing has improved, a new case definition has evolved. The consensus guidelines from the European Society of Cardiology (ESC) and the American College of Cardiology (ACC) expand on earlier AMI definitions to incorporate the new generation cardiac troponin assays into the definition of AMI.

The troponin complex is located on the thin filament of the contractile apparatus. It consists of three isotopes: T, I and C. These subunits are the products of different genes and are not related to each other in protein structure. The troponin complex plays a fundamental role in transmission of intracellular calcium and troponin T, I and C are called regulatory proteins because of their functional significance[49]. Unlike troponin C, troponins I and T found in cardiac muscle can be differentiated from troponin I and T found in skeletal muscle[46]. Troponin T and I are not normally present in the blood of healthy individuals. Commercial assays have been developed for cardiac troponin T (cTnT) and cardiac troponin I (cTnI). There are discrepancies in reference values due to variation in equipment and testing methods and interpretation of research findings. Initially the specificity of cTnT was reported as less that that of cTnI due to its increase in renal disease and certain musculoskeletal disorders. However, recent advances in laboratory technology have increased the specificity for cTnT.

Controversy persists over which measurements of troponin to use, cTnT or cTnI. Currently one manufacturer holds the patent restrictions on assays for cTnT but there are at least 10 different cTnI assays. However, there appears to be less standardization for cTnI as variations in the cutoff concentration for abnormal levels of cTnI exist as well as interassay variability among the many available immunoassays[50]. Wu et al. has shown that there may be as much as a twenty-fold difference in value for a sample being tested by two different assays, as some antibodies are more reactive to one or another of the specific forms of cTnI[51]. This was one of the considerations in the Calgary Health Region's decision to select cTnT. Standardization of the assay to findings in the literature is much clearer given that

there is only the one assay. As a result, troponin T measurements are now widely used indicators of AMI in Canada and abroad.

Introduction of cardiac troponin T into routine clinical care allows for the highly accurate, sensitive and specific determination of myocardial injury[8]. The greatest progress in laboratory research has resulted from the discovery of new and more promising biochemical markers of myocardial damage. Cardiac troponins are selectively released by damaged myocardiocytes, have a specificity that has not only allowed for an improvement in the diagnosis of acute cardiac ischemic disorders, but has also enabled us to make a more reliable stratification of risk and prediction of outcomes[52].

The use of the new ESC/ACC AMI definition incorporating troponin has been shown to diagnose more AMI in comparison to the old WHO definition and importantly captures all patients who were detected as true AMIs by the previous definition, while at the same time not flagging those with non-cardiac sources of CK elevation[53;54].

Cardiac troponin T (cTnT) is a distinct protein that differs from other markers in biological function, molecular mass and cytosolic pool. It is highly accurate for determination of myocardial injury and is considered to be a "definitive" marker of AMI[52]. Previous markers have shown false positive results in people with skeletal muscle damage although the first generation assays exhibited some non-specific binding to skeletal-muscle troponin. The cTnT assays have shown consistently high sensitivity (94-100%) and specificity (93-96%)[47;55-60].

Prognostic Value of Cardiac Troponin T

In 1986, Ohman et al concluded that it is now clear that any amount of myocardial damage, as detected by cTnT, implies an impaired clinical outcome for the patient.[61] This is confirmed with findings from three meta-analyses that elevated troponins can identify patients at high risk for both short and long-term adverse outcomes.[54;62;63]

Non-ischemic Causes of Cardiac Troponin T Elevation

It is now increasingly recognized, however, that elevation of cardiac troponin levels may result from massive pulmonary embolus[64] or non-ischemic mechanisms of myocardial injury due to increased wall stress (eg. myocarditis, severe heart failure, left ventricular hypertrophy) or from trauma to the heart (eg. cardiac contusion). Additionally, troponins are elevated in 30-50% of patients with pericarditis, and this is thought to be caused by epicardial inflammation rather than myocyte necrosis.[65] Elevated troponins have also been reported in critically ill patients, in patients with hypothyroidism, and in patients with chemotherapy induced myocardial toxicity.[66;67]

Cardiac Troponin T Elevation in Patients with and without Renal Dysfunction

In the past, there has been concern that renal dysfunction may impair the prognostic value of cTnT as it is cleared by the kidney but this issue has recently been studied.[68] Increased cTnT levels are frequently observed in patients with renal insufficiency even when the suspicion of active ischemia is relatively low. Although the underlying pathophysiology is not understood, it may reflect ongoing, perhaps sub-clinical, myocardial damage. Aviles et

al demonstrated that cTnT levels predict short-term prognosis in patients with acute coronary syndromes regardless of their level of creatinine clearance using data from the Global Use of Strategies to Open Occluded Arteries in Acute Coronary Syndromes (GUSTO IV-ACS).[69] Furthermore, regardless of the presence of symptoms, elevated cTnT levels are indicative of myocardial damage and denote an increased risk of morbidity and mortality. A recent systematic review showed that cTnI had high specificity but that cTnT had only moderate specificity. However, the authors did note that this was improved with the later generation assays. Additionally, this review supports previous research that cTnT had value in predicting two-year mortality.[70]

Cardiac Troponin Levels in Patients Undergoing Procedures

Mechanical injury, such as ablation, implantable defibrillator discharges and cardioversion can all induce cardiac injury and can therefore result in elevated troponin levels.[67] It is also well recognized that cardiac markers may increase in up to a third of patients following percutaneous intervention (PCI).[71] In the majority of cases, this is of a minor degree and may be due to side branch occlusion or microembolization. However, several studies confirm that increased cardiac markers in this population are associated with adverse outcomes. Elevated troponins are also detected in about 12% of patients undergoing major vascular surgery, and peri-operative MI (detected through elevated troponins predicted a 3.75-fold increase in long term mortality.[72] For patients undergoing coronary artery bypass grafting (CABG) the diagnostic discrimination levels are not so clear, but again, the higher the biomarker value, the greater the amount of damage to the myocardium.[66]

Cardiac Troponin Assays

In the new myocardial infarction criteria, an increased troponin value is defined as a measurement exceeding the 99th percentile of a reference control group. These documents also state that the acceptable imprecision (CV – coefficient of variation) at the 99th percentile for the assay should be defined <10%. In response to this and to reduce the probability of false positive results manufacturers continue to improve precision. A third generation cTnT assay (Elecsys, Roche Diagnostics) is currently available and this assay uses a human recombinant cTnT for calibration, which substantially improves the precision and sensitivity of the test over the first-generation assays.[73;74] For AMI diagnosis, it has nearly absolute myocardial tissue specificity as well as high sensitivity. Normally, cTnT is not detectable in the blood of healthy persons and the 99th percentile of the troponin T level in a reference population is now below the lower limit of detection of 0.01 µg per milliliter.[69;75] Calgary Health Region uses the third generation cTnT assay.

Computerized Laboratory Systems

Many health systems are developing computerized laboratory data, such as troponin T measurements, indicating that these sorts of data have future potential for widespread use in disease surveillance initiatives.

Laboratory services in Calgary are centrally coordinated with a standardized protocol for cTnT testing using the third generation cTnT assay, with regular compilation of cTnT measurements into a computerized database. This compilation of standardized laboratory data therefore allowed an opportunity to identify individuals from all hospitals in Calgary who have undergone cTnT testing.

CHAPTER 4: OBJECTIVES and HYPOTHESES

4.1 SPECIFIC OBJECTIVES:

A. To determine the sensitivity and PPV of the old ICD-9-CM coding for AMI (410.xx) in adult inpatients discharged from hospitals within the Calgary Health Region (CHR) between January 2002 and March 2002 against a reference standard of those individuals with positive cardiac troponin T (cTnT) results from the Calgary Laboratory Services (CLS) database during the same time period.

B. To determine the sensitivity and PPV of the new ICD-10-CA coding for AMI (I21.x) in adult inpatients discharged from hospitals within the CHR between April and September 2002 against a reference standard of those individuals with positive cTnT results from the CLS database during the same time period.

C. To replicate 'B' using data from a more recent 6 month period (October 2002 to March 2003).

D. To describe the clinical and demographic characteristics, as well as length of hospital stay and in-hospital mortality rates between the groups identified from the above objectives (ICD-9-CM AMI coded versus cTnT positive; ICD-10-CA AMI coded versus cTnT positive).

E. To conduct a chart review to describe the clinical and demographic characteristics of the discordant cases to determine if there are any recurring explanations documented in charts for these cases.

    a. AMI-code Negative and cTnT Positive

    b. AMI-code Positive and cTnT Negative

F. To determine incidence rates of AMI based on each of the AMI health surveillance definitions studied above.

   a. AMI-code Positive

   b. cTnT Positive

   c. AMI-code Positive *and* cTnT Positive

   d. AMI-code Positive *or* cTnT Positive

4.2 RESEARCH HYPOTHESES:

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A. The troponin database will identify some individuals with AMI who were not identified by the ICD-9-CM administrative data method.

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B. The troponin database will identify some individuals with AMI who were not identified by the ICD-10-CA administrative data method.

C. The sensitivity of the administrative data methods described above for identifying individuals with AMI will be less than 90% relative to the criterion reference standard of individuals with AMI identified through the troponin database.

D. There will be differences in the profile of AMI patients between the groups (ICD-9-CM AMI-code positive and cTnT positive; ICD-10-CA AMI-code positive and cTnT positive).

E. Chart review will reveal recurring explanations for the discordant cases (eg ECG abnormalities with no associated rise in troponin T results; eg diagnoses of myocarditis or pulmonary embolism leading to the elevated troponin T results).

F. There will be statistically significant differences in the incidence rates derived from the different AMI definitions.

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CHAPTER 5 - METHODOLOGY and DATA ANALYSIS

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5.1 Design and Rationale

We studied the cohort of adult patients discharged from Calgary hospitals over a 15-month period (January 2002 – Mar 2003) with a diagnosis of AMI to assess and validate International Classification of Diseases coding (ICD-9-CM and ICD-10-CA) for identifying individuals with AMI against the reference standard of laboratory test results indicative of AMI. The initial 3-month period (Period1) was coded in ICD-9-CM format and the subsequent 12-month period was coded in ICD-10-CA format (Period 2 and Period 3). Two periods were assessed during the new ICD-10 coding as we recognized that the evaluation of the ICD-10-CA coding system immediately after its introduction may reveal some coding problems that would subsequently disappear as coders familiarize themselves with the new coding system and rules. Therefore, we assessed whether the estimate of data from the first 6 months of implementation differs from (and specifically whether it was lower than) the second 6 months of ICD-10-CA data recording.

5.2 Data Sources

a) Administrative - hospital separation data – the Calgary Health Region Corporate Data Department supplied data for both inpatients and outpatients.

b) Calgary Laboratory Services supplied monthly troponin results used to form the troponin database.

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5.3 Identification of AMI cases

a. Administrative Data

Adult patients admitted with a diagnosis of AMI, as determined by screening appropriate administrative codes from the discharge administrative data at all of the three adult Calgary tertiary care hospitals between January 2002 and March 2003 were identified. In addition, to satisfy the criteria of Calgary residency, potential study candidates were excluded if corresponding patient postal codes, as defined by Alberta Health and Wellness 2001 boundaries, were outside Calgary Health Region boundaries. Alberta Health and Wellness [personal communication – Larry Svenson – Health Surveillance Branch] confirmed that in 2001, 98% of AMI in Calgary residents were managed in Calgary hospitals. Both inpatient and outpatients records were screened and appropriate AMI cases identified. Appendix 1 provides an itemized listing of the ICD-9-CM and ICD-10-CA definitions of AMI. The corresponding ICD-9-CM codes are 410.0x to 410.9x. The corresponding ICD-10-CA codes are I21.x. In both systems x represents integers from 0 through 9. To avoid including duplicate patients, patients transferred during their episode of care were assessed according to hospital of first admission but procedures and length of stay were compiled into "episodes of care" for analysis as a single AMI case. The ICD-9-CM uses the 5th digit to represent episode of care. In the new ICD-10-CA classification there is a specific code, I22 to represent "subsequent MI admissions" (eg. follow up admissions for cardiac procedures). Post-MI readmission patients and patients who have been discharged and subsequently electively re-admitted for a cardiac procedure were excluded.

We chose to analyze only inpatients in the proposed AMI definitions. We reviewed the data on the outpatients as we recognized that not all patients with a diagnosis of AMI are admitted. Some patients may die in the emergency departments (ED) and therefore not be admitted, some patients may discharge themselves from ED against medical advice, and others may have troponins drawn but still get discharged – i.e., missed diagnosis. However, we were concerned about the "Query MI" cases in the ED data that might get coded as AMIs. Therefore, this study evaluated the following administrative data definitions:

AMI definition 1 – ICD-9-CM coded AMI in hospital inpatient data

AMI definition 2 – ICD-10-CA coded AMI in hospital inpatient data

b. Calgary Laboratory Services data

Currently **all** patients presenting to hospital with chest pain routinely have at least one cardiac troponin T (cTnT) level ordered by their physician – most order serial testing. Physicians in clinics may also order cTnT testing. All results were archived in the troponin database. The troponin database was screened to identify adult patients in the Calgary Health Region with cTnT values measured between January 2002 and March 2003. During the period of study cTnT levels were determined by means of the third generation cardiac troponin T assay (Elecsys, Roche Diagnostics). An abnormal cTnT was defined using the diagnostic discrimination limit given by the company and therefore was defined as positive and indicative of myocardial injury if a troponin value is at least 0.1 µg per milliliter (mL). Therefore the **cTnT definition of positive** included cases if the cTnT test result was at least 0.1 µg/mL and **cTnT negative** included cTnT values less than 0.1 µg/mL. The definitions

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were applied to an episode of care for analysis. Most individuals had serial cTnT testing and we used the peak cTnT test result among serial tests when applying the above definition.

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5.4 Linkage of Data Files

First, the troponin database was screened to identify positive cTnT cases. Duplicates were removed and the data were cleaned to identify adult patients with a valid Alberta Health Care number as defined by the Alberta Health Care algorithm. Patient's residence postal code was used to define residence in the Calgary Health Region. Second, adult inpatient records from the Calgary Health Region's administrative data stores were screened for AMI diagnostic codes. This administrative inpatient database file was linked to the troponin database, using the patients' Alberta Health Care number as the primary merging variable. We reviewed the hospital admission date and discharge date to ensure that troponin T values were within these dates ($\pm$ 1 day). Linkage of the databases was required for determination of the proportion of common cases and to calculate the sensitivity and PPV of the hospital separation data against the reference standard laboratory data. We removed the personal identifiers once all linkages were complete.

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5.5 Administrative Data Review

We requested and received demographic information, the most responsible diagnosis (MRD), and all diagnostic codes on AMI-coded patients. Cases were screened for an AMI-code (ICD-9-CM or ICD-10-CA) in any diagnostic field. We also received procedure codes so that a history of trauma or surgery that could influence cardiac biomarker values could be

identified. This same information was also received for cTnT positive and AMI-code negative cases and AMI-code positive and cTnT negative cases in the first period to evaluate the accuracy of administrative coding and to describe demographic and clinical characteristics of these groups.

The burden of illness for the patient was assessed by determining the co-morbidity variables for the patient and using the clinical co-morbidity index developed by Elixhauser[41] (see Section 5.6). For the discrepant cases (ie cTnT positive AMI-code negative cases or AMI-code positive but cTnT negative cases) we compiled a review of the most responsible diagnosis – the main reason for hospitalization. A priori, we expected that many of the cTnT positive and AMI-code negative cases to be coded as specific conditions such as pulmonary embolus, congestive heart failure, myocarditis, myositis and renal dysfunction, all conditions known to cause elevated troponin levels in these subsets of patients. We also expected that the AMI-code positive but cTnT negative patients were perhaps present as a result of the newness of the cTnT and we expected to find creatinine kinase (CK, or CK-MB) – an alternative cardiac biomarker - present.

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5.6 Variables of Interest

The following variables were analyzed per defined true positive group (cTnT positive and AMI-code positive) and compared by period: 1) Age in years at time of hospitalization or positive cTnT result, 2) sex – male/female, 3) length of hospital stay and 4) mortality during hospital stay – defined as death occurring in hospital any time before hospital discharge - yes/no. Additionally, the co-morbidity variables were defined using the clinical

co-morbidity index developed by Elixhauser et al and recently validated and enhanced by Quan for research relying on *International Classification of Diseases* (ICD-9-CM) diagnosis codes.[44] The ICD-10-CA diagnosis codes for co-morbidities have been cross-referenced to the previous ICD-9-CM codes and were used for this analysis. Elixhauser uses the following comprehensive list of co-morbidity variables: congestive heart failure, cardiac arrhythmias, valvular disease, pulmonary circulation disorders, peripheral vascular disease, hypertension-complicated and uncomplicated, paralysis, neurological conditions, chronic pulmonary disease, diabetes – complicated and uncomplicated, hypothyroidism, renal failure, liver disease, peptic ulcer, AIDS, lymphoma, metastatic cancer, solid tumor, rheumatoid arthritis, coagulopathy, obesity, weight loss, fluid and electrolyte disorders, blood loss anemia, deficiency anemia, alcohol abuse, psychoses and depression. A list of these diagnoses with the corresponding ICD-9-CM and ICD-10-CA codes is attached in APPENDIX 2. The SAS code (version 8.1) used to define these variables is also attached in APPENDIX 3.

Comparisons were performed using cross-tabulations and either Fishers' exact or chi-square tests of significance. Mean age and length of stay were compared using Students t-test or ANOVA. All analyses were performed with the SPSS® statistical package (version 13.0, SPSS Inc., Chicago, Illinois).

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5.7 Chart Review

We also performed a comprehensive chart review on the Period 1 discrepant cases using a chart abstraction form (APPENDIX 4). Two individuals (PDG and GP) reviewed the patient chart. A random series of 10 charts were independently reviewed and

documentation was compared for agreement. Agreement was near perfect (Kappa .89, $p<0.00001$)

Key variables of interest were the presence of each of the three elements that constitute the WHO definition of AMI: ischemic symptoms, positive cardiac enzymes suggestive of ischemia and ECG changes consistent with ischemia. The ESC/ACC guidelines include troponin in the new AMI definition with either symptoms or ECG changes suggestive of ischemia.

The presence of specific co-morbid conditions associated with elevated troponin levels were documented as well as other lab results. This review allowed us to descriptively document the circumstances surrounding discrepant cases (i.e., presence/absence of key WHO criteria, and presence/absence of other notable conditions that may be contributing to discrepancies in diagnosis and determine any recurring explanations for discrepancies).

Serial ECGs, if available, were reviewed with a clinically-trained physician to determine presence/absence of dynamic ST changes suggestive of ischemia as a global assessment of occurrence of an AMI using Minnesota code criteria[76]. A copy of the ECG review form is attached in APPENDIX 5.

As the objective of this chart review was entirely related to description and characterization of discrepant cases, only proportions and descriptions of the clinical profile of discrepant cases were reported.

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5.8 Sensitivity and Positive Predictive Value Calculations

Cells a, b, and c in the two-by-two table below were completed using the definition for cTnT positive test results and each of the administrative coding definitions of AMI for each of the study periods.

		Troponin T results	
		Positive	Negative
AMI coded	Yes	a	b
	No	c	d

Cells a, b, and c were completed by counting the number of common positive cases (cell 'a' = true positives) and the number of discrepant cases (i.e., cell 'b' = AMI-code positive and no positive cTnT test result and cell 'c' = AMI-code negative and cTnT positive) between administrative data and laboratory AMI definitions. Specificity could not be accurately determined in this study because we could not accurately estimate cell 'd' – the true negatives, as this would be infinite (those patients with cTnT negative or not measured and also no diagnostic AMI code in the discharge administrative data).

We determined the sensitivity (a/a+c) and positive predictive value (PPV = a/a+b) of the old ICD-9-CM coding for AMI (410.xx) in adult individuals discharged from hospitals within the Calgary Health Region between January 2002 and March 2002 against a reference standard of those individuals with positive cTnT results from the troponin database using the positive AMI laboratory definition during the same time period. Binomial 95% confidence intervals (CI) were calculated for the estimates of sensitivity.

We determined the sensitivity (± 95% CI) and PPV of the new ICD-10-CA coding for AMI (I21.x) in adult individuals discharged from CHR hospitals for both Period 2 and 3 against a reference standard of those individuals with positive cTnT results from the troponin database during the same time period. Binomial 95% confidence intervals (CI) were calculated for the estimates of sensitivity.

Comparisons across periods were performed using cross-tabulations and either Fishers' exact or chi-square tests of significance. Analyses were performed using STATA® statistical package version 8.2(StataCorp, College Station, TX).

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5.9 Incidence Calculations

We determined the following 4 surveillance definitions for the following incidence calculations for each of the defined periods:

a) using the number of administrative AMI-coded cases as the numerator and the CHR adult population as the denominator (i.e., administrative data definition).

b) using the number of cTnT positive cases as the numerator and the CHR adult population as the denominator (i.e., Laboratory Definition).

c) using the number of true positives (i.e., cTnT positive *and* AMI-code positive) for the numerator and then used the Calgary Health Region adult population as the denominator.

d) using the number of positive cTnT cases *or* AMI-code positive cases in the Period as the numerator and the CHR adult population as the denominator.

As Period 1 covered 3 months or ¼ of the calendar year the numerator during this period was multiplied by 4 to determine the annual rate. Periods 2 and 3 both covered 6 months so we multiplied the numerator by 2 to determine the annual rate.

The denominator figures of population estimates were received from the Health Surveillance Branch of Alberta Health and Wellness. We were provided with 2 estimates using the health region boundaries from April, 2001:

Population Estimate 1: estimated population of Calgary Health Region for people over 20 years of age was 724,582 as of 31 March 2002.

Population Estimate 2: estimated population of Calgary Health Region for people over 20 years of age was 744,286 as of 31 March 2003.

We used Population Estimate 1 for Period 1 calculations and Population Estimate 2 for Period 3. For Period 2 we used the average of Population Estimate 1 and 2 – i.e. 734,434.

Comparisons across periods were performed using cross-tabulations and either Fishers' exact or chi-square tests of significance. Analyses were performed using STATA® statistical package (version 8.0).

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5.10 Ethical Considerations

Ethical approval has been received from the Conjoint Ethics Review Board at the University of Calgary and approval is attached (APPENDIX 6). This research was carried out according to the Tri-Council Policy Statement – ethical conduct for research involving humans(77). Data was presented in aggregate form and individual patients were not identified. Individual patients were never contacted, and real time AMI care was not

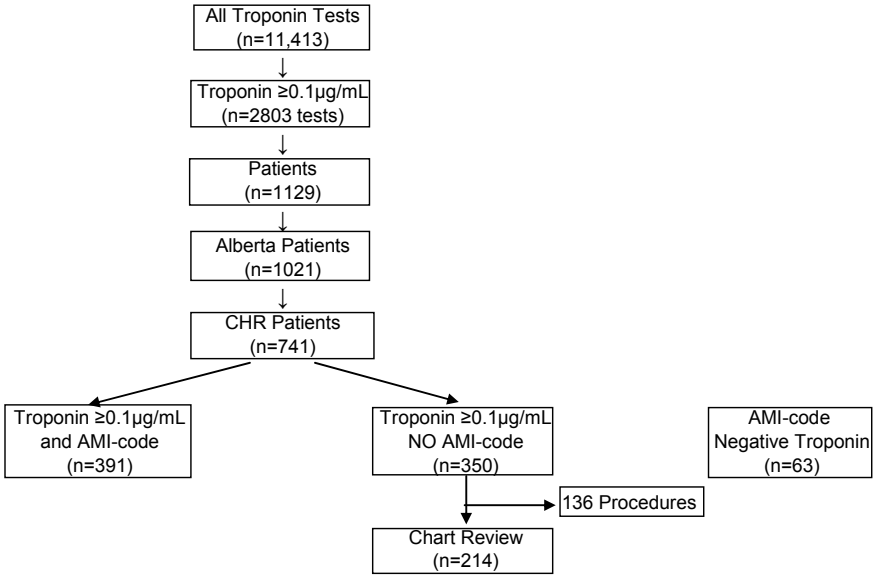
influenced in any way by this research. Useful information from this study has the potential to contribute information that in turn could guide future policy change in AMI care and benefit future AMI patients.

CHAPTER 6: RESULTS – Period 1

6.1 Study Population

Between 1 January 2002 and 31 March 2002 (Period 1), 11,413 troponin specimens were processed and recorded in the centralized laboratory database maintained by Calgary Laboratory Services. Of these 2803 tests (1129 patients) had documented troponin T levels greater than the usual level to define AMI of 0.1 µg/mL and were over 20 years of age. Most of these patients had an Alberta address (1021) and 741 adult patients had a valid postal code corresponding to Calgary Health Region (CHR) residence. We restricted the laboratory cohort to the CHR to allow for a comparable cohort from administrative data capturing discharges from CHR acute-care facilities. These 741 patients comprise our troponin study cohort for Period 1, the derivation of which is summarized in Figure 6.1.

Figure 6.1 Flow Chart of the Study Population for Period 1 – January to March 2002



As seen there are 741 patients with at least one positive cardiac troponin T (cTnT) result. The patients in the cTnT positive registry were then merged using the patients Alberta health care number to data from the same period on patients from the CHR administrative database that captures discharges from the region's three adult in-patient acute care facilities. We found that 391 (52.8%) patients had a corresponding AMI administrative diagnosis code (cTnT positive and AMI-code positive). The other 350 (47.2%) patients were cTnT positive but did not have a corresponding AMI diagnosis code in any of the diagnoses fields (cTnT positive and No AMI-code).

6.2 Sensitivity and Positive Predictive Value

Below, we present results comparing cTnT results with presence or absence of AMI codes in a traditional two-by-two table (Table 6.1) using the centralized laboratory database as the reference standard.

Table 6.1 Two-by-two table of cTnT results and AMI-coding.

		Gold Standard Troponin T Test Results		
		Positive	Negative	Total
AMI-code	YES	a (391)	b (63)	454
	NO	c (350)	d	
	Total	741		

Sensitivity is the proportion of patients of a disease detected by the surveillance system. In this AMI cohort, we considered those with a positive troponin T test result to be individuals

with the target disorder, and AMI coding (present or absent) to be the 'test' for which sensitivity is being determined. Sensitivity is a measure of the probability of correctly identifying an AMI-case through a presence of AMI coding, and is synonymous with a true positive rate. To calculate sensitivity we used the formula a/a+c in the traditional two-by-two table where cell 'a' represents those with cTnT positive and a corresponding administrative AMI code and cell 'c' represents those with cTnT positive without a corresponding administrative AMI code. In our study population, among 741 with positive cTnT, 391 had AMI codes present in administrative data, a finding that indicates a sensitivity of 52.8% (95% CI: 49.2 - 56.4%).

We also calculated the positive predictive value (PPV) defined as the probability that the person with the administrative definition of AMI is a true positive. To calculate PPV we used the formula a/a+b and found that among 454 patients with AMI codes present, 391 had positive cTnT. This corresponds to a PPV of 86.1% (95% CI: 82.9 - 89.3%). In our study, specificity can not accurately be estimated because we are unable to define the true negatives (cell d) -- those patients with negative cTnT or not measured and also no AMI code in administrative data. The absence of information on cell 'd' in Table 6.1 also prevents us from determining the negative predictive value.

6.3 Description of cTnT Positive Cases without an Administrative AMI-Code

In exploring the clinical characteristics of the cTnT positive cases without administrative AMI coding, we found that 136 had associated cardiac procedures at the time of the troponin draw that might explain the elevated cardiac troponin levels. We investigated these procedures further and found that 88 patients underwent cardiac bypass surgery, 28

patients had cardiac valve repair/replacement, 10 underwent PCI, 4 had a permanent pacemaker inserted, and 6 required defibrillation. These cardiac procedures explain a subset of the cTnT and AMI-coded cases.

However, this still left 214 patients who had positive cTnT levels documented, but no associated cardiac procedure and no corresponding AMI code. We extracted the corresponding most responsible diagnosis (MRD) code for these 214 patients. The results of this analysis are listed in Table 6.2 and show that many patients (86) had a cardiac diagnosis code including atherosclerosis (n=40), arrest (n=1), arrhythmias (n=7), contusion (n=1), cardiomyopathy (n=1), congestive heart failure (n=22), myocarditis (n=2), pericarditis (n=2), unstable angina (n=4) and valve disorder (n=6). Meanwhile, the other 128 patients had an assigned MRD that we classified as being 'non-cardiac'. The specific clinical diagnoses detected are listed in Table 6.2 below. Only a few patients had the widely-recognized 'high cTnT diagnoses' of renal failure (n=11) and pulmonary embolus (n=3).

Table 6.2 Most Responsible Diagnosis for Patients with Positive cTnT Results and AMI-code Negative

DIAGNOSES	**Number of Cases**
CARDIAC DIAGNOSES (Total)	**86**
Atherosclerosis (heart)	40
Cardiac Arrest	1
Cardiac Arrhythmias (Atrial fib/flutter)	7
Cardiac Contusion	1
Cardiomyopathy	1
Congestive Heart Failure	22
Myocarditis/Pericarditis	4
Unstable Angina	4
Valvular Disease	6
NON-CARDIAC DIAGNOSES (Total)	**128**
Amyotrophic Lateral Sclerosis	1

Anemia	1
Aneurysm (thoracic)	2
Cholecystitis	1
Bronchitis/COPD	9
Diabetes Mellitus	10
Delerium	2
Dimentia/organic brain syndrome	3
Fractures (skull, transcervical, ribs)	5
GI (iliostomy, ulcer, diverticulosis)	12
Hypotension	2
Hypothermia	1
Hypothyroidism	1
Infection and Inflammatory Reaction	3
Inguinal hernia	1
Liver cirrhosis	2
Malignancy	11
Necrosis due to burn	1
Necrotizing fasciitis	1
Neurological Disorders (convulsions, ICH, anoxia)	12
Osteoarthritis	2
Pancreatitis	1
Peripheral Vascular Disorders	4
Pneumonia	14
Polymositis	2
Pulmonary Embolus	3
Pulmonary Disease (Fibrosis/Insufficiency)	2
Renal Failure	11
Respiratory Failure	2
Septicemia	2
Viral disease	1
Volume depletion	2
Other complication of procedure	1

6.4 Comparison of Co-morbidity Variables in the cTnT Positive AMI-code Negative Group versus the cTnT Positive AMI-code Positive Group

Further characterization of these patients was performed through analysis of the administrative diagnostic codes as well as a detailed chart review.

In the cTnT positive and AMI-code positive group, we found 40 cases that were discharged after April 1, 2002 and therefore were coded using ICD-10-CA and are therefore not included in this characterization analysis. Our analysis therefore focuses on 351 cases with ICD-9-CM diagnostic codes. The demographic and clinical characteristics of the patients for the cTnT positive and AMI-coded cases were compared to the cTnT positive cases without administrative coding of AMI. As detailed in the Methods section the co-morbidity variables were defined using the clinical co-morbidity index developed by Elixhauser and subsequently modified and enhanced by Quan. The coding definitions used to define the Elixhauser co-morbidity variables are presented in APPENDIX 2. The prevalence of co-morbidities in each of the two groups are presented in Table 6.3.

The cTnT positive AMI-code positive patients are younger (68 versus 72 years, p=0.013) and have a higher percentage of males (64.7 versus 72.0%, p=0.002) than the cTnT positive AMI-code negative patients. In addition, the former generally have a lower prevalence of co-morbid conditions such as pulmonary circulation disease, peripheral vascular disease, neurological disease, liver disease, cancer and rheumatoid arthritis. Renal disease was notably much less frequent in the AMI-coded group (p<0.0001).

Table 6.3 Demographic and Co-Morbid Characteristics for the cTnT Positive Patients With and Without Corresponding Administrative AMI Codes.

	cTnT Positive AMI- Code Present	**cTnT Positive No AMI Code Present**	**P**
Number of patients	**351**	**214**	
Mean age (years)	68.1	72.0	.013

Gender (%male)	64.7	51.4	.002
Comorbidity variables	**%**	**%**	
Congestive heart failure (%)	33.3	30.4	.557
Cardiac arrhythmias (%)	26.8	29.8	.476
Valvular disease (%)	8.8	9.9	.752
Pulmonary circulation disorders (%)	1.4	8.3	<0.0001
Peripheral vascular disease (%)	8.0	16.0	.007
Hypertension (%)	49.6	40.9	.057
Paralysis (%)	1.7	1.7	1.000
Other neurological (%)	3.4	8.8	.013
Chronic pulmonary disease (%)	14.5	20.4	.086
Diabetes mellitus (%)	26.2	26.0	1.000
Hypothyroidism (%)	6.6	6.6	1.000
Renal failure (%)	7.4	25.4	<0.0001
Liver disease (%)	1.4	3.9	.118
Peptic ulcer disease (%)	0.9	1.7	.414
Aids (%)	0	0	
Lymphoma (%)	0.6	1.1	.608
Metastatic cancer (%)	0.6	5.0	.001
Solid tumor without metastasis (%)	2.8	7.2	.025
Rheumatoid arthritis (%)	1.1	5.5	.007
Coagulopathy (%)	4.6	4.4	1.000
Obesity (%)	2.3	1.1	.507

Weight loss (%)	0.3	1.7	.116
Fluid and electrolyte disorders (%)	10.8	22.7	<0.0001
Blood loss anemia (%)	0.9	3.3	.068
Deficiency anemia (%)	2.3	4.4	.187
Alcohol abuse (%)	1.1	3.3	.097
Drug abuse (%)	2.0	1.1	.725
Psychoses (%)	1.7	1.1	.722
Depression (%)	4.6	4.4	1.000

6.5 Comparison of Outcomes for the cTnT Positive AMI-code Negative Group versus the cTnT Positive AMI-code Positive Group

Table 6.4 shows that the total length of stay was significantly less in the AMI-coded group ($p<0.0001$). In-hospital mortality was significantly lower in the AMI-coded group as compared to the non-AMI-coded group (12.0 versus 22.1% respectively, $p<.003$).

Table 6.4 Clinical Outcomes for the cTnT Positive Patients With and Without Corresponding Administrative AMI Code.

	cTnT Positive AMI-coded	**cTnT Positive No AMI Code**	**p**
Number of Patients	351	214	
Total Length of Stay	9.9 $\pm$ 9.6	21.6 $\pm$ 30.3	<0.0001
In-hospital Mortality (%)	12.0	22.1	0.003

6.6 Chart Review of the cTnT Positive AMI-code Negative Group

A detailed chart review of the no AMI-coded group (with cTnT positive) was performed to determine previous cardiac history as well as the presence/absence of key AMI criteria including cardiac biomarkers, cardiac signs or symptoms and ECG findings. Prior cardiac history, defined as history of MI, documented coronary disease on cardiac catheterization or prior revascularization, or prior angioplasty or bypass grafting surgery, was present in 29.7%of the cTnT positive and AMI-code negative cases.

Of note, clinician comments relating to the elevated troponin results were only present in 85 (39.7%) of cases. Of these, clinicians documented associated renal disease on the patient's health record in 29 cases. Cardiac signs or symptoms were recorded in the chart as being present on admission or during hospitalization in 90 cases (42.1%). Our chart review also assessed presence/absence of explicit documentation of 'AMI' being present in the discharge summary report and found this to be present in 43 cases (20.0%). Despite this, AMI was not coded in the administrative discharge abstracts for these cases (i.e., a coding 'error of omission').

ECG's were reviewed according to published criteria and 34% were found to have dynamic changes(76).

Table 6.5 Information documented in the health record chart indicating presence of ischemic symptoms, presence of AMI and dynamic changes on the ECG.

	Data Available (n)	**n (%) with Characteristic**	**95% CI**
Ischemic symptoms documented	214	90 (42.1%)	35.5 – 48.7%

AMI documented	214	43 (20.0%)	14.7 – 25.3%
Dynamic changes present on ECG	212	72 (34.0%)	27.6 – 40.4%

Table 6.6 describes some of the clinician comments made in charts relating to elevated troponin levels as documented in our chart review. Comments were documented in the medical history in 22.0%, in the progress notes in 32.5% and in the discharge summary in only 6.7% of cases. Comments were varied and focused on explanations for the elevated troponin results. As stated earlier, there were some comments documenting elevated creatinine levels and abnormal renal function as well as comments suggesting myocardial ischemia. Despite the latter comment often appearing, AMI was not coded in these cases.

Table 6.6 Examples of the Comments Documented by Clinicians in the Progress Notes of the Health Record for Patients with cTnT Positive AMI-Code Negative

"Elevated troponins – likely due to acute renal failure"
"Some degree of troponin elevation secondary to chronic renal failure"
"Elevated troponins consistent with myocardial ischemia"
"Possible new MI"
"Troponins elevated – NSTEMI (non ST Elevation MI)"
"Positive troponins without AMI – consult cardiology"
"Elevated troponins but CK normal"
"Troponins elevated but if CK negative conclude no significant event"
"Admit to CCU"
"Troponin positive – ECHO"
"Sepsis"
"Shock"
"Multi-system failure"
"Elevated troponins likely related to arrhythmia"
"Elevated troponins likely secondary to muscle damage"
"Afib or creatinine"
"History of myocarditis"
"Prior MI; Rule out MI"
"Documented post-op MI"

6.7 Chart Review of the AMI-code Positive and cTnT Negative Cases

We identified 63 cases where AMI was coded, but the cTnT was negative. The MRD for these 63 patients was extracted and a detailed chart review was performed on these cases. The results of the MRD analysis are listed in Table 6.7 and show that the majority (75%) of these patients had an assigned MRD that we classified as being 'cardiac'.

Table 6.7 Most Responsible Diagnosis for Patients with AMI-code Positive and cTnT Negative

DIAGNOSES	**Number of Cases**
CARDIAC DIAGNOSES (Total)	**48**
Acute Myocardial Infarction	33
Aortic Dissection/rupture	2
Atherosclerosis (heart)	4
Congestive Heart Failure	6
Unstable Angina	2
Valvular Disease	1
NON-CARDIAC DIAGNOSES (Total)	**15**
Bronchitis/COPD	1
Delirium	2
Embolism (venous)	1
Fractures (transcervical)	1
GI bleed	1
Hypertension	1
Infection and Inflammatory Reaction	1
Inguinal hernia	1
Malignant neoplasm	1
Neurological Disorders	1
Pneumonia	3
Spondylosis	1

Cardiac signs or symptoms were recorded in the chart as being present on admission or during hospitalization in 38 cases (60%). All charts were coded as AMI by health record

coders but only 44 cases (69.8%) had a clinician documenting AMI. However, there were numerous "rule-out MI" designations in the chart that appear to have been subsequently coded as AMI.

ECG's were available and reviewed on 61 patients – 1 patient had a pacemaker, 2 LVH and 6 LBBB making assessment for ischemia difficult. Of the remaining 52, 34 had documented ischemia. Only 9 (14.3%) patients did not have either cardiac symptoms or ischemia by ECG criteria.

It is noteworthy that this subgroup of AMI-code positive and cTnT negative had a high in-hospital mortality rate of 22.2%.

The majority (94%) of patients had cTnT results documented on the chart and 56% of patients had a troponin level documented in the health record chart that is typically referred to as "possible myocardial ischemia" (i.e., between 0.03 and 0.1 µg/mL).

Table 6.8 Chart Review of Cardiac Troponin T Results for Patients with AMI-code Positive and cTnT 'Negative'

Cardiac Troponin T Results	**Number of Cases n (%)**
No troponin drawn	4 (6.3%)
<0.03 µg/mL	22 (34.9%)
0.03 - <0.1 µg/mL	35 (55.6%)
> 0.1 µg/mL*	2 (3.2%)

* positive cTnT test results presumably due to date cut-offs in the laboratory database.

6.8 AMI-coded Patients in the Emergency Room

We also assessed the emergency department (ED) database and found that during this same time period there were 420 cases admitted to the ED with the diagnosis of AMI. Of these 265 (63%) were admitted with positive cTnT levels and also had an in-hospital code of AMI assigned, 80 patients were admitted without positive cTnT, 2 patients signed themselves out against medical advice, 7 patients died, and 49 patients were discharged and did not have positive cTnT levels. Notably 17 patients (4%) were discharged although they had positive cTnT results.

6.9 Annual Incidence Rates According to Four Potential Surveillance Definitions for AMI

A central theme underlying this research is that of disease surveillance. The preceding analyses reveal that the incidence of AMI may be influenced by the approach taken to defining presence or absence of AMI in a disease surveillance initiative. Recognizing that both hospital discharge data (with ICD coding) and laboratory data represent information sources for disease surveillance, we assessed 4 different 'surveillance definitions' for AMI:

1) AMI-code positive

2) cTnT positive

3) cTnT positive *and* AMI-code positive

4) cTnT positive *or* AMI-code positive

Table 6.9 Annual Incidence Rates for cTnT Positive and AMI-code Positive group, cTnT Positive or AMI-code Positive group, Troponin Positive group and AMI-code Positive group

Surveillance definitions	**n***	**Annual Incidence Rates per 100,000 CHR Adult Population****
AMI code positive	454	250.41
Troponin positive	741	408.70
cTnT positive *and* AMI code positive	391	215.66
cTnT positive *or* AMI code positive	804	443.45

* n represents the 3 months of Period 1
** CHR population over age 20 years = 724,582 (31 March 2002)

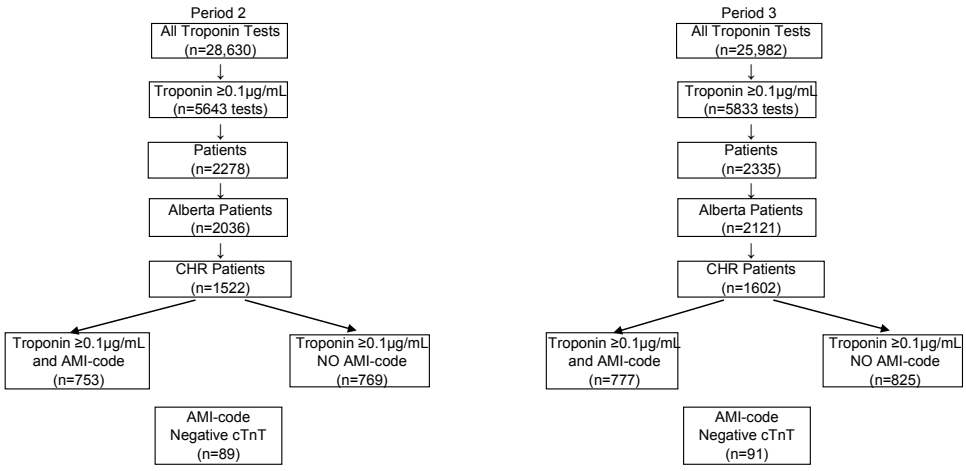
The calculated incidence rates varied considerably across definitions as shown in Table 6.9. A surveillance definition based only on presence of administrative data coding for AMI (i.e., the currently used approach in many surveillance and health services research initiatives) yields an incidence of 250.4 per 100,000 population (aged 20 and above), while a definition based only on positive cTnT yields an incidence of 407.7 per 100,000 population. The cTnT positive *and* AMI-code present definition yields the lowest incidence of 215.7 per 100,000 adults. The cTnT positive *or* AMI-coded positive definition yields the highest annual incidence of AMI of 443.5 per 100,000 adult population.

CHAPTER 7: RESULTS – Comparison of Period 1, 2 and 3

7.1 Study Population

Period 1 has previously been described. Period 2 includes specimens and discharges between 1 April 2002 and 30 September 2002 and Period 3 is defined as the time period between 1 October 2002 and 31 March 2003. If we extrapolate Period1 from 3 months to 6 months to be able to compare numbers we see that the number of Calgary Health Region adult patients with positive cTnT is increasing slightly over time, from 1482 in period 1 to 1522 in period 2, and to 1602 in period 3. Figure 7.1 presents the study population identification process conducted for Period 2 and Period 3.

Figure 7.1 Flow Chart of the Study Population for Period 2 and Period 3



7.2 Sensitivity and Positive Predictive Value Across Time Periods

In Table 7.1 results comparing sensitivity or the true positive rate are presented. Sensitivity decreases slightly across the time periods from 52.8% in Period 1 to 48.5% in Period 3 but the observed difference is not statistically significant (p = 0.154). We compared Period 1 against Period 2 as there was a coding change from ICD-9-CM to ICD-10-CA between these two periods. A Fisher exact test reveals that there was no statistically significant difference in sensitivity between these two time periods (p = 0.152). We also compared Period 2 against Period 3 to see if there was a difference to account for the learning curve (i.e., early period of new coding vs later period of new coding) and found that there was again no statistically significant difference (p=0.591).

We then calculated the Positive Predictive Value (PPV) defined as the probability that the person with the administrative code of AMI is truly an AMI. The PPV varied slightly across the periods, but again, the observed difference was not statistically significant (p = 0.132). The PPV increased from Period 1 to Period 2 and there is a trend toward statistical significance of this difference (p=0.086). There is no difference between Periods 2 and 3.

Table 7.1 Sensitivity and Positive Predictive Value for Periods 1, 2 and 3.

	Period 1	**Period 2**	**Period 3**	**p**
Sensitivity (95% CI)	52.8% (49.2-56.4)	49.5%(47.0-52.0)	48.5%(46.1-50.9)	.154
PPV (95% CI)	86.1%(82.9-89.3)	89.4%(87.4-91.4)	89.5%(87.5-91.5)	.132

7.3 Comparison Across Time Periods of Co-morbidity Variables in the cTnT Positive AMI-code Positive Group

Further characterization of these patients was performed through analysis of the administrative diagnostic codes to define clinical co-morbidity variables as described earlier for Period 1.

The demographic and clinical characteristics of the patients for the cTnT positive and AMI-coded cases were compared across the periods. The co-morbidity variables were defined using the clinical co-morbidity index developed by Elixhauser and subsequently modified and enhanced by Quan et al. The prevalence of co-morbidities in each of the groups is presented in Table 7.2.

Age and sex did not vary over time. Generally, the prevalence of co-morbid conditions is similar across the groups with a trend toward more CHF patients in the early period and pulmonary disorders and obesity being highest during Period 2.

Table 7.2 Demographic and Co-Morbid Characteristics for the cTnT Positive AMI-code Positive Patients

	Period 1	**Period 2**	**Period 3**	**p**
Number of patients	341	753	777	
Mean Age (years)	68.1	69.1	68.3	.447
Gender (%Male)	64.7	66.5	64.8	.739
Co-morbidity Variables				
Congestive Heart Failure (%)	33.3	26.8	27.3	.064
Cardiac Arrhythmias (%)	26.8	25.6	25.2	.863
Valvular Disease (%)	8.8	8.2	7.7	.818

Pulmonary Circulation Disorders (%)	1.4	4.4	2.9	.028
Peripheral Vascular Disease (%)	8.0	7.2	6.2	.545
Hypertension (%)	49.6	54.2	54.5	.279
Paralysis (%)	1.7	1.6	2.6	.389
Other Neurological (%)	3.4	5.8	5.6	.218
Chronic Pulmonary Disease (%)	14.5	13.9	13.0	.770
Diabetes Mellitus (%)	26.2	25.6	27.8	.622
Hypothyroidism (%)	6.6	7.4	6.8	.832
Renal failure (%)	7.4	8.5	8.9	.712
Liver Disease (%)	1.4	1.3	2.6	.181
Peptic Ulcer Disease (%)	0.9	1.5	0.9	.530
AIDS (%)	0	0	0	
Lymphoma (%)	0.6	0.7	0.3	.870
Metastatic Cancer (%)	0.6	1.1	1.7	.286
Solid Tumor without Metastasis (%)	2.8	4.4	3.0	.279
Rheumatoid Arthritis (%)	1.1	2.4	1.5	.266
Coagulopathy (%)	4.6	2.9	2.9	.288
Obesity (%)	2.3	4.4	2.3	.043
Weight Loss (%)	0.3	0.3	0.5	.817
Fluid and Electrolyte Disorders (%)	10.8	10.5	10.0	.903
Blood Loss Anemia (%)	0.9	2.1	1.2	.193
Deficiency Anemia (%)	2.3	1.5	1.2	.409
Alcohol Abuse (%)	1.1	3.1	2.6	.160
Drug Abuse (%)	2.0	0.3	0.6	.007
Psychoses (%)	1.7	0.3	0	.002
Depression (%)	4.6	3.5	2.9	.375

7.4 AMI Incidence Rates According to the Four Surveillance Definitions

As previously discussed, analyses from Period 1 revealed that the incidence of AMI may be influenced by the approach taken to defining presence or absence of AMI in a disease surveillance initiative. As both hospital discharge data (with ICD coding) and laboratory data represent information sources for disease surveillance, we assessed 4 different 'surveillance definitions' for AMI: 1) AMI-code positive; 2) cTnT positive; 3) cTnT positive and AMI-code positive and 4) cTnT positive or AMI-code positive.

The calculated incidence rates varied considerably across definitions as shown in Table 7.3. Analysis of the differences in incidence estimates derived from each of the surveillance definitions is statistically significant within periods ($p < 0.0001$ for each period). The cTnT positive *or* AMI-coded positive definition yields the highest annual incidence of AMI in all periods. The cTnT positive *and* AMI-code present definition, meanwhile, yields the lowest annual incidence rate in all periods. Analysis of the statistical significance of incidence estimates across periods, as determined from each of the four surveillance definition according to incidence rates revealed no statistically significant differences ($p=0.560$, $p=0.733$, $p=0.862$, and $p=0.860$ for each of the four surveillance definitions).

Table 7.3 Annual Incidence Rates for Surveillance Definitions Across Periods

Surveillance Definitions	Period 1 Annual Incidence Rates per 100,000 CHR adult population*	Period 2 Annual Incidence Rates per 100,000 CHR adult population**	Period 3 Annual Incidence Rates per 100,000 CHR adult population+
AMI Code Positive	250.63	229.29	233.24
cTnT Positive	409.06	414.47	430.48
cTnT Positive *and* AMI Code Positive	215.85	205.06	208.79
cTnT Positive *or* AMI Code Positive	443.84	438.71	454.93

* Estimated CHR population over age 20 years = 724,582 (31 March 2002)
** Estimated CHR population over age 20 years = 734,434 (average population of 31 March 2002 and 31 March 2003)
+ Estimated CHR population over age 20 years = 744,286 (31 March 2003)

The preceding results therefore globally indicate that the study findings vary only minimally across the three time periods studied. The greatest variation in results relates to the surveillance definitions used within each time period, rather than to any time trends in sensitivity or positive predictive value of administrative data coding for AMI.

CHAPTER 8: DISCUSSION

The results presented in the preceding chapters provide insight into: 1) the sensitivity and positive predictive value of administrative hospital discharge data coded in ICD-9-CM and ICD-10 for detection of AMI, 2) the transition from ICD-9-CM to ICD-10-CA and insights into the relative performance of these 2 coding systems, 3) the clinical profiles of cTnT positive patients who do not have AMI coded, and 4) MI surveillance and potential definitions that could be adopted in future disease surveillance systems.

8.1 Sensitivity and Positive Predictive Value of Administrative Hospital Discharge Data

We found the true positive rate or sensitivity to be 52.8% (95%CI: 49.2-56.4) for Period 1, 49.5% (95%CI: 47.0-52.0) for Period 2 and 48.5% (95% CI: 46.1-50.9). Cases had both administrative AMI-codes and positive cTnT test results and interestingly there was not a statistically significant difference across the periods. The sensitivity decreased from Period 1 to 2 with a trends towards significance (p=.086).

Our sensitivity of AMI coding in all three periods is lower than previously reported.[29;32;78-84] Reasons for the difference in sensitivity are probably related to the use of a different gold standard in previous studies. Many studies used the medical record as the gold standard. The largest AMI surveillance study - the WHO-MONICA project reported sensitivity of 74% (range 35-90%).[23] A more recent Canadian study by Austin et al reported a sensitivity of 89% and the gold standard used in this study was the coronary care unit discharge diagnosis.[78]

Sensitivity or the proportion of AMI cases detected by the surveillance system is affected by the likelihood that persons with AMI seek medical care and can be counted in the system, that AMI is correctly diagnosed and that AMI is correctly coded. In Period 1 in our group of patients with cTnT positive and no AMI-code, we identified 20% that should have been coded as AMI given the presence of explicit mention of AMI in physician notes – i.e., errors of omission on the part of the health record coders. We also found cases where the clinician failed to explicitly state AMI in the discharge note but for which documentation of the presence of biomarkers, symptoms, and ECG changes were consistent with a definite diagnosis of AMI. Many of the these patients with cTnT positive and AMI-code negative were hospitalized for a long period of time and therefore the health record charts were of excessive length.

Coding accuracy is affected by diagnosis definitions and interpretation of the codes. Coding accuracy of MI might improve with mapping old and new terminology in order to assist health record coders with terminology. For example, the new coding system still uses the old terminology of transmural and Q-wave MI rather than the contemporary terminology of ST Elevation Myocardial Infarction (STEMI) that the clinician would record in contemporary care.

Improved coding and improved documentation in the health record could lead to improvement of the positive predictive value of the surveillance definitions. This could be achieved through both coder and physician education. Currently CIHI is leading an improvement in quality of health record coding and our results could be used to exemplify the importance of accurate coding. The transition to automated coding practices and the

electronic health record will hopefully improve this process. Finally, physicians need to be educated in regards to the broadening use of ICD codes (i.e., its use in surveillance activities) and the importance of explicit documentation in the discharge summary. Feedback from studies such as this should help improve future standardization and documentation.

8.2 Transition from ICD-9-CM to ICD-10-CA

The ICD coding systems were developed to classify morbidity and mortality records. Although the ICD-9-CM contains a large volume of clinical codes it does have its limitations and is not a comprehensive clinical data set. Overall, the new ICD-10 system has more codes and is more comprehensive allowing for richer coding of clinical information.[38] ICD-10 coding algorithms for measurement of co-morbidities have been developed through translation of the ICD-9-CM codes. The two co-morbidity tools developed by Charlson et al.[40] and Elixhauser et al.[41] are widely used to measure case-mix and burden of disease. With the transition to ICD-10 coding, new algorithms for defining co-morbidity needed to be developed and as ICD-10 uses a new alphanumeric system, many codes are not directly translatable. Recent independent research by Halfon et al.[85] and Sundararajan et al.[86] has led to new ICD-10 coding algorithms to define Charlson co-morbidites. In collaboration with Halfon and Sundararajan, Quan and colleagues have validated and enhanced the coding algorithms of Elixhauser.[44]

The changes in the coding definition for MI are in relation to duration from onset. The old ICD-9 system includes MI specified as acute or with a stated duration of 8 weeks and the new ICD-10 system specifies as acute or with a specified duration of 4 weeks or less from onset.

We reviewed two 6-month periods of ICD-10 coding as we recognized that the first 6-months of ICD-10-CA may not provide the best estimate of administrative data validity in a new coding system (i.e., this early period might underestimate validity). We therefore allowed for a "learning curve" as health record coders learned the new rules and system. Interestingly, our data showed that AMI sensitivity actually went down one percent - from 49.5% in Period 2 to 48.5% during Period 3. Perhaps a similar review of the data from 2003/04 would reveal an improvement in sensitivity as the learning curve may indeed be longer than 6 months. However, as previously stated, the MI definitions and terminology did not change in any major way between ICD-9 and ICD-10 aside from nuances surrounding the duration of onset. The latter point would suggest that there is unlikely to be a major improvement in the sensitivity of MI coding attributable to enhanced coding in the new ICD-10 coding system.

8.3 Elevation of Cardiac Troponin Without AMI Administrative Coding

Cardiac troponins can be raised in many patients other than those presenting with acute coronary syndromes (ACS).[66;67;87] These findings are supported by our data that show that approximately 50% of the patients we studied had elevated troponins without corresponding AMI-codes. Cardiac troponins have been reported to be elevated as a result of increased wall stress in patients with congestive heart failure[88-90], or hypertension with left ventricular hypertrophy. Additionally, troponins have been reported to be elevated in myocarditis[91], pericarditis[65;92], pulmonary embolism[64;93-96], critically ill patients (i.e., septic shock)[97-99], renal failure[68-70;100-102] and in patients undergoing chemotherapy where cardiotoxicity may be involved[103;104]. Increases in cTnT defined as positive are indicative

of myocardial injury but are not necessarily synonymous with AMI. Further study is needed to elucidate the mechanisms of troponin release in these patients as they are not the typical MI, and may represent a new type of clinical syndrome that some have referred to as 'troponinitis'.[105]

Our results from Period 1 showed that 136 patients underwent a procedure known to cause elevated troponins. Mechanical injury (i.e., ablation, implantable defibrillators) can also cause cardiac injury and therefore elevate troponins.[87] Unfortunately, during cardiac surgery there is the large mass of muscle damage and ischemia that occurs around the time of cardioplegia.[106-110] Some limited studies have suggested diagnostic discrimination levels. However, more studies are needed to determine the usefulness of cardiac biomarkers in the diagnosis of peri-operative MI after cardiac surgical procedures as no current biomarker is able to distinguish AMI from injury associated with the procedure itself.[109] Similarly, troponin elevations are reported in 30-50% of patients undergoing angioplasty.[111-114] These events are indicative of at least small scale myocardial injury, so should be recognized as such.[67]

It is less clear, however, whether such cases should be considered as traditional AMI cases in the context of MI surveillance, and the question arises as to whether peri-procedural MI's should be tracked separately from routine AMI surveillance.

8.4 Surveillance Definitions

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The consensus guidelines of the European Society of Cardiology, the American College of Cardiology and the American Heart Association proposed a new definition of AMI with positive biomarkers, ischemic ECG criteria and symptoms that has been adopted

clinically. However, these guidelines do not provide direction for epidemiologists and health surveillance initiatives.

Surveillance activities are a dynamic activity with the evolution of new biomarkers, new diagnostic tests and new definitions. Better surveillance initiatives are required as public health and health care systems change. These initiatives can thereby provide critical information that can be used to assess and analyze regional differences and trends over time in the incidence of MI. Complete capture of individuals with AMI is thus a crucial first step in the conduct of disease surveillance and health services research.

The findings of this research reveal that the incidence of AMI may be influenced by the approach taken to defining presence or absence of AMI in a disease surveillance initiative. Recognizing that both hospital discharge data (with ICD coding) and laboratory data represent information sources for disease surveillance, we assessed 4 different 'surveillance definitions' for AMI: 1) AMI-code positive, 2) cTnT positive, 3) cTnT positive *and* AMI-code positive, and 4) cTnT positive *or* AMI-code positive.

Definition 1: AMI-code Positive

Definition 1 of AMI-code positive is currently the routine basis for AMI surveillance, epidemiology and health services research in many countries. Our data yielded incidence rates of 230-250 per 100,000 adult population in the Calgary Health Region. Unfortunately, we have reported errors of omission relating to both the clinician not explicitly documenting MI and health record coders not coding MI when it has been documented. Additionally, there are cases coded as MI that do not meet the definition of MI i.e., were coded as MI when

the clinician had documented “rule out MI” or “old MI”. This supports previous findings of error rates of 18-43% in administrative data.[26]

As previously discussed, these findings need to be disseminated to clinicians so that they might work together to employ a universal lexicon in charting. Additionally, a coordinated effort by coders, clinicians, administrators and governments needs to occur to improve quality, efficiency and usefulness. Currently, information is being standardized through the use of ICD-10-CA coding across Canada. As well, automated coding and standardization of the documentation will minimize inconsistencies in coding and allow for benchmarking and comparisons across the country.

Definition 2: cTnT Positive

Definition 2 of cTnT positive cases attempts to simplify MI definitions to strictly positive troponin results and yields incidence rates of 409 per 100,000 adult population in the Calgary Health Region during Period 1, a slight increase to 415 in Period 2 and to 430 in Period 3. We assessed this definition to recognize the primary role of cardiac biomarkers. This definition is reproducible, timely, and simple. Such considerations aside, indiscriminate troponin measurement should be avoided. In addition, further study regarding troponins is needed as controversy remains as to the appropriate diagnostic cut points. Finally, tracking of troponin rises subsequent to procedures should be monitored to determine appropriate cut points.

Definition 3: cTnT Positive *and* AMI-code Positive

We found the lowest yield when this definition is applied to our study cohort. We found rates of 216 per 100,000 adult population in the Calgary Health Region in Period 1 and this rate actually decreased slightly over the next periods. This definition is perhaps too strict in that our analyses and chart reviews reveal that it will miss some true AMI patients.

Definition 4: cTnT Positive *or* AMI-code Positive

This definition yields the highest annual incidence rates per period with 444 per 100,000 adult population in the Calgary Health Region in Period 1, 439 in Period 2 and 455 in Period 3. If this definition were to be implemented, coordinated lab and data systems would be required. This is feasible in Canada and other developed countries where movement towards the electronic health record is underway. It is hoped that the transition to the electronic health record will also expedite, standardize and improve the coding process as well as ensure the sustainability of surveillance initiatives.

Choosing the "best" definition for Health Surveillance

Quality data systems are vital to good health surveillance. The Calgary Health Region is a leading health region in this regard with its automated and standardized coding rules that have the potential to minimize miscoding (though not entirely). Calgary is also a leader in laboratory medicine with a centralized laboratory data system that allows for monitoring and electronic compilation of important diagnostic tests (i.e., troponins, creatinine, HgA1C). Integration of these data systems adds huge value to understanding the incidence of AMI.

Our results indicate that the study findings vary only minimally across the three time periods studied. The greatest variation in results relates, rather, to the surveillance definitions used within each time period, more than to any time trends in sensitivity or PPV of administrative data coding. Because new definitions do confuse efforts to follow trends and outcomes, methods to adjust the new criteria to the old will need to be developed. Our results highlight the need for a new surveillance definition and the question still remains of which one to use.

Each of the four surveillance definitions studied has its limitations. Our results show a range in incidence rates from 216 when the most conservative definition of cTnT positive *and* AMI-code positive is used to 416 when the most liberal definition of cTnT positive *or* AMI-code is used. These two definitions (one very 'liberal' and the other very 'conservative') provide confidence intervals of sorts on the true incidence of AMI, since one probably overestimates the incidence while the other underestimates. As previously discussed, each definition has its strengths and weaknesses, and recognizing this, one approach for future disease surveillance activities would be to recommend the reporting of more than one rate, so that a range of estimated incidence can be communicated (i.e., the 'true' incidence of MI is somewhere between x per 100,000 population and y per 100,000 population).

The 'cTnT positive *and* AMI-code positive' definition is likely to be a highly specific definition that would be good to use in instances when research or surveillance has as its goal the identification of individuals and each definite AMI cases (e.g., for a follow up survey of care post-AMI).

In studies at the population level, meanwhile, where the goal is perhaps to identify any individuals at increased risk for cardiac events based on past cardiac events, the more liberal cTnT positive *or* AMI-code positive definition would perhaps be better.

We recognize that not all jurisdictions are capable of AMI surveillance using the definition of cTnT positive *or* AMI-code positive in that integrated laboratory systems are not available in all health regions. Trying to integrate such systems would, in some instances, be expensive and overwhelming. However, regions like the Calgary health region could serve as sentinel surveillance sites. In addition, surveillance data from Calgary could be used to play a critical role in regions with limited resources or where only administrative data is available by producing information on the sensitivity of coding for various conditions. That information could then be used to calculate 'inflated' disease prevalence and incidence measures for other jurisdictions that do not have laboratory data based on the estimates of missed cases determined in regions like Calgary, where both coded administrative data and laboratory data exist.

These findings are applicable to other chronic diseases where lab results identify disease. Adding laboratory data to restricted administrative data can enhance data definitions and surveillance of chronic disease. For example, renal disease is quantified using creatinine levels and diabetes can be defined using hemoglobin A1C values and/or fasting or random glucose values. Similarly, thyroid disease could be detected through a combination of abnormal stimulating hormone (TSH) and thyroxine levels.

Finally, we must remember that for surveillance purposes, the sensitivity and positive predictive values do not need to be perfect. A surveillance system can still be useful in

monitoring trends, as long as sensitivity and PPV remain stable over time. The "best' definition for AMI surveillance therefore depends to some extent on the primary objectives of the users and stakeholders.

LIMITATIONS

None of the surveillance methods assessed in this proposal were able to detect patients who suffer asymptomatic or 'silent' AMI as many of these patients are not hospitalized and therefore are not registered in the inpatient, outpatient, or troponin datasets. It has been reported that as many as 25% of infarcts are silent, especially in patients with diabetes.[115] The epidemiology of silent AMI – an important area in need of further research – can thus not be clarified by this research.

We could not study specificity in this proposal, since we could not determine the true numbers of 'no AMI' cases among patients who did not have troponins measured (i.e., cell 'd' in the 2 X 2 table presented in the methodology section).

We used the laboratory data as the "reference standard" and this may require some caution in the interpretation of results. It is acknowledged that there is no perfectly sensitive and specific system for detecting all AMIs.

Finally, as mentioned earlier, we recognize that our assessment of ICD-10-CA coded AMIs occurred at a relatively early time in ICD-10-CA implementation. One possible explanation for the low sensitivity seen in ICD-10CA is the suboptimal application of the new coding system, with subsequent potential for improvement. However, we have pointed out that there are reasons to believe that the sensitivity will not improve much with time, as the constraints of ICD-10-CA are not all that different from those existing in ICD-9-CM.

CONCLUSIONS

Given the uncertainty of optimal methodologies for surveillance, there is a strong need for research into surveillance methodologies. Although this study was performed during the time of transition from ICD-9-CM to ICD-10 coding, we found that this important coding system changeover did not significantly influence MI coding or incidence estimates. The increased availability of electronic health information, linkages across data systems and integration of laboratory data at the individual level represent important opportunities for the methodological enhancement of disease surveillance. Better surveillance information, in turn, can lead to more efficient and effective disease control activities. We reviewed 4 definitions of AMI surveillance and though the optimal choice of an AMI surveillance definition is far from being clear, we suggest a definition based on a combination of laboratory data and administrative hospital discharge data. Regardless of surveillance definition used, ongoing efforts to improve administrative data coding quality will remain an important goal.

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APPENDIX 1 – ICD-9-CM and ICD-10-CA codes for AMI

ICD-9-CM Coding

410 Acute myocardial infarction

Classification of an MI is according to the location in the heart when known.

The following **fifth-digit subclassification** is for use with category 410:

0 episode of care unspecified

1 initial episode of care – use fifth-digit 1 to designate the first episode of care (regardless of facility site) for a newly diagnosed MI. The fifth-digit 1 is assigned regardless of the number of times a patient may be transferred during the initial episode of care.

2 subsequent episode of care - use fifth-digit 2 to designate an episode of care following the initial episode of care when the patient is admitted for further observation, evaluation or treatment for a MI that has received initial treatment, but is still less than 8 weeks old.

410.0 Of anterolateral wall
410.1 Of other anterior wall
410.2 Of inferolateral wall
410.3 Of inferoposterior wall
410.4 Of other inferior wall (diaphragmatic NOS, inferior wall NOS)
410.5 Of other lateral wall (apical-lateral, basil-lateral, high lateral, posterolateral)
410.6 True posterior wall infarction (posterobasal, strictly posterior)
410.7 Subendocardial infarction – nontransmural infarction
410.8 Of other specified site (atrium, papillary muscle, septum alone)
410.9 Unspecified site (acute myocardial infarction NOS, coronary occlusion NOS)

ICD-10-CA Coding

I21 – Acute myocardial infarction

Includes: myocardial infarction specified as acute or with a stated duration of 4 weeks (28 days) or less from onset.

Excludes: certain current complications following acute myocardial infarction (I23.-).

- old (I25.2)
- specified or chronic or with a stated duration of more than 4 weeks from onset (I25.8)
- subsequent (I22.-)
- post myocardial infarction syndrome (I24.1)

I21.0 Acute transmural (Q-wave) myocardial infarction of anterior wall. Includes: transmural infarction of: anterior, anteroapical, anterolateral, anteroseptal.

I21.1 Acute transmural (Q-wave) myocardial infarction of inferior wall. Includes: transmural infarction of diaphragmatic wall, inferior, inferolateral, and inferoposterior.

I21.2 Acute transmural (Q-wave) myocardial infarction of other sites. Includes: apical-lateral, basal-lateral, high lateral, lateral NOS, true posterior, posterobasal, posterolateral, posteroseptal and septal NOS.

I21.3 Acute transmural (Q-wave) myocardial infarction of unspecified site. Includes transmural myocardial infarction NOS.
I21.4 Acute subendocardial myocardial infarction. Includes: Non-Q-wave myocardial infarction, ST elevation infarction (acute) of: anterior wall, lateral wall, other sites, unspecified sites.
I21.40 Acute subendocardial myocardial infarction of anterior wall.
I21.41 Acute subendocardial myocardial infarction of inferior wall.
I21.42 Acute subendocardial myocardial infarction of other sites. Includes: subendocardial myocardial infarction of: lateral wall, posterior wall.
I21.49 Acute subendocardial myocardial infarction, unspecified site.
I21.9 Acute myocardial infarction, unspecified. Includes: myocardial infarction NOS.

- The ICD-9-CM uses the 5th digit to represent episode of care. This is not the case in the new ICD-10-CA classification. The new ICD-10-CA system uses I22 to represent subsequent MI.

APPENDIX 2: Elixhauser coding

Table 2 ICD-9-CM and ICD-10 coding algorithms for Elixhauser comorbidities

Comorbidities	Elixhauser's original ICD-9-CM	Elixhauser AHRQ-Web ICD-9-CM	ICD-10	Enhanced ICD-9-CM
Congestive heart failure	398.91, 402.11, 402.91, 404.11, 404.13, 404.91, 404.93, 428.x	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.x	I09.9, I11.0, I13.0, I13.2, I25.5, I42.0, I42.5-I42.9, I43.x, I50.x, P29.0	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 425.4-425.9, 428.x
Cardiac arrhythmias	426.10, 426.11, 426.13, 426.2-426.53, 426.6-426.8, 427.0, 427.2, 427.31, 427.60, 427.9, 785.0, V45.0, V53.3	--	I44.1-I44.3, I45.6, I45.9, I47.x-I49.x, R00.0, R00.1, R00.8, T82.1, Z45.0, Z95.0	426.0, 426.13, 426.7, 426.9, 426.10, 426.12, 427.0-427.4, 427.6-427.9, 785.0, 996.01, 996.04, V45.0, V53.3
Valvular disease	093.2, 394.0-397.1, 424.0-424.91, 746.3-746.6, V42.2, V43.3	093.2, 394.x-397.1, 397.9, 424.x, 746.3-746.6,V42.2, V43.3	A52.0, I05.x-I08.x, I09.1, I09.8, I34.x-I39.x, Q23.0-Q23.3, Z95.2-Z95.4	093.2, 394.x-397.x, 424.x, 746.3-746.6, V42.2, V43.3
Pulmonary circulation disorders	416.x, 417.9	416.x, 417.9	I26.x, I27.x, I28.0, I28.8, I28.9	415.0, 415.1, 416.x, 417.0, 417.8, 417.9
Peripheral vascular disorders	440.x, 441.2, 441.4, 441.7, 441.9, 443.1-443.9, 447.1, 557.1, 557.9, V43.4	440.x, 441.x, 442.x, 443.1-443.9, 447.1, 557.1,557.9, V43.4	I70.x, I71.x, I73.1, I73.8, I73.9, I77.1, I79.0, I79.2, K55.1, K55.8, K55.9, Z95.8, Z95.9	093.0, 437.3, 440.x, 441.x, 443.1-443.9, 447.1, 557.1, 557.9, V43.4
Hypertension				
Hypertension, uncomplicated	401.1, 401.9	401.1, 401.9, 642.0	I10.x	401.x

Comorbidities	Elixhauser's original ICD-9-CM	Elixhauser AHRQ-Web ICD-9-CM	ICD-10	Enhanced ICD-9-CM
Hypertension, complicated	402.10, 402.90, 404.10, 404.90, 405.1, 405.9	401.0, 402.x-405.x, 642.1, 642.2, 642.7, 642.9	I11.x-I13.x, I15.x	402.x-405.x
Paralysis	342.0, 342.1, 342.9-344.x	342.x-344.x, 438.2-438.5	G04.1, G11.4, G80.1, G80.2, G81.x, G82.x, G83.0-G83.4, G83.9	334.1, 342.x, 343.x, 344.0-344.6, 344.9
Other neurological disorders	331.9, 332.0, 333.4, 333.5, 334.x, 335.x, 340.x, 341.1-341.9, 345.0, 345.1, 345.4, 345.5, 345.8, 345.9, 348.1, 348.3, 780.3, 784.3	330.x-331.x, 332.0, 333.4, 333.5, 334.x-335.x, 340, 341.1-341.9, 345.x, 347.x, 780.3, 784.3	G10.x-G13.x, G20.x-G22.x, G25.4, G25.5, G31.2, G31.8, G31.9, G32.x, G35.x-G37.x, G40.x, G41.x, G93.1, G93.4, R47.0, R56.x	331.9, 332.0, 332.1, 333.4, 333.5, 333.92, 334.x-335.x, 336.2, 340.x, 341.x, 345.x, 348.1, 348.3, 780.3, 784.3
Chronic pulmonary disease	490-492.8, 493.00-493.91, 494.x-505.x, 506.4	490x-492.x, 493.x, 494x--505.x, 506.4	I27.8, I27.9, J40.x-J47.x, J60.x-J67.x, J68.4, J70.1, J70.3	416.8, 416.9, 490.x -505.x, 506.4, 508.1, 508.8
Diabetes, uncomplicated	250.0-250.3	250.0-250.3, 648.0	E10.0, E10.1, E10.9, E11.0, E11.1, E11.9, E12.0, E12.1, E12.9, E13.0, E13.1, E13.9, E14.0, E14.1, E14.9	250.0-250.3
Diabetes, complicated	250.4-250.7, 250.9	250.4-250.9, 775.1	E10.2-E10.8, E11.2-E11.8, E12.2-E12.8, E13.2-E13.8, E14.2-E14.8	250.4-250.9
Hypothyroidism	243-244.2, 244.8, 244.9	243-244.2, 244.8, 244.9	E00.x-E03.x, E89.0	240.9, 243.x, 244.x, 246.1, 246.8

Comorbidities	Elixhauser's original ICD-9-CM	Elixhauser AHRQ-Web ICD-9-CM	ICD-10	Enhanced ICD-9-CM
Renal failure	403.11, 403.91, 404.12, 404.92, 585.x, 586.x, V42.0, V45.1, V56.0, V56.8	403.01, 403.11, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, 585.x, 586.x, V42.0, V45.1, V56.x	I12.0, I13.1, N18.x, N19.x, N25.0, Z49.0-Z49.2, Z94.0, Z99.2	403.01, 403.11, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, 585.x, 586.x, 588.0, V42.0, V45.1, V56.x
Liver disease	070.32, 070.33, 070.54, 456.0, 456.1, 456.2, 571.0, 571.2-571.9, 572.3, 572.8, V42.7	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 456.0, 456.1, 456.20, 571.0, 571.2--571.9, 572.3, 572.8, V42.7	B18.x, I85.x, I86.4, I98.2, K70.x, K71.1, K71.3-K71.5, K71.7, K72.x-K74.x, K76.0, K76.2-K76.9, Z94.4	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 070.6, 070.9, 456.0-456.2, 570.x, 571.x, 572.2-572.8, 573.3, 573.4, 573.8, 573.9, V42.7
Peptic ulcer disease excluding bleeding	531.70, 531.90, 532.70, 532.90, 533.70, 533.90, 534.70, 534.90, V12.71	531.41, 531.51, 531.61, 531.7, 531.91, 532.41, 532.51, 532.61, 532.7, 532.91, 533.41, 533.51, 533.61, 533.7, 533.91, 534.41, 534.51, 534.61, 534.7, 534.91	K25.7, K25.9, K26.7, K26.9, K27.7, K27.9, K28.7, K28.9	531.7, 531.9, 532.7, 532.9, 533.7, 533.9, 534.7, 534.9
AIDS/HIV	042.x-044.x	042.x-044.x	B20.x-B22.x, B24.x	042.x-044.x
Lymphoma	200.x-202.3x, 202.5-203.0, 203.8, 238.6, 273.3, V10.71, V10.72, V10.79	200.x-202.3, 202.5-203.0, 203.8, 238.6, 273.3	C81.x-C85.x, C88.x, C96.x, C90.0, C90.2	200.x-202.x, 203.0, 238.6
Metastatic cancer	196.x-199.x	196.x-199.x	C77.x-C80.x	196.x-199.x

Comorbidities	Elixhauser's original ICD-9-CM	Elixhauser AHRQ-Web ICD-9-CM	ICD-10	Enhanced ICD-9-CM
Solid tumor without metastasis	140.x-172.x, 174.x, 175.x, 179.x-195.x, V10.x	140.x-172.x, 174.x, 175.x, 179.x-195.x	C00.x-C26.x, C30.x-C34.x, C37.x-C41.x, C43.x, C45.x-C58.x, C60.x-C76.x, C97.x	140.x-172.x, 174.x-195.x
Rheumatoid arthritis/collagen vascular diseases	701.0, 710.x, 714.x, 720.x, 725.x	701.0, 710.x, 714.x, 720.x, 725.x	L94.0, L94.1, L94.3, M05.x, M06.x, M08.x, M12.0, M12.3, M30.x, M31.0-M31.3, M32.x-M35.x, M45.x, M46.1, M46.8, M46.9	446.x, 701.0, 710.0-710.4, 710.8, 710.9, 711.2, 714.x, 719.3, 720.x, 725.x, 728.5, 728.89, 729.30
Coagulopathy	286.x, 287.1, 287.3-287.5	286.x, 287.1, 287.3-287.5	D65-D68.x, D69.1, D69.3-D69.6	286.x, 287.1, 287.3-287.5
Obesity	278.0	278.0	E66.x	278.0
Weight loss	260.x-263.x	260.x-263.x, 783.2	E40.x-E46.x, R63.4, R64	260.x-263.x, 783.2, 799.4
Fluid and electrolyte disorders	276.x	276.x	E22.2, E86.x, E87.x	253.6, 276.x
Blood loss anemia	280.0	280.0, 648.2	D50.0	280.0
Deficiency anemia	280.1-281.9, 285.9	280.1-281.9, 285.2, 285.9	D50.8, D50.9, D51.x-D53.x	280.1-208.9, 281.x
Alcohol abuse	291.1, 291.2, 291.5-291.9, 303.9, 305.0, V113	291.0-291.3, 291.5, 291.8, 291.9, 303.x, 305.0	F10, E52, G62.1, I42.6, K29.2, K70.0, K70.3, K70.9, T51.x, Z50.2, Z71.4, Z72.1	265.2, 291.1-291.3, 291.5-291.9, 303.0, 303.9, 305.0, 357.5, 425.5, 535.3, 571.0-571.3, 980.x V11.3
Drug abuse	292.0, 292.82-292.89, 292.9, 304.0, 305.2-305.9	292.0, 292.82-292.89, 292.9, 304.x, 305.2-305.9, 648.3	F11.x-F16.x, F18.x, F19.x, Z71.5, Z72.2	292.x, 304.x, 305.2-305.9, V65.42
Psychoses	295.x-298.x, 299.1	295.x-298.x, 299.1	F20.x, F22.x-F25.x, F28.x, F29.x, F30.2, F31.2, F31.5	293.8, 295.x, 296.04, 296.14, 296.44, 296.54, 297.x, 298.x
Depression	300.4, 301.12, 309.0, 309.1, 311	300.4, 301.12, 309.0, 309.1, 311	F20.4, F31.3-F31.5, F32.x, F33.x, F34.1, F41.2, F43.2	296.2, 296.3, 296.5, 300.4, 309.x, 311

APPENDIX 3 – SAS Code for Elixhauser

Enhanced ICD-9-CM Elixhauser Variable Definitions with Diagnosis Type

```
array ec{16} dx1-dx16;
array ecsuf(116) dxsuf1-dxsuf16;
array ecty(117) dxtyp1-dxtyp16;
echf=0;
do i=1 to 16;
if ((substr (ec{i},1,4)='3989' and ecsuf{i}='1') or (substr (ec{i},1,4)='4021'and ecsuf{i}='1')
or (substr (ec{i},1,4)='4029' and ecsuf{i}='1') or (substr (ec{i},1,4)='4041' and ecsuf{i}='1')
or (substr (ec{i},1,4)='4041' and ecsuf{i}='3')or (substr (ec{i},1,4)='4049' and ecsuf{i}='1')
or (substr (ec{i},1,4)='4049'and ecsuf{i}=3) or substr (ec{i},1,4)='4280'
or substr (ec{i},1,4)='4281' or substr (ec{i},1,4)='4282'
or substr (ec{i},1,4)='4283' or substr (ec{i},1,4)='4284'
or substr (ec{i},1,4)='4285' or substr (ec{i},1,4)='4286'
or substr (ec{i},1,4)='4287' or substr (ec{i},1,4)='4288'
or substr (ec{i},1,4)='4289') and ecty{i}~='2'
then echf=1;
end;

array ecarh{16} dx1-dx16;
array ecarhty{16} dxtyp1-dxtyp16;
ecrhy=0;
do i=1 to 16;
if ((substr (ecarh{i},1,4)='4261'and ecsuf{i}='0') or (substr (ecarh{i},1,4)='4261'and
ecsuf{i}='1')
or (substr (ecarh{i},1,4)='4261' and ecsuf{i}='3') or substr (ecarh{i},1,4)='4262'
or substr (ecarh{i},1,4)='4263' or substr (ecarh{i},1,4)='4264'
or (substr (ecarh{i},1,4)='4265' and ecsuf{i}='0') or (substr (ecarh{i},1,4)='4265' and
ecsuf{i}='1')
or (substr (ecarh{i},1,4)='4265' and ecsuf{i}='2') or (substr (ecarh{i},1,4)='4265' and
ecsuf{i}='3')
or substr (ecarh{i},1,4)='4266' or substr (ecarh{i},1,4)='4267'
or substr (ecarh{i},1,4)='4268' or substr (ecarh{i},1,4)='4270'
or substr (ecarh{i},1,4)='4272' or (substr (ecarh{i},1,4)='4273' and ecsuf{i}='1')
or (substr (ecarh{i},1,4)='4276' and ecsuf{i}='0') or substr (ecarh{i},1,4)='4279'
or substr (ecarh{i},1,4)='7850' or substr (ecarh{i},1,4)='v450'
or substr (ecarh{i},1,4)='V533') and ecarhty{i}~='2'
then ecrhy=1;
end;

array evd{16} dx1-dx16;
array evdty{16} dxtyp1-dxtyp16;
```

```
evald=0;
do i=1 to 16;
if (substr (evd{i},1,4)='0932' or substr (evd{i},1,4)='3940'
or substr (evd{i},1,4)='3941' or substr (evd{i},1,4)='3942'
or substr (evd{i},1,4)='3949' or substr (evd{i},1,3)='395'
or substr (evd{i},1,3)='396' or substr (evd{i},1,4)='3970'
or substr (evd{i},1,4)='3971' or substr (evd{i},1,4)='4240'
or substr (evd{i},1,4)='4241' or substr (evd{i},1,4)='4242'
or substr (evd{i},1,4)='4243' or (substr (evd{i},1,4)='4249' and ecsuf{i}='1')
or (substr (evd{i},1,4)='4249' and ecsuf{i}='1') or substr (evd{i},1,4)='7463'
or substr (evd{i},1,4)='7464' or substr (evd{i},1,4)='7465'
or substr (evd{i},1,4)='7466' or substr (evd{i},1,4)='V422'
or substr (evd{i},1,4)='V433') and evdty{i}~='2'
then evald=1;
end;

array pcd{16} dx1-dx16;
array pcdty{16} dxtyp1-dxtyp16;
epcd=0;
do i=1 to 16;
if (substr (pcd{i},1,3)='416' or substr (pcd{i},1,4)='4179')
and pcdty{i}~='2'
then epcd=1;
end;

array pv{16} dx1-dx16;
array pvty{16} dxtyp1-dxtyp16;
epvd=0;
do i=1 to 16;
if (substr (pv{i},1,3)='440' or substr (pv{i},1,4)='4412'
or substr (pv{i},1,4)='4414' or substr (pv{i},1,4)='4417'
or substr (pv{i},1,4)='4419' or substr (pv{i},1,4)='4431'
or substr (pv{i},1,4)='4438' or substr (pv{i},1,4)='4439'
or substr (pv{i},1,4)='4471' or substr (pv{i},1,4)='5571'
or substr (pv{i},1,4)='5579' or substr (pv{i},1,4)='v434')
and pvty{i}~='2'
then epvd=1;
end;

array hyu{16} dx1-dx16;
array hyuty{16} dxtyp1-dxtyp16;
ehypun=0;
do i=1 to 16;
if (substr (hyu{i},1,4)='4011' or substr (hyu{i},1,4)='4019')
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and hyuty{i}~='2'
then ehypun=1;
end;

array hyc{16} dx1-dx16;
array hycty{16} dxtyp1-dxtyp16;
ehypc=0;
do i=1 to 16;
if ((substr (hyc{i},1,4)='4021' and ecsuf{i}='0') or (substr (hyc{i},1,4)='4029'and
ecsuf{i}='0')
or (substr (hyc{i},1,4)='4041' and ecsuf{i}='0') or (substr (hyc{i},1,4)='4049' and
ecsuf{i}='0')
or (substr (hyc{i},1,4)='4051' and ecsuf{i}='1') or (substr (hyc{i},1,4)='4051' and
ecsuf{i}='9')
or (substr (hyc{i},1,4)='4059' and ecsuf{i}='1') or (substr (hyc{i},1,4)='4059' and
ecsuf{i}='9'))
and hycty{i}~='2'
then ehypc=1;
end;

array par{16} dx1-dx16;
array paty{16} dxtyp1-dxtyp16;
epara=0;
do i=1 to 16;
if (substr (par{i},1,4)='3420' or (substr (par{i},1,4)='3421' and ecsuf{i}='0')
or (substr (par{i},1,4)='3421' and ecsuf{i}='0') or (substr (par{i},1,4)='3421' and
ecsuf{i}='2')
or substr (par{i},1,4)='3429' or substr (par{i},1,3)='343'
or substr (par{i},1,3)='344') and paty{i}~='2'
then epara=1;
end;

array oneu{16} dx1-dx16;
array oneuty{16} dxtyp1-dxtyp16;
eothneu=0;
do i=1 to 16;
if (substr (oneu{i},1,4)='3319' or substr (oneu{i},1,4)='3320'
or substr (oneu{i},1,4)='3334' or substr (oneu{i},1,4)='3335'
or substr (oneu{i},1,3)='334' or substr (oneu{i},1,3)='335'
or substr (oneu{i},1,3)='340' or substr (oneu{i},1,4)='3411'
or substr (oneu{i},1,4)='3418' or substr (oneu{i},1,4)='3419'
or substr (oneu{i},1,4)='3450' or (substr (oneu{i},1,4)='3451' and ecsuf{i}='0')
or (substr (oneu{i},1,4)='3451' and ecsuf{i}='1') or substr (oneu{i},1,4)='3454'
or (substr (oneu{i},1,4)='3455' and ecsuf{i}='0') or (substr (oneu{i},1,4)='3455' and
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ecsuf{i}='1')
or substr (oneu{i},1,4)='3458' or (substr (oneu{i},1,4)='3459' and ecsuf{i}='0')
or (substr (oneu{i},1,4)='3459' and ecsuf{i}='1') or substr (oneu{i},1,4)='3481'
or substr (oneu{i},1,4)='3483' or substr (oneu{i},1,4)='7803'
or substr (oneu{i},1,4)='7843') and oneuty{i}~='2'
then eothneu=1;
end;

array cepd{16} dx1-dx16;
array cepdty{16} dxtyp1-dxtyp16;
ecpd=0;
do i=1 to 16;
if (substr (cepd{i},1,3)='490' or substr (cepd{i},1,3)='491'
or substr (cepd{i},1,3)='492' or substr (cepd{i},1,3)='493'
or substr (cepd{i},1,3)='494' or substr (cepd{i},1,3)='495'
or substr (cepd{i},1,3)='496' or substr (cepd{i},1,3)='500'
or substr (cepd{i},1,3)='501' or substr (cepd{i},1,3)='502'
or substr (cepd{i},1,3)='503' or substr (cepd{i},1,3)='504'
or substr (cepd{i},1,3)='505' or substr (cepd{i},1,4)='5064')
and cepdty{i}~='2'
then ecpd=1;
end;

array diau{16} dx1-dx16;
array diauty{16} dxtyp1-dxtyp16;
ediabun=0;
do i=1 to 16;
if (substr (diau{i},1,4)='2500' or substr (diau{i},1,4)='2501'
or substr (diau{i},1,4)='2502' or (substr (diau{i},1,4)='2503' and ecsuf{i}='0')
or (substr (diau{i},1,4)='2503' and ecsuf{i}='1') or (substr (diau{i},1,4)='2503' and
ecsuf{i}='2')
or (substr (diau{i},1,4)='2503' and ecsuf{i}='3')) and diauty{i}~='2'
then ediabun=1;
end;

array diac{16} dx1-dx16;
array diacty{16} dxtyp1-dxtyp16;
ediac=0;
do i=1 to 16;
if (substr (diac{i},1,4)='2504' or substr (diac{i},1,4)='2505'
or substr (diac{i},1,4)='2506' or (substr (diac{i},1,4)='2507' and ecsuf{i}='0')
or (substr (diac{i},1,4)='2507' and ecsuf{i}='1') or (substr (diac{i},1,4)='2507' and
ecsuf{i}='2')
or (substr (diac{i},1,4)='2507' and ecsuf{i}='1') or (substr (diac{i},1,4)='2509' and
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ecsuf{i}='0')
or (substr (diac{i},1,4)='2509' and ecsuf{i}='1') or (substr (diac{i},1,4)='2509' and
ecsuf{i}='2')
or (substr (diac{i},1,4)='2509' and ecsuf{i}='3')) and diacty{i}~='2'
then ediac=1;
end;

array hyth{16} dx1-dx16;
array hythty{16} dxtyp1-dxtyp16;
ehythyro=0;
do i=1 to 16;
if (substr (hyth{i},1,3)='243' or substr (hyth{i},1,4)='2440'
or substr (hyth{i},1,4)='2441' or substr (hyth{i},1,4)='2442'
or substr (hyth{i},1,4)='2448' or substr (hyth{i},1,4)='2449')
and hythty{i}~='2'
then ehythyro=1;
end;

array rf{16} dx1-dx16;
array rfty{16} dxtyp1-dxtyp16;
erenfail=0;
do i=1 to 16;
if ((substr (rf{i},1,4)='4031' and ecsuf{i}='1') or (substr (rf{i},1,4)='4039' and ecsuf{i}='1')
or (substr (rf{i},1,4)='4041' and ecsuf{i}='1') or (substr (rf{i},1,4)='4049' and ecsuf{i}='2')
or substr (rf{i},1,3)='485' or substr (rf{i},1,3)='586'
or substr (rf{i},1,4)='V420' or substr (rf{i},1,4)='V451'
or substr (rf{i},1,4)='V560' or substr (rf{i},1,4)='V568')
and rfty{i}~='2'
then erenfail=1;
end;

array ld{16} dx1-dx16;
array ldty{16} dxtyp1-dxtyp16;
elivd=0;
do i=1 to 16;
if ((substr (ld{i},1,4)='0703' and ecsuf{i}='2') or (substr (ld{i},1,4)='0703' and ecsuf{i}='3')
or (substr (ld{i},1,4)='0705' and ecsuf{i}='4') or substr (ld{i},1,4)='4560'
or substr (ld{i},1,4)='4561' or (substr (ld{i},1,4)='4562' and ecsuf{i}='0')
or (substr (ld{i},1,4)='4562' and ecsuf{i}='1') or substr (ld{i},1,4)='5710'
or substr (ld{i},1,4)='5712' or substr (ld{i},1,4)='5713'
or substr (ld{i},1,4)='5714' or substr (ld{i},1,4)='5715'
or substr (ld{i},1,4)='5716' or substr (ld{i},1,4)='5718'
or substr (ld{i},1,4)='5719' or substr (ld{i},1,4)='5723'
or substr (ld{i},1,4)='5728' or substr (ld{i},1,4)='V427')
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and ldty{i}~='2'
then elivd=1;
end;

array pu{16} dx1-dx16;
array puty{16} dxtyp1-dxtyp16;
epepul=0;
do i=1 to 16;
if ((substr (pu{i},1,4)='5317' and ecsuf{i}='0') or (substr (pu{i},1,4)='5319' and ecsuf{i}='0')
or (substr (pu{i},1,4)='5327' and ecsuf{i}='0') or (substr (pu{i},1,4)='5329' and ecsuf{i}='0')
or (substr (pu{i},1,4)='5337' and ecsuf{i}='0') or (substr (pu{i},1,4)='5339' and ecsuf{i}='0')
or (substr (pu{i},1,4)='5347' and ecsuf{i}='0') or (substr (pu{i},1,4)='5349' and ecsuf{i}='0')
or (substr (pu{i},1,4)='V127' and ecsuf{i}='1'))
and puty{i}~='2'
then epepul=1;
end;

array aids{16} dx1-dx16;
array aidsty{16} dxtyp1-dxtyp16;
eaids=0;
do i=1 to 16;
if (substr (aids{i},1,3)='042' or substr (aids{i},1,3)='043'
or substr (aids{i},1,3)='044') and aidsty{i}~='2'
then eaids=1;
end;

array lym{16} dx1-dx16;
array lymty{16} dxtyp1-dxtyp16;
elymph=0;
do i=1 to 16;
if (substr (lym{i},1,3)='200' or substr (lym{i},1,3)='201'
or substr (lym{i},1,4)='2020' or substr (lym{i},1,4)='2021'
or substr (lym{i},1,4)='2022' or substr (lym{i},1,4)='2023'
or substr (lym{i},1,4)='2025' or substr (lym{i},1,4)='2026'
or substr (lym{i},1,4)='2028' or substr (lym{i},1,4)='2029'
or substr (lym{i},1,4)='2030' or substr (lym{i},1,4)='2038'
or substr (lym{i},1,4)='2386' or substr (lym{i},1,4)='2733'
or substr (lym{i},1,4)='V1071' or substr (lym{i},1,4)='V1072'
or substr (lym{i},1,4)='V1079') and lymty{i}~='2'
then elymph=1;
end;

array mc{16} dx1-dx16;
array mcty{16} dxtyp1-dxtyp16;
```

```
emetcan=0;
do i=1 to 16;
if (substr (mc{i},1,3)='196' or substr (mc{i},1,3)='197'
or substr (mc{i},1,3)='198' or substr (mc{i},1,3)='199')
and mcty{i}~='2'
then emetcan=1;
end;

array st{16} dx1-dx16;
array stty{16} dxtyp1-dxtyp16;
esolidt=0;
do i=1 to 16;
if (substr (st{i},1,3)='140' or substr (st{i},1,3)='141'
or substr (st{i},1,3)='142' or substr (st{i},1,3)='143'
or substr (st{i},1,3)='144' or substr (st{i},1,3)='145'
or substr (st{i},1,3)='146' or substr (st{i},1,3)='147'
or substr (st{i},1,3)='148' or substr (st{i},1,3)='149'
or substr (st{i},1,3)='150' or substr (st{i},1,3)='151'
or substr (st{i},1,3)='152' or substr (st{i},1,3)='153'
or substr (st{i},1,3)='154' or substr (st{i},1,3)='155'
or substr (st{i},1,3)='156' or substr (st{i},1,3)='157'
or substr (st{i},1,3)='158' or substr (st{i},1,3)='159'
or substr (st{i},1,3)='160' or substr (st{i},1,3)='161'
or substr (st{i},1,3)='162' or substr (st{i},1,3)='163'
or substr (st{i},1,3)='164' or substr (st{i},1,3)='165'
or substr (st{i},1,3)='170' or substr (st{i},1,3)='171'
or substr (st{i},1,3)='172' or substr (st{i},1,3)='174'
or substr (st{i},1,3)='175' or substr (st{i},1,3)='179'
or substr (st{i},1,3)='180' or substr (st{i},1,3)='181'
or substr (st{i},1,3)='182' or substr (st{i},1,3)='183'
or substr (st{i},1,3)='184' or substr (st{i},1,3)='185'
or substr (st{i},1,3)='186' or substr (st{i},1,3)='187'
or substr (st{i},1,3)='188' or substr (st{i},1,3)='189'
or substr (st{i},1,3)='190' or substr (st{i},1,3)='191'
or substr (st{i},1,3)='192' or substr (st{i},1,3)='193'
or substr (st{i},1,3)='194' or substr (st{i},1,3)='195'
or substr (st{i},1,3)='V10') and lymty{i}~='2'
then esolidt=1;
end;

array ra{16} dx1-dx16;
array raty{16} dxtyp1-dxtyp16;
erheuma=0;
do i=1 to 16;
```

```
if (substr (ra{i},1,4)='7010' or substr (ra{i},1,3)='710'
or substr (ra{i},1,3)='714' or substr (ra{i},1,3)='720'
or substr (ra{i},1,3)='725') and raty{i}~='2'
then erheuma=1;
end;

array cg{16} dx1-dx16;
array cgty{16} dxtyp1-dxtyp16;
ecoag=0;
do i=1 to 16;
if (substr (cg{i},1,3)='286' or substr (cg{i},1,4)='2871'
or substr (cg{i},1,4)='2873' or substr (cg{i},1,4)='2874'
or substr (cg{i},1,4)='2875') and cgty{i}~='2'
then ecoag=1;
end;

array ob{16} dx1-dx16;
array obty{16} dxtyp1-dxtyp16;
eobese=0;
do i=1 to 16;
if (substr (ob{i},1,4)='2780') and obty{i}~='2'
then eobese=1;
end;

array wgtl{16} dx1-dx16;
array wgtlty{16} dxtyp1-dxtyp16;
ewgtl=0;
do i=1 to 16;
if (substr (wgtl{i},1,3)='260' or substr (wgtl{i},1,3)='261'
or substr (wgtl{i},1,3)='262' or substr (wgtl{i},1,3)='263')
and wgtlty{i}~='2'
then ewgtl=1;
end;

array fed{16} dx1-dx16;
array fedty{16} dxtyp1-dxtyp16;
efed=0;
do i=1 to 16;
if (substr (fed{i},1,3)='276') and fedty{i}~='2'
then efed=1;
end;

array bla{16} dx1-dx16;
array blaty{16} dxtyp1-dxtyp16;
```

```
ebla=0;
do i=1 to 16;
if (substr (bla{i},1,4)='2800') and blaty{i}~='2'
then ebla=1;
end;

array da{16} dx1-dx16;
array daty{16} dxtyp1-dxtyp16;
edefan=0;
do i=1 to 16;
if (substr (da{i},1,4)='2801' or substr (da{i},1,4)='2808'
or substr (da{i},1,4)='2809' or substr (da{i},1,3)='281'
or substr (da{i},1,4)='2859') and daty{i}~='2'
then edefan=1;
end;

array aa{16} dx1-dx16;
array aaty{16} dxtyp1-dxtyp16;
eaa=0;
do i=1 to 16;
if (substr (aa{i},1,4)='2911' or substr (aa{i},1,4)='2912'
or substr (aa{i},1,4)='2915' or substr (aa{i},1,4)='2918'
or substr (aa{i},1,4)='2919' or (substr (aa{i},1,4)='3039' and ecsuf{i}='0')
or (substr (aa{i},1,4)='3039' and ecsuf{i}='1') or (substr (aa{i},1,4)='3039' and ecsuf{i}='2')
or (substr (aa{i},1,4)='3039' and ecsuf{i}='3') or (substr (aa{i},1,4)='3050' and ecsuf{i}='0')
or (substr (aa{i},1,4)='3050' and ecsuf{i}='1') or (substr (aa{i},1,4)='3050' and ecsuf{i}='2')
or (substr (aa{i},1,4)='3050' and ecsuf{i}='3') or substr (aa{i},1,4)='V113')
and aaty{i}~='2'
then eaa=1;
end;

array drga{16} dx1-dx16;
array drgaty{16} dxtyp1-dxtyp16;
edruga=0;
do i=1 to 16;
if (substr (drga{i},1,4)='2920' or (substr (drga{i},1,4)='2928' and ecsuf{i}='2')
or (substr (drga{i},1,4)='2928' and ecsuf{i}='3') or (substr (drga{i},1,4)='2938' and
ecsuf{i}='4')
or (substr (drga{i},1,4)='2938' and ecsuf{i}='9') or substr (drga{i},1,4)='2929'
or substr (drga{i},1,4)='3040' or substr (drga{i},1,4)='3041'
or substr (drga{i},1,4)='3042' or substr (drga{i},1,4)='3043'
or substr (drga{i},1,4)='3045' or substr (drga{i},1,4)='3046'
or substr (drga{i},1,4)='3047' or substr (drga{i},1,4)='3048'
or (substr (drga{i},1,4)='3049' and ecsuf{i}='0') or (substr (drga{i},1,4)='3049' and
```

```
ecsuf{i}='1')
or (substr (drga{i},1,4)='3049' and ecsuf{i}='2') or (substr (drga{i},1,4)='3049' and
ecsuf{i}='3'))
and drgaty{i}~='2'
then edruga=1;
end;

array psych{16} dx1-dx16;
array psychty{16} dxtyp1-dxtyp16;
epsych=0;
do i=1 to 16;
if (substr (psych{i},1,3)='295' or substr (psych{i},1,3)='296'
or substr (psych{i},1,3)='297' or substr (psych{i},1,3)='298'
or (substr (psych{i},1,4)='2991' and ecsuf{i}='0') or (substr (psych{i},1,4)='2991' and
ecsuf{i}='1'))
and psychty{i}~='2'
then epsych=1;
end;

array dep{16} dx1-dx16;
array depty{16} dxtyp1-dxtyp16;
edepr=0;
do i=1 to 16;
if (substr (dep{i},1,4)='3004' or (substr (dep{i},1,4)='3011' and ecsuf{i}='2')
or substr (dep{i},1,4)='3090' or substr (dep{i},1,4)='3091'
or substr (dep{i},1,3)='311') and depty{i}~='2'
then edepr=1;
end;
run;
```

Elixhauser ICD-10 codes

```
/*************************************************/
/* Define database for ICD10                     */
/*************************************************/
libname mydir "p:\icd10_elixhauer";
options pagesize=300 linesize=69;
data mydir.icd102_2;
set mydir.icd101;

array ec2{16} dx_1-dx_16;
Etchf=0;
do i=1 to 16;
```

```
if (substr(ec2{i},1,4) in
('I099','I110','I130','I132','I255','I420','I425','I426','I427','I428','I429','P290') or
   substr(ec2{i},1,3) in ('I50','I43'))
then Etchf=1;
end;

array ecarh2{16} dx_1-dx_16;
Etcrhy=0;
do i=1 to 16;
if (substr(ecarh2{i},1,4) in
('I441','I442','I443','I456','I459','R000','R001','R008','T821','Z950','Z450') or
   substr(ecarh2{i},1,3) in ('I47','I48','I49'))
then Etcrhy=1;
end;

array evd2{16} dx_1-dx_16;
Etvald=0;
do i=1 to 16;
if (substr(evd2{i},1,3) in ('I05','I06','I07','I08','I34','I35','I36','I37','I38','I39') or
  substr(evd2{i},1,4) in
('A520','I091','I098','Q230','Q231','Q232','Q233','Z952','Z953','Z954'))
then Etvald=1;
end;

array pcd2{16} dx_1-dx_16;
Etpcd=0;
do i=1 to 16;
if (substr(pcd2{i},1,3) in ('I26','I27')or
   substr(pcd2{i},1,4) in ('I280,I288','I289'))
then Etpcd=1;
end;

array pv2{16} dx_1-dx_16;
Etpvd=0;
do i=1 to 16;
if (substr(pv2{i},1,3) in ('I70','I71') or
   substr(pv2{i},1,4) in
('I771','I731','I738','I739','I790','I792','K551','K558','K559','Z958','Z959'))
then Etpvd=1;
end;

array hyu2{16} dx_1-dx_16;
Ethypun=0;
do i=1 to 16;
```

```
if (substr(hyu2{i},1,3)in ('I10') )
then Ethypun=1;
end;

array hyc2{16} dx_1-dx_16;
Ethypc=0;
do i=1 to 16;
if (substr(hyc2{i},1,3) in ('I11','I12','I13','I15'))
then Ethypc=1;
end;

Ethyp=0;
if Ethypun=1 | Ethypc=1 then Ethyp=1;

array par2{16} dx_1-dx_16;
Etpara=0;
do i=1 to 16;
if (substr(par2{i},1,4) in
('G801','G802','G041','G114','G830','G831','G832','G833','G834','G839') or
   substr(par2{i},1,3) in ('G81','G82'))
then Etpara=1;
end;

array oneu2{16} dx_1-dx_16;
Etothneu=0;
do i=1 to 16;
 if (substr(oneu2{i},1,3) in
('G10','G11','G12','G13','G20','G21','G22','G32','G35','G36','G37','G40','G41','R56') or
    substr(oneu2{i},1,4) in ('G312','G318','G319','G254','G255','G931','G934','R470'))
then Etothneu=1;
end;

array cepd2{16} dx_1-dx_16;
Etcpd=0;
do i=1 to 16;
 if (substr(cepd2{i},1,3) in
('J40','J41','J42','J43','J44','J45','J46','J47','J60','J61','J62','J63','J64','J65','J66','J67') or
    substr(cepd2{i},1,4) in ('J684','I278','I279','J701','J703'))
then Etcpd=1;
end;

array diau2{16} dx_1-dx_16;
Etdiabun=0;
do i=1 to 16;
```

```
 if substr(diau2{i},1,4) in
('E100','E101','E109','E110','E111','E119','E120','E121','E129','E130','E131','E139','E140','E
141','E149')
then Etdiabun=1;
end;

array diac2{16} dx_1-dx_16;
Etdiac=0;
do i=1 to 16;
 if (substr(diac2{i},1,4) in ('E102', 'E103', 'E104', 'E105', 'E106', 'E107', 'E108', 'E112',
'E113', 'E114', 'E115', 'E116', 'E117', 'E118', 'E122', 'E123', 'E124', 'E125', 'E126', 'E127',
'E128', 'E132', 'E133', 'E134', 'E135', 'E136', 'E137', 'E138', 'E142', 'E143', 'E144', 'E145',
'E146', 'E147', 'E148'))
then Etdiac=1;
end;

array hyth2{16} dx_1-dx_16;
Ethythyro=0;
do i=1 to 16;
if (substr(hyth2{i},1,3) in ('E00','E01','E02','E03')  or
   substr(hyth2{i},1,4) in ('E890'))
then Ethythyro=1;
end;

array rf2{16} dx_1-dx_16;
Etrenfail=0;
do i=1 to 16;
if (substr(rf2{i},1,3) in ('N18','N19') or
   substr(rf2{i},1,4) in ('N250','Z490','Z491','Z492','Z940','Z992','I120','I131'))
then Etrenfail=1;
end;

array ld2{16} dx_1-dx_16;
Etlivd=0;
do i=1 to 16;
if (substr(ld2{i},1,3) in ('B18','I85','K70','K72','K73','K74') or
   substr(ld2{i},1,4) in
('I864','I982','K711','K713','K714','K715','K717','Z944','K760','K762','K763','K764','K765','K
766','K767','K768','K769'))
then Etlivd=1;
end;

array pu2{16} dx_1-dx_16;
Etpepul=0;
```

```
do i=1 to 16;
if (substr(pu2{i},1,4) in ('K257','K259','K267','K269','K277','K279','K287','K289'))
then Etpepul=1;
end;

array aids2{16} dx_1-dx_16;
Etaids=0;
do i=1 to 16;
if (substr(aids2{i},1,3) in ('B20','B21','B22','B24'))
then Etaids=1;
end;

array lym2{16} dx_1-dx_16;
Etlymph=0;
do i=1 to 16;
if (substr(lym2{i},1,3)in ('C81','C82','C83','C84','C85','C88','C96') or
   substr(lym2{i},1,4)in ('C900','C902'))
then Etlymph=1;
end;

array mc2{16} dx_1-dx_16;
Etmetcan=0;
do i=1 to 16;
if substr(mc2{i},1,3) in ('C77','C78','C79','C80') then Etmetcan=1;
end;

array st2{16} dx_1-dx_16;
Etsolidt=0;
do i=1 to 16;
if (substr(st2{i},1,3) in
('C00','C01','C02','C03','C04','C05','C06','C07','C08','C09','C10','C11','C12','C13','C14','C15
') or
   substr(st2{i},1,3) in ('C16','C17','C18','C19') or
   substr(st2{i},1,3) in
('C20','C21','C22','C23','C24','C25','C26','C30','C31','C32','C33','C34','C37','C38','C39','C40
') or
   substr(st2{i},1,3) in
('C41','C43','C45','C46','C47','C48','C49','C50','C51','C52','C53','C54','C55') or
   substr(st2(i),1,3) in
('C56','C57','C58','C60','C61','C62','C63','C64','C65','C66','C67','C68','C69','C70') or
   substr(st2(i),1,3) in ('C71','C72','C73','C74','C75','C76','C97'))
then Etsolidt=1;
end;
```

```
array ra2{16} dx_1-dx_16;
Etrheuma=0;
do i=1 to 16;
if (substr(ra2{i},1,4) in
('L940','L941','L943','M120','M123','M310','M311','M312','M313','M461','M468','M469') or
   substr(ra2{i},1,5) in ('M3130','M3131') or
   substr(ra2{i},1,3) in ('M05','M06','M08','M30','M32','M33','M34','M35','M45'))
then Etrheuma=1;
end;

array cg2{16} dx_1-dx_16;
Etcoag=0;
do i=1 to 16;
if (substr(cg2{i},1,3) in ('D65','D66','D67','D68') or
   substr(cg2{i},1,4) in ('D691','D693','D694','D695','D696'))
then Etcoag=1;
end;

array ob2{16} dx_1-dx_16;
Etobese=0;
do i=1 to 16;
if (substr(ob2{i},1,3) in ('E66'))
then Etobese=1;
end;

array wgtl2{16} dx_1-dx_16;
Etwgtl=0;
do i=1 to 16;
if (substr(wgtl2{i},1,3) in ('E40','E41','E42','E43','E44','E45','E46','R64') or
  substr(wgtl2{i},1,4) in ('R634'))
then Etwgtl=1;
end;

array fed2{16} dx_1-dx_16;
Etfed=0;
do i=1 to 16;
if (substr(fed2{i},1,3) in ('E86','E87') or
   substr(fed2{i},1,4) in ('E222','R571'))
then Etfed=1;
end;

array bla2{16} dx_1-dx_16;
Etbla=0;
do i=1 to 16;
```

```
if (substr(bla2{i},1,4) in ('D500'))
then Etbla=1;
end;

/*drop D50.0*/
array da2{16} dx_1-dx_16;
Etdefan=0;
do i=1 to 16;
if (substr(da2{i},1,3) in ('D51','D52','D53') or
   substr(da2{i},1,4) in ('D508','D509'))
then Etdefan=1;
end;

array aa2{16} dx_1-dx_16;
Etaa=0;
do i=1 to 16;
if (substr(aa2{i},1,3) in ('F10','E52','T51') or
   substr(aa2{i},1,4) in ('G621','I426','K292','K700','K703','K709','Z714','Z721','Z502'))
then Etaa=1;
end;

array drga2{16} dx_1-dx_16;
Etdruga=0;
do i=1 to 16;
if (substr(drga2{i},1,3) in ('F11','F12','F13','F14','F15','F16','F18','F19') or
   substr(drga2{i},1,4)in ('Z715','Z722'))
then Etdruga=1;
end;

array psych2{16} dx_1-dx_16;
Etpsych=0;
do i=1 to 16;
if (substr(psych2{i},1,3) in ('F20','F22','F23','F24','F25','F28','F29')or
   substr(psych2{i},1,4) in ('F302','F312','F315'))
then Etpsych=1;
end;

array dep2{16} dx_1-dx_16;
Etdepr=0;
do i=1 to 16;
if (substr(dep2{i},1,3) in ('F32','F33') or
   substr(dep2{i},1,4) in ('F341','F412','F204','F432','F313','F314','F315'))
then Etdepr=1;
end;
```

```
drop i; run;
proc freq data=mydir.icd102_2;
```

APPENDIX 4: Chart Abstraction Form

Hospital Number: _____ ULI: _____
Date of Birth: _____ Age: ____ Sex: __Male __Female

Date/time of hospital ADMISSION: _____Status:_____

Diagnosis on ER sheet:_____

Description of Chief Complaint: _____

	YES	NO
Patient able to communicate symptoms		
Weakness, dizziness or loss of consciousness		
Cardiac Arrest		
Ischemic symptoms on Admission:		
Retrosternal Chest Pain		
Jaw pain, neck pain, arm pain		
Prolonged pain >20 minutes at rest		
Associated SOB		
Associated nausea/vomiting		
Associated diaphoresis		
ECG indicative of ischemia on Admission:		
ST elevation:		
ST depression:		
T wave inversion:		
History of CAD – note date:		
Previous MI:		
Previous PCI:		
Previous CABG:		
IV Nitro (NTG) in ER		

LABORATORY DATA – please note if troponin ordered STAT

Enzymes indicative of ischemia: **Date/tI**	**Value**
* Peak troponin T	
Peak CK	
Peak CK-MB	
AST	
WBC	
Creatinine	

DURING HOSPITALIZATION (*if around time of troponin):

Ischemic symptoms:	YES	NO
Description of chief complaint:		
Chest Pain:		
Associated SOB:		

Associated nausea/vomiting:		
Associated diaphoresis:		
Weakness, dizziness or LOC		
ECG indicative of ischemia (close to time of troponin):		
ST elevation:		
ST depression:		
T wave inversion:		
Nitro around time of troponin: IV /sl /patch		
Heparin around time of troponin		

Procedures/Notes during Hospitalization: _____

Comments about elevated troponin:
Med HX: ___ Comment: _____

Progress Notes: ___ Comment: _____

Other comments: _____

CO-MORBID CONDITIONS

	YES	**NO**
Hypertension		
Hyperlipidemia		
CHF		
Diabetes Mellitus	Type I Type II	
PVD		
CVD		
Renal disease	Chronic Acute	
Dialysis during hospitalization		
Pulmonary Embolus		
Pulmonary – chronic lung disease		
Malignancy in the past 5 years		
Myocarditis		
Myositis		
Other:		

Discharge date: _____ Diagnosis on Discharge Summary:

	YES	**NO**
Discharge status:		
Alive and discharged home		
Alive/transferred to another facility		
Deceased		
AMI documented on admission history		
AMI documented in progress notes		
AMI documented in discharge summary		

APPENDIX 5: ECG FORM

Site: _____ ID#: _____

Date/time of troponin:_____

No ECG's available: _____

Please note with a check mark if YES.

	ECG_pre	ECG_trop	ECG_FU
DATE			
Pacemaker			
LBBB			
Ischemia			
Dynamic changes			
Ischemia resolved			

If ischemia ticked please document the following: Q waves noted in any lead

ST Segment Elevation ≥ 1mm in leads I, aVL, V5, V6; II, III, aVF
or ≥ 2mm in leads V1, V2, V3, V4

ST Segment Depression ≥ 2 mm in leads I, aVL, or V6; II, III, aVF; or V1, V2, V3, V4, V5

T inversion ≥ 5 mm in leads I, aVL, or V6; II, III, aVF; or V1, V2, V3, V4, V5

ECG_Pre (Historical if available)

	Q	ST↑	ST↓	T↓
Lateral (I, AVL,V6)				
Anterior (V1 - V5)				
Inferior (II,III,AVF)				

Comments:

ECG_trop (closest to time of troponin)

	Q	ST↑	ST↓	T↓
Lateral (I, AVL,V6)				
Anterior (V1 - V5)				
Inferior (II,III,AVF)				

Comments:

ECG_followup

	Q	ST↑	ST↓	T↓
Lateral (I, AVL,V6)				
Anterior (V1 - V5)				
Inferior (II,III,AVF)				

Comments:

APPENDIX 6: Ethics Approval

UNIVERSITY OF CALGARY

FACULTY OF MEDICINE

Office of Medical Bioethics
Heritage Medical Research Building/Rm 93
Telephone: (403) 220-7990
Fax: (403) 283-8524

2002-12-05

Dr. W.A. Ghali
Department of Medicine
HSC
Calgary, Alberta

Dear Dr. Ghali:

RE: **Health Surveillance for Acute Myocardial Infarction in Canada: A Comparison of Administrative and Laboratory Data Case Definitions**
Student: Ms. D. Galbraith **Degree: MSc**

Grant-ID: 16805

The above-noted thesis proposal and the questionnaire have been submitted for Committee review and found to be ethically acceptable. Please note that this approval is subject to the following conditions:

(1) a copy of the informed consent form must have been given to each research subject, if required for this study;
(2) a Progress Report must be submitted by 2003-12-05, containing the following information:
    (i) the number of subjects recruited;
    (ii) a description of any protocol modification;
    (iii) any unusual and/or severe complications, adverse events or unanticipated problems involving risks to subjects or others, withdrawal of subjects from the research, or complaints about the research;
    (iv) a summary of any recent literature, finding, or other relevant information, especially information about risks associated with the research;
    (v) a copy of the current informed consent form;
    (vi) the expected date of termination of this project;
(3) a Final Report must be submitted at the termination of the project.

Please note that you have been named as a principal collaborator on this study because students are not permitted to serve as principal investigators. Please accept the Board's best wishes for success in your research.

Yours sincerely,

Christopher J. Doig, MD, MSc, FRCPC
Chair, Conjoint Health Research Ethics Board

cc: Adult Research Committee Dr. R.S. Sauve (information) Ms. D. Galbraith