*Scandinavian Journal of Public Health*, 1–9

**ORIGINAL ARTICLE**

# Completeness and correctness of acute myocardial infarction diagnoses in a medical quality register and an administrative health register

RAGNA ELISE STØRE GOVATSMARK[1,2], IMRE JANSZKY[1,3], STIG ARILD SLØRDAHL[2,4], MARTA EBBING[5], RUNE WISETH[6,7], BJØRNAR GRENNE[6,7], ELISABETH VESTERBEKKMO[6] & KAARE HARALD BØNAA[2,6,7,8]

*[1]Department of Public Health and Nursing, Norwegian University of Science and Technology, Trondheim, Norway, [2]Department of Medical Quality Registers, St Olavs hospital, Trondheim University Hospital, Norway, [3]Regional Center for Health Care Improvement, St Olavs hospital, Trondheim University Hospital, Norway, [4]The Central Norway Regional Health Authority, Norway, [5]Norwegian Institute of Public Health, Oslo, Norway, [6]Clinic for Heart Disease, St Olavs hospital, Trondheim University Hospital, Norway, [7]Department of Circulation and Medical Imaging, Norwegian University of Science and Technology, Trondheim, Norway and [8]Department of Community Medicine, University of Tromsø—The Arctic University of Norway, Tromsø, Norway*

**Abstract**

*Aims:* Health registers are used for administrative purposes, disease surveillance, quality assessment, and research. The value of the registers is entirely dependent on the quality of their data. The aim of this study was to investigate and compare the completeness and correctness of the acute myocardial infarction (AMI) diagnosis in the Norwegian Myocardial Infarction Register and in the Norwegian Patient Register. *Methods*: All Norwegian patients admitted directly to St Olavs hospital, Trondheim University Hospital, Trondheim University Hospital from 1 July to 31 December 2012 and who had plasma levels of cardiac troponin T measured during their hospitalization ($n$=4835 unique individuals, $n$=5882 hospitalizations) were identified in the hospital biochemical database. A gold standard for AMI was established by evaluation of maximum troponin T levels and by review of the information in the medical records. Cases of AMI in the registers were classified as true positive, false positive, true negative, and false negative according to the gold standard. We calculated sensitivity, positive predictive value (PPV), specificity, and negative predictive value (NPV). *Results*: The Norwegian Myocardial Infarction Register had a sensitivity of 86.0% (95% confidence interval (CI) 82.8–89.3%), PPV of 97.9% (96.4–99.3%), and specificity of 99.9% and NPV of 98.9% (98.6-99.2%) (99.8–100%). The corresponding figures for the Norwegian Patient Register were 85.8% (95% CI 82.5–89.1%), 95.1% (92.9–97.2%), and 99.7% (99.5–99.8%) and 98.9% (98.6-99.2%), respectively. Both registers had a sensitivity higher than 95% when compared to hospital discharge diagnoses. The results were similar for men and women and for cases below and above 80 years of age. ***Conclusions*: The Norwegian Myocardial Infarction Register and the Norwegian Patient Register are adequately complete and correct for administrative purposes, disease surveillance, quality assessment, and research.**

**Keywords:** *Completeness, correctness, validity, data quality, health register, medical quality register, administrative register, hospital discharge register, myocardial infarction*

## Introduction

Health registers are established for administrative purposes, disease surveillance, and quality monitoring of healthcare services, and may also be used for clinical and epidemiological research. Administrative registers are typically established to manage healthcare services and for reimbursement purposes, based on the codes for diagnoses and procedures registered during the hospitalization. Disease- or procedure-specific medical

Correspondence: Ragna Elise Støre Govatsmark, Norwegian University of Science and Technology, Faculty of Medicine and Health Sciences, Department of Public Health and Nursing, Postbox 8905, N-7491 Trondheim, Norway. E-mail: ragna.e.govatsmark@ntnu.no

*Date received 21 March 2017; reviewed 22 August 2018; accepted 28 August 2018*


DOI: 10.1177/1403494818803256
journals.sagepub.com/home/sjp
SAGE

quality registers are established for disease surveillance and monitoring of the quality of healthcare, and include more detailed information about risk factors, treatments, and outcomes.

The value of health registers is dependent on the quality of their data [1]. Two frequently cited data quality attributes are completeness and correctness. Data completeness is the extent to which all the data that could have been registered have actually been registered, whereas data correctness, also referred to as validity, is the extent to which the registered data are in conformity with the truth [1, 2]. A systematic review of acute myocardial infarction (AMI) diagnoses in administrative registers suggests that hospitalization data have high completeness and correctness, and can be used to identify patients with AMI [3]. Medical quality registers of patients with AMI have been found to be less complete than administrative registers, however [4–10]. Few studies have investigated the correctness of AMI in medical quality registers although such registers are frequently used as a "gold standard" to investigate the completeness and correctness of administrative registers [11, 12].

The purpose of this study was to investigate and compare the completeness and correctness of a national medical quality register for AMI patients, the Norwegian Myocardial Infarction Register, and a national administrative health register, the Norwegian Patient Register, using data from a university hospital.

## Methods

Norway has a public health care system for all inhabitants, and the resources are evenly distributed geographically, providing few disparities in access to health care. Acute illness, such as AMI, requiring hospitalization is treated free of cost in public hospitals, usually in the community hospital nearest the patient. The present study was conducted at St Olavs Hospital, Trondheim University Hospital, which is the fifth largest Norwegian community hospital, covering a population of 300,000 inhabitants. The hospital is also a referral hospital for 700,000 inhabitants in the central part of Norway, and has facilities for percutaneous coronary intervention (PCI) and heart surgery. The hospital had approximately 54,000 somatic hospitalizations annually during the study period [13].

### *The Norwegian Myocardial Infarction Register*

The Norwegian Myocardial Infarction Register (hereafter referred to as the Myocardial Infarction Register) was established as a regional medical quality register in the Central Norway Regional Health Authority in 2001, and became part of the Norwegian Cardiovascular Disease Register in 2012, when the latter register was established [14]. According to the Norwegian Health Register Act [15], all hospitals are required to register patients hospitalized with an AMI in the Myocardial Infarction Register. No patient consent is needed.

The Myocardial Infarction Register is an electronic data system containing for each hospitalization of AMI patients the patient's unique national identification number, the date and time for the start of AMI symptoms, hospital admission and discharge, and information about the patient's risk factors for AMI, medical history, symptoms and clinical findings, electrocardiographic (ECG) and echocardiographic results, plasma levels of cardiac troponins, and the use of drugs and other treatments.

Specially trained nurses or the treating physicians complete the case report form while the patient is hospitalized, or after discharge. All hospitalized patients with AMI should be registered regardless of whether the patient is treated in a cardiac, medical, surgical, or other type of ward. The discharge diagnoses (one main diagnosis and an unlimited number of secondary diagnoses) in the hospital patient administrative system are used by most hospitals to manually ensure the completeness of AMI in the Myocardial Infarction Register. A user manual provides definitions of the variables [16].

### *The Norwegian Patient Register*

The Norwegian Patient Register is a national administrative health register that retrieves patient data from the specialist health service, including demographic and medical information about hospitalizations. The data are used for reimbursement and management purposes. It is mandatory for the hospitals to report relevant information to the register [17]. The Norwegian Patient Register contains the unique national identification number, date and time for the hospital admission and discharge, the ICD-10 codes for the main and secondary discharge diagnoses, procedure codes, and other administrative data. At the study hospital the ICD-10 codes and diagnostic or therapeutic procedure codes recorded by the treating physicians in the medical discharge note in the electronic medical record are manually transferred to the hospital patient administrative system. Each month relevant data are extracted from the hospital patient administrative system and sent to the Norwegian Patient Register.

### *Review of electronic medical records to establish a "gold standard" for the diagnosis of AMI*

The electronic medical records contain all written information about the patient such as: (a) information

about medical history, use of drugs, and details about the present illness such as symptoms and findings on clinical examinations; (b) the daily notes by the attending physician; (c) laboratory findings, ECG, and results of imaging procedures; (d) the daily notes and observations by registered nurses; (e) the discharge note sent to the patient's primary care physician or other hospitals which contains a summary of the medical history, findings on clinical examination, and the treatment prescribed, as well as the diagnostic considerations including the main and secondary discharge diagnoses.

To establish a "gold standard" of all hospitalizations due to AMI and not due to AMI we first used the database at St Olavs Hospital biomedical department to identify all hospitalizations between 1 July and 31 December 2012 during which plasma cardiac troponin T was measured. For patients with several hospitalizations during the study period, all hospitalizations were included. The laboratory used a high-sensitive troponin T assay (Roche, Basel, Switzerland). The following data were obtained from the biomedical laboratory database for each patient: the unique national identification number, age, gender, dates and times for hospital admission and discharge, all plasma troponin T values, and the first serum creatinine value measured during each hospitalization. Patients transferred from other hospitals were excluded because the medical records for these patients may contain insufficient information for reliable assessment of the diagnosis.

Next, specially trained nurses performed a review of the electronic medical records of all Norwegian patients who were hospitalized during the study period and who had a maximum plasma troponin T value higher than 10 ng/L ($n$=3924). We considered hospitalizations with a maximum troponin T value below 10 ng/L ($n$=1958) as true negative cases in the gold standard, without performing a review of the electronic medical records [18, 19]. The following information from the electronic medical records were extracted for hospitalizations with troponin T higher than 10 ng/L: ICD-10 codes for the main and secondary discharge diagnoses, procedure codes, risk factors for AMI, medical history including diseases or treatments within 28 days prior to the hospitalization, symptoms leading to the hospital admission, and date and time for start of symptoms, ECG findings, results of echocardiographic examinations, and status at hospital discharge. It was also noted whether it was mentioned in the medical notes that the patient had had an AMI, regardless of whether this diagnosis appeared as a discharge diagnosis. All this information was then used to determine whether the patient had a possible, probable, or definite AMI [20] or not an AMI according to the universal myocardial infarction definition criteria [19].

One of four cardiologists made the final decision about the diagnosis for patients classified by the nurses as having undergone a possible or probable AMI, and for all cases of disagreement between the nurses and the diagnosis in the electronic medical record. In cases of uncertainty a decision was made by consensus among the four cardiologists. All cases of possible or probable AMI were in the end classified as an AMI or not an AMI. By these procedures all hospitalizations during which troponin T was measured were categorized as an AMI hospitalization or not an AMI hospitalization. This established the gold standard used in the present paper.

The decision level of high-sensitive troponin T to discriminate among cases and non-cases of AMI was based on the imprecision (coefficient of variation $<$10%) of the fourth-generation troponin T assay of 30 ng/L. In Norway the decision level for AMI was kept unchanged at $>$30 ng/L for high-sensitive troponin T until 2013 [21]. Procedural AMIs were defined according to the universal definition of myocardial infarction with troponin T higher than three times the decision level for procedural AMI related to PCI and troponin T higher than five times the decision level for procedural AMI related to coronary artery bypass grafting (CABG) [19]. In addition, either ischemic symptoms or ECG changes, or angiographic demonstration of loss of major coronary artery patency, or demonstration of new loss of myocardial wall motion by imaging was required, as specified in the third universal definition of myocardial infarction [18].

The reviewers were blinded for registrations in the Myocardial Infarction Register and in the Norwegian Patient Register. Ultimately, the Norwegian identification number was used to link data from the Myocardial Infarction Register and the Norwegian Patient Register with the gold standard.

### *Statistics*

A patient could have more than one hospitalization during the study period. In all analyses we used hospitalization (hereafter referred to as case) as the analytical unit. The cases in the Myocardial Infarction Register and the Norwegian Patient Register were compared to the cases in the gold standard and were classified as true positive (TP), false positive (FP), false negative (FN), or true negative (TN). Completeness was defined equivalent to sensitivity (TP/(TP+FN)), i.e. the proportion of cases of true

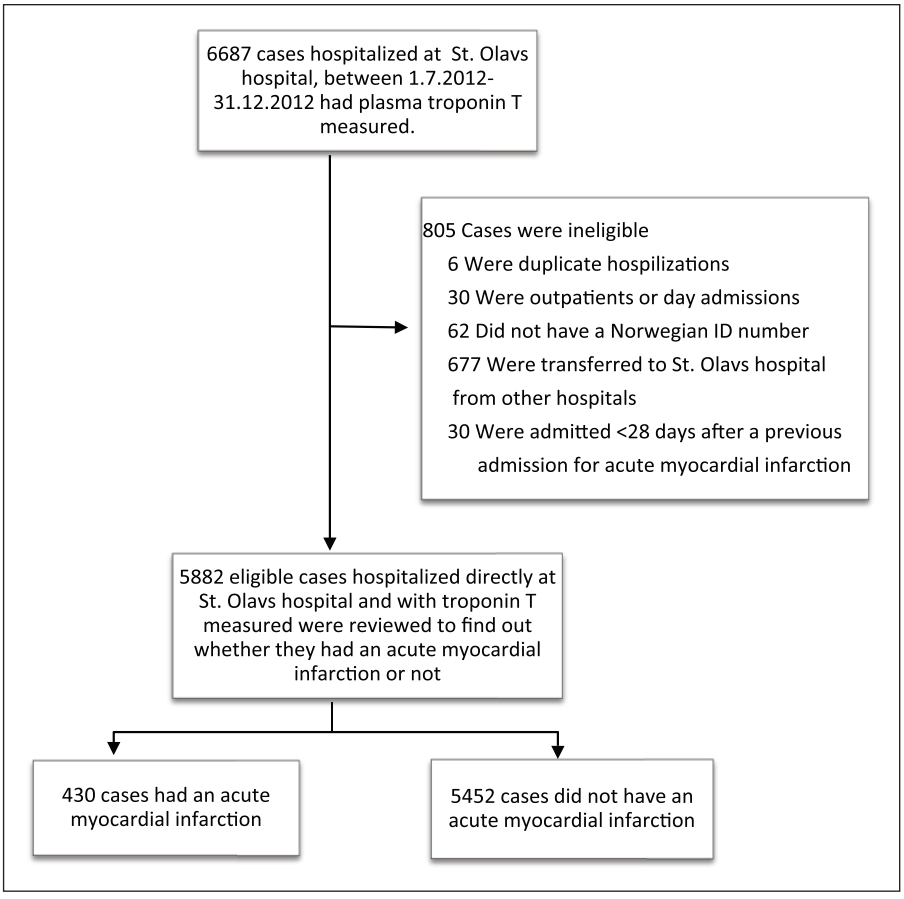



Figure 1. Flow chart for establishing a "gold standard" of AMI and non-AMI cases for evaluation of the correctness and completeness of the Norwegian Myocardial Infarction Register and the Norwegian Patient Register[1].
[1]The "gold standard" for AMI was established by evaluation of maximum troponin T levels and by review of the information in the medical records.

AMI according to the gold standard that was also present in the registers [1, 2]. Correctness was defined equivalent to positive predictive value (PPV) (TP/(TP+FP)), i.e. the proportion of cases of AMI present in the registers that were cases of true AMI according to the gold standard [2]. In addition, we calculated the specificity (TN/(TN+FP)), i.e. the proportion of non-AMI cases correctly identified as such, and the negative predictive value (NPV) (TN/(TN+FN)), i.e. the proportion of non-AMI cases not present in the registers. The analyses were stratified by age groups and gender. We used IBM SPSS 23.0 for analyses.

The Regional Committee for Medical and Health Research Ethics considered the study to be a quality assessment project, and the study was therefore approved by the Norwegian Data Protection Authority and the Norwegian Directorate of Health. Patient consent was not required. The reporting and interpretation of data from the Norwegian Patient Register are the responsibility of the authors, and no endorsement by the Norwegian Patient Register is inferred.

## Results

We identified a total of 6687 cases (5522 unique patients) who had plasma troponin T concentration measured during hospitalization in the study period. We excluded 6 duplicate cases, 30 cases who were outpatients, 677 cases transferred to St Olavs Hospital from other hospitals, 62 cases without a Norwegian identification number, and 30 cases hospitalized within 28 days following a previous AMI. Thus, the final study population consisted of 5882 cases (4835 unique patients) (Figure 1).

Of the 5882 cases included in the study, 3162 (53.8%) cases were among males. The mean (SD) age was 63.5 (17.3) years for male cases and 66.5 (19.5) years for female cases. Only 30.5% ($n$=1792) of the cases who had troponin T measured had a cardiovascular disease as the main diagnosis in the

Table I. Distribution of maximum troponin T concentration by main discharge diagnoses among 5882 cases who had plasma troponin T measured during hospitalization.

| Main discharge diagnosis (ICD-10) | Maximum troponin T levels (ng/L) | | | | |
|---|---|---|---|---|---|
| | <10 *n* (%) | 10–14 *n* (%) | 15–30 *n* (%) | >30 *n* (%) | Total *n* (%) |
| Cardiovascular disease | | | | | |
| Ischemic heart disease | | | | | |
| Acute myocardial infarction I21-I22 | 1 (0.1) | 1 (0.1) | 1 (0.1) | 306 (16.4)[1] | 309 (5.3) |
| Unstable angina pectoris I20.0 | 9 (0.5) | 8 (1.1) | 30 (2.3) | 40 (2.1) | 87 (1.5) |
| Other ischemic heart disease I20.1-9, I23-I25 | 49 (2.5) | 66 (9.0) | 89 (6.7) | 198 (10.6) | 402 (6.8) |
| Arrhythmia I44-I49, R00 | 124 (6.3) | 68 (9.3) | 116 (8.8) | 133 (7.1) | 441 (7.5) |
| Heart failure I50 | 3 (0.2) | 9 (1.2) | 34 (2.6) | 111 (5.9) | 157 (2.7) |
| Other cardiovascular diseases[1] | 91 (4.6) | 41 (5.6) | 82 (6.2) | 182 (9.7) | 396 (6.7) |
| Cerebrovascular disease I60-I69 | 75 (3.8) | 35 (4.8) | 99 (7.5) | 79 (4.2) | 288 (4.9) |
| Chest pain, dyspnea[2] | 413 (21.1) | 89 (12.2) | 95 (7.2) | 52 (2.8) | 649 (11.0) |
| Infections | | | | | |
| Respiratory infections and failure J00-J47, J80-86.9, J96, U04 | 174 (8.9) | 101 (13.8) | 212 (16.0) | 227 (12.1) | 714 (12.1) |
| Other infections A00-B95 | 96 (4.9) | 16 (2.2) | 47 (3.5) | 46 (2.5) | 205 (3.5) |
| Gastrointestinal diseases K00-K93 | 160 (8.2) | 38 (5.2) | 64 (4.8) | 64 (3.4) | 326 (5.5) |
| Injuries and trauma S00-T98, V0n-Y98 | 112 (5.7) | 25 (3.4) | 55 (4.2) | 57 (3.0) | 249 (4.2) |
| Renal failure N17-N19 | 3 (0.2) | 3 (0.4) | 10 (0.8) | 38 (2.0) | 54 (0.9) |
| Cancer C00-C97, D00-D09 | 45 (2.3) | 38 (5.2) | 76 (5.7) | 61 (3.3) | 220 (3.7) |
| Other diseases[3] | 603 (30.8) | 192 (26.3) | 315 (23.8) | 275 (14.7) | 1385 (23.5) |
| Total | 1958 (100) | 730 (100) | 1325 (100) | 1869 (100) | 5882 (100) |

[1]I00-I15, I26-I43, I51-I52, I70-I99.
[2]R06, R07, R09, R55, R56, R57.
[3]D10-D48, D50-H95.9, J60-J70, J90-J94, J95, J98, J99, L00-M99, N00-N08, N10-N16, N20-N99, O00-Q99, R01-R05, R10-R54, R58-R99, Z00-Z99.

hospital discharge note, and only 5.3% (*n*=309) had an AMI as the main discharge diagnosis (Table I).

A total of 1869 (31.8%) of the cases in the study population had a maximum troponin T value above 30 ng/L, the cut-off level for an AMI diagnosis during the study period (Table I). Among these cases, only 382 (20.5%) were discharged with AMI as the main (*n*=306) or a secondary (*n*=74) diagnosis (Table I).

*The gold standard.* Of the 5882 cases evaluated to establish the gold standard, we identified 430 cases (65% male) with an AMI (Figure 1). Of those, the mean age for male and female was 67.1 and 74.5 years, respectively. Among cases with AMI in the gold standard, the median maximum troponin T level was 894 ng/L among males versus 586 ng/L among females.

*Cases of AMI in the Myocardial Infarction Register compared to the gold standard.* We found 370 TP cases of AMI and 8 FP cases of AMI in the Myocardial Infarction Register (Table II). Furthermore, we identified 60 cases of AMI in the gold standard not registered in the Myocardial Infarction Register (Table II). Estimated measures of completeness and correctness of the Myocardial Infarction Register indicated a sensitivity of 86.0% (95% confidence interval (CI) 82.8–89.3%), a PPV of 97.9% (96.4–99.3%), a specificity of 99.9% (99.8–100%), and an NPV of 98.9% (98.6–99.2%) (Figure 2). There was no significant difference in the sensitivity, PPV, specificity, and NPV between those younger and older than 80 years of age, or between males and females (Supplementary Table IS).

Table III shows the discharge diagnoses in the electronic medical records given to the 60 FN cases of AMI in the Myocardial Infarction Register. Thirteen cases had AMI as main or secondary diagnosis on the discharge note, but the diagnosis had not been manually transferred to the patient administrative system. In nine cases it was mentioned in the medical notes that the patient had undergone an AMI, but the ICD-10 code for an AMI was not included among the discharge diagnoses (data not shown). Thirteen FN cases had a procedure-related

Table II. Distribution of true and false positives and negatives in the Norwegian Myocardial Infarction Register and the Norwegian Patient Register according to classification in the gold standard[1].

| | Gold standard[1] | | |
|---|---|---|---|
| | AMI | No AMI | Total |
| Norwegian Myocardial Infarction Register | | | |
| AMI | 370 | 8 | 378 |
| No AMI | 60 | 5444 | 5504 |
| Total | 430 | 5452 | 5882 |
| Norwegian Patient Register | | | |
| AMI | 369 | 19 | 388 |
| No AMI | 61 | 5433 | 5494 |
| Total | 430 | 5452 | 5882 |

AMI: acute myocardial infarction.
[1]The gold standard was established by review of medical records as described in "Materials".

AMI, whereas 15 FN cases were among patients with ST-elevation myocardial infarctions, according to the gold standard (data not shown).

Of the eight FP cases in the Myocardial Infarction Register (Table II), seven were diagnosed with an AMI in the electronic medical record (data not shown).

*Cases of AMI in the Norwegian Patient Register compared to the gold standard.* We found 369 TP cases of AMI and 19 FP cases of AMI in the Norwegian Patient Register (Table II). Furthermore, we identified 61 cases of AMI not registered in the Norwegian Patient Register. Estimated measures of completeness and correctness of the Norwegian Patient Register indicated a sensitivity of 85.8% (95% CI 82.5–89.1%), a PPV of 95.1% (92.9–97.2%), a specificity of 99.7% (99.5–99.8%), and an NPV of 98.9% (98.6–99.2%) (Figure 2). When we restricted the analysis to AMI as the main diagnosis only, we found a sensitivity of 66.4% (62.0–70.9%), a PPV of 96.9% (95.0–98.9%), a specificity of 99.8% (99.7–99.9%), and an NPV of 97.4% (97.0–97.8%). There was no significant difference in the sensitivity, PPV, specificity, and NPV between those younger and older than 80 years, or between males and females (Supplementary Table IS).

Table III shows the discharge diagnoses in the electronic medical record given to the 61 FN cases of AMI in the Norwegian Patient Register. Six cases had AMI as the main or secondary diagnosis on the discharge note, but the diagnosis had not been manually extracted to the patient administrative system. In 15 cases it was mentioned in the medical notes that the patient had had an AMI, but the AMI diagnosis was not included among the discharge diagnoses (data not shown). Seventeen of the FN cases had a procedure-related AMI, according to the gold standard (data not shown).

Of the 19 FP cases, 10 cases were diagnosed with an AMI in the discharge note, and of those, five were categorized as procedure-related AMIs. Nine FP cases had no I21 or I22 diagnosis or no mentioning of AMI in the text of the discharge note (data not shown).

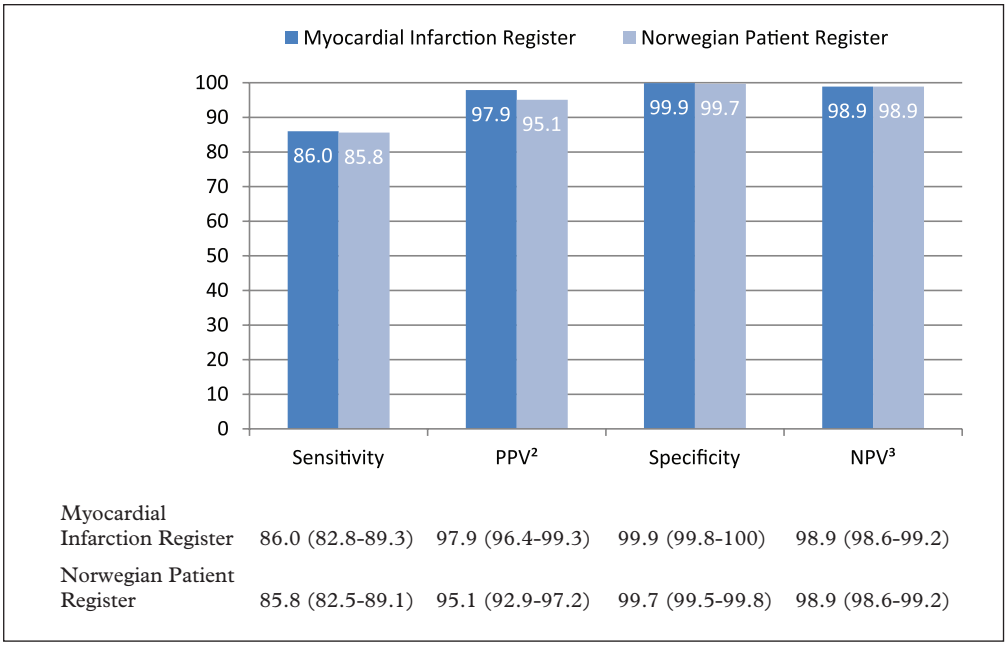
*Cases of AMI in the registers compared to diagnoses in the discharge note.* Compared to a diagnosis of AMI in the discharge note, the Myocardial Infarction Register had a sensitivity of 95.1%, a PPV of 97.4%, a specificity of 99.8%, and an NPV of 99.7%. The corresponding figures for the Norwegian Patient Register were 98.2%, 97.9%, 99.9%, and 99.9%, respectively.

## Discussion

We found that data in the Myocardial Infarction Register and in the Norwegian Patient Register were both rather complete (sensitivity 86.0% versus 85.8%) and highly correct (PPV 97.9% versus 95.1%). The correctness of the Norwegian Patient Register improved when we restricted the analysis to cases with AMI as the main diagnosis. Sensitivity for both registers was higher than 95% when compared to hospital discharged diagnoses. The results were similar in both genders, and in cases younger and older than 80 years of age. The Myocardial Infarction Register and the Norwegian Patient Register both use the diagnoses in the medical records as a primary data source. This is the main reason for the results being similar for the two registers.

We found few FP cases in both registers, although there were more in the Norwegian Patient Register than in the Myocardial Infarction Register. Half of the FP cases in the Norwegian Patient Register were due to typing errors when the ICD-10 codes in the discharge note were manually entered into the hospital patient administrative system from which the codes are automatically transferred to the Norwegian Patient Register. This illustrates that electronic transfer of diagnostic codes is preferable. However, manual transfer of data from medical records to the Myocardial Infarction Register enables registrars to reassess the AMI diagnosis in the patient administrative system and thereby reduce the number of FP cases.

Although relatively few FN cases were found in the registers, about 60 (14%) of the AMI cases in the gold standard were not included in the registers. This was partly due to typing errors in the discharge note or in the patient administrative system. However, most could be explained by misjudgement




| | | | | |
|---|---|---|---|---|
| Myocardial Infarction Register | 86.0 (82.8-89.3) | 97.9 (96.4-99.3) | 99.9 (99.8-100) | 98.9 (98.6-99.2) |
| Norwegian Patient Register | 85.8 (82.5-89.1) | 95.1 (92.9-97.2) | 99.7 (99.5-99.8) | 98.9 (98.6-99.2) |

Figure 2. Sensitivity, positive predictive value, specificity, and negative predictive value of the Norwegian Myocardial Infarction Register and the Norwegian Patient Register compared to the gold standard[1].
[1]The values are percent with 95% confidence interval in parentheses.
[2]Positive predictive value.
[3]Negative predictive value.

Table III. Number of main discharge diagnoses for false negative cases in the Norwegian Myocardial Infarction Register and the Norwegian Patient Register.

| Discharge diagnoses | **False negative cases** | |
|---|---|---|
| | **Myocardial Infarction Register** | **Norwegian Patient Register** |
| Cardiovascular disease | | |
| Ischemic heart disease | | |
| Acute myocardial infarction as main diagnosis | 11 | 5 |
| Acute myocardial infarction as secondary diagnosis | 2 | 1 |
| Unstable angina pectoris | 5 | 8 |
| Other ischemic heart disease | 13 | 17 |
| Heart failure | 5 | 6 |
| Arrhythmia | 9 | 9 |
| Other cardiovascular diseases | 6 | 6 |
| Chest pain/dyspnea | 1 | 1 |
| Injury/trauma main diagnosis | 1 | 1 |
| Respiratory infections and failure | 2 | 2 |
| Cancer | 3 | 3 |
| Other diseases | 2 | 2 |
| Total | 60 | 61 |

of the diagnosis. The diagnosis of AMI has become more challenging with use of later-generation high-sensitive troponin assays compared to use of less sensitive biomarkers. In the early troponin era, it was thought that almost any increase in troponin levels should be labeled as an AMI. Subsequent studies, however, found increased plasma levels of cardiac troponins in many other conditions [22]. In the present study as much as 80% of cases who had troponin T levels above the cut-off level for AMI did not receive an AMI diagnosis, showing the importance of considering clinical criteria, such as the presence of symptoms and/or ECG changes compatible with myocardial ischemia.

The diagnosis of a procedural AMI related to PCI or CABG may be difficult, and the diagnostic criteria have changed over the years [18, 19]. The third universal definition of AMI published in 2012 [4] placed more emphasis on clinical criteria in addition to cardiac troponin for procedural AMI than the previous definition [19]. The third definition was published during the study period and this could have influenced the number of procedural AMI in the gold standard. However, we found FN cases even when we applied the stricter third universal definition of procedural AMI throughout the whole study period.

Traditional focus on troponin elevations after cardiac procedures without considering clinical evidence of myonecrosis would lead to the diagnosis of procedural myocardial infarctions without clinical significance [23]. Procedural AMIs have considerably less prognostic significance than spontaneous AMIs [24]. These two types of AMI should therefore

be reported separately in registers. This is done in the Myocardial Infarction Register, but not to the same extent in the Norwegian Patient Register.

High completeness is important when register data is used for assessing the quality of treatments or estimating disease incidence. When register data are used as end-points in epidemiological studies, high correctness is more important than high completeness, however. Under non-differential misclassification (i.e. disease is misclassified, but the misclassification does not depend on the exposure) even low completeness does not lead to biased risk ratios, as long as correctness is close to 100% [25].

Our results are in line with other studies showing high completeness and correctness of AMI diagnosis in administrative registers [3, 11, 12, 26]. The Myocardial Infarction Register was found to have higher completeness than was generally found in such registers in other countries [4–8, 10]. However, a recent report from the Swedish Heart Register (RIKS-HIA) also found high completeness compared to an administrative register [27]. High completeness in our registers is largely due to the mandatory registration by Norwegian law, which often is not the case in other countries. Comparing validation studies is difficult due to different sampling methods, sample size, and different gold standards and methods for validation.

The strength of this study is a comprehensive review of electronic medical records for all hospitalized patients who had their plasma troponin T measured, to establish a gold standard for AMI. The hospital used liberal criteria for measuring troponin T, making it possible to estimate TN cases. Our study has limitations. This is a hospital-based study and not a population-based study. We did not register non-hospitalized patients such as cases experiencing out-of-hospital sudden death, or chronically institutionalized patients if they were not transferred to the hospital if they got an AMI. This number is probably small, however. The reviewers were not blinded for the diagnoses mentioned in the electronic medical records. However, during the review we registered whether the diagnostic criteria for an AMI were met, and these registrations were used to validate the gold standard. We did not investigate inter-rater reliability. We used data from a single hospital, and this is a university hospital which may have better educated health professionals than other hospitals. However, Norway has a public health system with few disparities in access to health care. Notably, the study hospital is both a local hospital with a large catchment area as well as a referral hospital. The study hospital has been found to include the same proportion of AMI patients relative to the Norwegian Patient Register as other Norwegian hospitals, and AMI patients hospitalized in the study hospital had similar characteristics as AMI patients hospitalized in other Norwegian hospitals [28]. A gold standard based on patients with measured troponin during hospitalization could lead to exclusion of patients who died before troponin was measured. Most of these patients experienced a sudden out-of-hospital death and were not hospitalized or were declared dead before arrival. Because the registers cover only hospitalized patients, patients who died before arrival could not and should not be included in the present study. Patients undergoing resuscitation on arrival (and not declared dead on arrival) will have cardiac troponin measured regardless of whether they die or survive. We found no patients with AMI in the Myocardial Infarction Register or in the Norwegian Patient Register who were not included in the gold standard. This suggests that very few hospitalized AMI patients died before troponin T was measured. In Norway at the time of the study, the decision level for a diagnosis of AMI was higher than the current level, but this should not threaten the validity of our findings.

## Conclusion

We conclude that the Norwegian Myocardial Infarction Register and the Norwegian Patient Register are adequately complete and correct for administrative purposes, disease surveillance, quality assessment, and research.

## Acknowledgements

We thank Cecilie Høines and Kristin Hansen-Bomann for their valuable contribution to the data collection with high-quality review of the electronic medical records. We also thank Martin Fjellsøy for valuable contribution to the assessment of the AMI diagnoses.

## Declaration of conflicting interest

The authors declare that there is no conflict of interest.

## Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

## References

[1] Sorensen HT, Sabroe S and Olsen J. A framework for evaluation of secondary data sources for epidemiological research. *Int J Epidemiol* 1996;25:435–442.

[2] Hogan WR and Wagner MM. Accuracy of data in computer-based patient records. *J Am Med Inform Assoc* 1997;4: 342–355.

[3] McCormick N, Lacaille D, Bhole V, et al. Validity of myocardial infarction diagnoses in administrative databases: a systematic review. *PLoS One* 2014;9:e92286.
[4] Aspberg S, Stenestrand U, Koster M, et al. Large differences between patients with acute myocardial infarction included in two Swedish health registers. *Scand J Public Health* 2013;41:637–643.
[5] Eindhoven DC, Wierda E, de Bruijne MC, et al. The year of transparency: measuring quality of cardiac care. *Neth Heart J* 2015;23:457–465.
[6] Ferreira-Gonzalez I, Marsal JR, Mitjavila F, et al. Patient registries of acute coronary syndrome: assessing or biasing the clinical real world data? *Circ Cardiovasc Qual Outcomes* 2009;2:540–547.
[7] Herrett E, Smeeth L, Walker L, et al. The Myocardial Ischaemia National Audit Project (MINAP). *Heart* 2010;96:1264–1267.
[8] Jernberg T, Attebring MF, Hambraeus K, et al. The Swedish Web-system for enhancement and development of evidence-based care in heart disease evaluated according to recommended therapies (SWEDEHEART). *Heart* 2010;96:1617–1621.
[9] Radovanovic D and Erne P. AMIS Plus: Swiss registry of acute coronary syndrome. *Heart* 2010;96:917–921.
[10] Rosvall M, Ohlsson H, Hansen O, et al. Auditing patient registration in the Swedish quality register for acute coronary syndrome. *Scand J Public Health* 2010;38:533–540.
[11] Madsen M, Davidsen M, Rasmussen S, et al. The validity of the diagnosis of acute myocardial infarction in routine statistics: a comparison of mortality and hospital discharge data with the Danish MONICA registry. *J Clin Epidemiol* 2003;56:124–130.
[12] Pajunen P, Koukkunen H, Ketonen M, et al. The validity of the Finnish Hospital Discharge Register and Causes of Death Register data on coronary heart disease. *Eur J Cardiovasc Prev Rehabil* 2005;12:132–137.
[13] Key figures St. Olavs hospital, Trondheim University Hospital, Norway 2012–2014. https://stolav.no/Documents/Nøkkeltall%202012-2014%20for%20St.%20Olav.pdf (accessed 22 August 2018).
[14] Forskrift om innsamling og behandling av helseopplysninger i Nasjonalt register over hjerte- og karlidelser. https://lovdata.no/dokument/SF/forskrift/2011-12-16-1250 (accessed 22 August 2018).
[15] The Norwegian Health Register Act https://lovdata.no/dokument/NL/lov/2014-06-20-43 (accessed 22 August 2018).
[16] The Norwegian Myocardial Infarction Register, https://stolav.no/norsk-hjerteinfarktregister/registerfaglig-informasjon (accessed 22 August 2018).
[17] FOR-2007-12-07-1389. Forskrift om innsamling og behandling av helseopplysninger i Norsk pasientregister (Norsk pasientregisterforskriften). http://lovdata.no/dokument/SF/forskrift/2007-12-07-1389?q-norsk+pasientregisterforskriften (accessed 22 August 2018).
[18] Thygesen K, Alpert JS, Jaffe AS, et al. Third universal definition of myocardial infarction. *Circulation* 2012;126:2020–2035.
[19] Thygesen K, Alpert JS, White HD, et al. Universal definition of myocardial infarction. *Eur Heart J* 2007;28:2525–2538.
[20] Luepker RV, Apple FS, Christenson RH, et al. Case definitions for acute coronary heart disease in epidemiology and clinical research studies: a statement from the AHA Council on Epidemiology and Prevention; AHA Statistics Committee; World Heart Federation Council on Epidemiology and Prevention; the European Society of Cardiology Working Group on Epidemiology and Prevention; Centers for Disease Control and Prevention; and the National Heart, Lung, and Blood Institute. *Circulation* 2003;108:2543–2549.
[21] Aakre KM, Rotevatn S, Hagve TA, et al. [National guidelines for the interpretation of troponin values in the diagnosis of acute myocardial infarction]. *Tidsskr Nor Laegeforen* 2013;133:E1–6.
[22] Tanindi A and Cemri M. Troponin elevation in conditions other than acute coronary syndromes. *Vasc Health Risk Manag* 2011;7:597–603.
[23] Prasad A and Herrmann J. Myocardial infarction due to percutaneous coronary intervention. *N Engl J Med* 2011;364:453–464.
[24] Bonaa KH, Mannsverk J, Wiseth R, et al. Drug-eluting or bare-metal stents for coronary artery disease. *N Engl J Med* 2016;375:1242–1252.
[25] Rothman KJ, Greenland S and Lash TL. *Modern epidemiology*. 3rd ed. Philadelphia: Wolters Kluwer/Lippincott Williams Wilkins, 2008.
[26] Rubbo B, Fitzpatrick NK, Denaxas S, et al. Use of electronic health records to ascertain, validate and phenotype acute myocardial infarction: a systematic review and recommendations. *Int J Cardiol* 2015;187:705–711.
[27] SWEDEHEART Annual report 2017 http://www.ucr.uu.se/swedeheart/arsrapport-2017/swedeheart-annual-report-2017/viewdocument (accessed 22 August 2018).
[28] The Norwegian Myocardial Infarction Register, Annual report 2016, https://stolav.no/norsk-hjerteinfarktregister/rapporter (accessed 22 August 2018).