Time trends in incidence, treatment, and outcome in acute myocardial infarction in Norway 2013–19

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Aims
Acute myocardial infarction (AMI) is a common cause of morbidity and mortality. The aim of the present study was to assess time trends in the incidence, treatment, and outcome of AMI in a nationwide registry–based cohort of patients.

Methods and results
All patients with a first AMI registered in the Norwegian Myocardial Infarction Registry between 2013 and 2019 were included in this cohort study. The number of patients admitted to Norwegian hospitals with a first AMI decreased from 8933 in 2013 to 8383 in 2019. The proportion of patients with ST-elevation myocardial infarction (STEMI) was stable at 30% throughout the period, and the percentage of STEMI undergoing coronary angiography was stable at 87%. The proportion of patients with non-STEMI undergoing coronary angiography increased by 2.4% per year (95% confidence interval 1.6–3.3) from 58% in 2013 to 68% in 2019. More patients were discharged with secondary preventive medication at the end of study period. Age-adjusted 1-year mortality was reduced from 16.4% in 2013 to 15.1% in 2018. The changes over time were primarily seen in the oldest patient groups.

Conclusion
In the period 2013–19 in Norway, we found a reduction in hospitalizations due to a first AMI. Both the percentage of patients undergoing coronary angiography as well as the percentage discharged with recommended secondary preventative therapy increased during the period, and the age-adjusted 1-year mortality after AMI decreased. A national AMI register provides important information about trends in incidence, treatment, and outcome, and may improve adherence to guideline recommendations.

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CONCLUSION
In the time period 2013 to 2019, we found a reduction in hospitalizations for a first AMI in Norway. The percentage of patients being treated according to guidelines increased, and the age-adjusted one-year mortality after AMI decreased. A national AMI register provides important information about trends in incidence, treatment, and outcome, and may improve adherence to guideline recommendations.

AIM
To assess time trends in the incidence, treatment, and outcome of acute myocardial infarction (AMI) in a nationwide registry-based cohort of patients.

61625 patients with a first AMI 2013-2019
37% women
30% STEMI

Median age:
69 years (2013) – 70 years (2019)
Daily smokers:
31% (2013) - 26% (2019)

Keywords
Myocardial infarction • Time trends • Incidence • Outcome

Introduction
Cardiovascular disease is the most common cause of death in most European countries.1 Acute myocardial infarction (AMI) is a common and serious presentation of cardiovascular disease and is associated with a high rate of mortality.2,3

The Norwegian Myocardial Infarction Registry (NORMI) was established as a national medical quality register in 2013 and is among the few national registries in Europe with ongoing data registration and high case coverage.4,5 The register enables monitoring of incidence, treatment, and outcome after AMI. Through annual reports and scientific publications, the register has highlighted adherence to guideline recommendations for treatment of AMI.6–11

The European recommendations for the treatment of AMI have been updated several times during the study period, but the main recommendations for invasive assessment and secondary preventive treatment after AMI have remained unchanged.12–15

The aim of the present nationwide cohort study was to investigate time trends in hospital admissions, treatment, and outcome in patients with a first AMI in Norway in the period 2013–19.

Methods

The Norwegian Myocardial Infarction Registry
The NORMI, a part of the Norwegian Cardiovascular Disease Registry, is a national quality register. Registration into NORMI is mandatory without requiring patient’s consent. For definition of AMI, the NORMI adhered to the Third and Fourth Universal Definition of Myocardial Infarction during the study period.16,17 NORMI contains information on gender, age, cardiovascular risk factors, previous diseases and medication, symptoms and clinical findings, electrocardiogram (rhythm and ischaemic changes), in-hospital therapy and complications including death, as well as drugs prescribed at hospital discharge. The registration and quality of the information in the register have been described previously.18,19 Causes of death were obtained from the Norwegian Cause of Death Register.

Study population
All patients admitted to hospitals in Norway with a first AMI between 1 January 2013 and 31 December 2019 and registered in the NORMI were included in this cohort study.

Outcomes and follow up
The outcomes of the study were the percentage of patients receiving coronary angiography during hospitalization, the prescription rate of secondary preventive therapy at hospital discharge, and 1-year mortality in patients with a first AMI. Follow-up data were available through NORMI until 31 December 2019.

Patient and public involvement
This study used existing data from Norwegian national health registries. Registration into these registries is mandatory (the Norwegian Cardiovascular Disease Registry Regulation and the Norwegian Health Register Act), and consent by the patient was not required.
Statistics
Continuous variables are presented as the mean ± standard deviation or median (25th percentile, 75th percentile). Categorical variables are presented as numbers and percentages. Age-adjusted mortality rates were calculated using direct standardization. Time trends were analyzed (log-linear model) using the Joinpoint Regression Program (version 4.0; SEER software, National Cancer Institute, USA) and are presented as the expected annual percent changes with a 95% confidence interval (CI). Other data were analyzed using STATA version 17 (StataCorp LLC, College Station, TX, USA). A P-value of <0.05 was regarded as statistically significant.

Ethics
The Regional Committee for Medical and Health Research Ethics North approved the study (REK 2016/170).

Results
Hospital admissions
A total of 61,625 patients with a first AMI were registered in the NORMI in the period 2013–19. A total of 18,499 (30%) patients were classified as ST-elevation myocardial infarction (STEMI), and 40,709 (66%) patients as non-STEMI. The rest was unclassifiable. The number of registered patients per year with a first AMI was reduced from 8933 in 2013 to 8383 in 2019. The decline was minimal in the period 2013–15, but from 2016, we found a significant reduction of 4.4% (95% CI 4.1, 4.6) per year.

Clinical characteristics and risk factors
Clinical characteristics are presented in Table 1. A total of 22,581 patients (37%) with a first AMI were women. The proportion of women decreased from 37% in 2013 to 35% in 2019 (change per year: −0.9%, 95% CI −1.7, −0.2). The median age for men increased from 65 years (interquartile range 56–76 years) in 2013 to 67 years (interquartile range 57–76 years) in 2019. The median age in women was 76 years (interquartile range 66–85 years) throughout the study period. The proportion of smokers was reduced by 2.7% (95% CI 2.2, 3.2) per year, while the proportions of patients with diabetes and lipid-lowering therapy increased by 2.4% (95% CI 1.0, 3.8) and 2.0% (95% CI 0.4, 3.6) per year, respectively.

Coronary angiography and secondary preventive therapy
Invasive coronary angiography and percutaneous coronary intervention (PCI) were performed in 16,160 (87%) and 15,006 (81%) patients admitted with a first STEMI, and were performed in 25,561 (63%) and 17,101 (42%) patients admitted with a first non-STEMI, respectively. The proportion of patients with STEMI who underwent coronary angiography was stable during the period (change per year: 0.5%, 95% CI −0.4, 1.4), while the proportion of non-STEMI...
patients who underwent coronary angiography increased by 2.4% per year (95% CI 1.6, 3.3), from 58% in 2013 to 68% in 2019.

The proportion of women with non-STEMI who underwent coronary angiography increased by 3.2% per year (95% CI 1.6, 4.7) from 47% in 2013 to 56% in 2019, while the proportion of men with non-STEMI who underwent coronary angiography increased by 1.9% per year (95% CI 1.4, 2.4) from 68% in 2013 to 76% in 2019.

The proportion of patients with non-STEMI undergoing coronary angiography in relation to age is presented in Figure 2 and Table 2.

The prescription of dual antiplatelet therapy (acetylsalicylic acid and P2Y12 inhibitor) and statins in patients discharged alive increased from 76 to 77% for dual antiplatelet therapy (change per year: 0.4%, 95% CI 0.0, 0.7), and from 82 to 85% (change per year: 0.7%, 95% CI 0.4, 1.1) for statins during the study period.

### Table 1 Clinical characteristics in patients admitted to hospitals with first acute myocardial infarction in Norway 2013–19

| Year | n | %  | Year | n | %  | Year | n | %  | Year | n | %  | Year | n | %  |
|------|---|----|------|---|----|------|---|----|------|---|----|------|---|----|
| 2013 | n = 8933 |     | 2014 | n = 9012 |     | 2015 | n = 9020 |     | 2016 | n = 8926 |     | 2017 | n = 8773 |     | 2018 | n = 8578 |     | 2019 | n = 8383 |
| Men  | 5609 | 63 | 5656 | 63 | 5640 | 63 | 5652 | 63 | 5562 | 63 | 5454 | 64 | 5471 | 65 |
| Median age (year, interquartile range) | 69 (59–81) |     | 69 (59–81) |     | 70 (59–81) |     | 70 (59–81) |     | 70 (60–80) |     | 70 (60–80) |     | 70 (59–79) |
| Smoking | 2777 | 31 | 2677 | 30 | 2642 | 29 | 2501 | 28 | 2393 | 27 | 2315 | 27 | 2204 | 26 |
| Antihypertensive therapy | 3984 | 45 | 3881 | 43 | 4005 | 44 | 3882 | 43 | 3863 | 44 | 3880 | 45 | 3779 | 45 |
| Diabetes | 1434 | 16 | 1403 | 16 | 1485 | 16 | 1491 | 17 | 1579 | 18 | 1535 | 18 | 1482 | 18 |
| Lipid-lowering therapy | 2287 | 26 | 2164 | 24 | 2203 | 24 | 2265 | 25 | 2343 | 27 | 2318 | 27 | 2319 | 28 |
| Previous percutaneous coronary intervention | 466 | 5 | 463 | 5 | 444 | 5 | 465 | 5 | 510 | 6 | 488 | 6 | 450 | 5 |
| Previous coronary artery bypass grafting | 397 | 4 | 391 | 4 | 370 | 4 | 394 | 4 | 393 | 4 | 349 | 4 | 308 | 4 |
| Previous stroke (all types) | 713 | 8 | 643 | 7 | 670 | 7 | 603 | 7 | 640 | 7 | 600 | 7 | 518 | 6 |
Table 2  Coronary angiography and percutaneous coronary intervention in patients with acute non-ST-elevation myocardial infarction (first myocardial infarction) in Norway 2013–19

| Age (years) | Patients | Coronary angiography | PCI | n | % | Patients | Coronary angiography | PCI | n | % | Patients | Coronary angiography | PCI | n | % | Patients | Coronary angiography | PCI | n | % | Patients | Coronary angiography | PCI | n | % |
|------------|---------|----------------------|-----|---|---|---------|----------------------|-----|---|---|---------|----------------------|-----|---|---|---------|----------------------|-----|---|---|---------|----------------------|-----|---|---|
| 18–49      | 425     | 363                  | 85  | 243| 57| 414     | 355                  | 86  | 244| 59| 395     | 342                  | 87  | 241| 61| 451     | 380                  | 84  | 254| 56|
| 50–66      | 1771    | 1502                 | 85  | 1021| 58| 1771    | 1508                 | 85  | 1056| 60| 1687    | 1450                 | 86  | 1025| 61| 1712    | 1467                 | 86  | 1065| 62|
| 67–79      | 1750    | 1192                 | 68  | 731 | 42| 1898    | 1343                | 71  | 821 | 43| 1843    | 1262                 | 68  | 792 | 43| 1940    | 1373                 | 71  | 864 | 45|
| 80–89      | 1472    | 419                  | 28  | 268 | 18| 1447    | 414                  | 29  | 259 | 18| 1428    | 445                  | 31  | 289 | 20| 1393    | 497                  | 36  | 305 | 22|
| ≥90        | 445     | 17                   | 4   | 13  | 3| 517     | 17                   | 3   | 8  | 2 | 579     | 22                   | 4   | 17  | 3 | 497      | 37                   | 7   | 26  | 5 |

| Age (years) | Patients | Coronary angiography | PCI | n | % | Patients | Coronary angiography | PCI | n | % | Patients | Coronary angiography | PCI | n | % | Patients | Coronary angiography | PCI | n | % | Patients | Coronary angiography | PCI | n | % |
|------------|---------|----------------------|-----|---|---|---------|----------------------|-----|---|---|---------|----------------------|-----|---|---|---------|----------------------|-----|---|---|---------|----------------------|-----|---|---|
| 18–49      | 348     | 303                  | 87  | 196| 56| 368     | 318                  | 86  | 214| 58| 352     | 293                  | 83  | 352| 200| 57      |
| 50–66      | 1677    | 1465                 | 87  | 1058| 63| 1586    | 1394                 | 88  | 1026| 65| 1644    | 1446                 | 88  | 979 | 60|
| 67–79      | 2002    | 1459                 | 73  | 926 | 46| 1887    | 1410                | 75  | 918 | 49| 1902    | 1422                 | 75  | 932 | 49|
| 80–89      | 1336    | 519                  | 39  | 339 | 25| 1281    | 493                  | 38  | 335 | 26| 1126    | 507                  | 45  | 433 | 30|
| ≥90        | 484     | 42                   | 9   | 35  | 7| 480     | 53                   | 11  | 34  | 7 | 398     | 32                   | 8   | 24  | 6 |
| Age (years) | 2013 | 2014 | 2015 |
|------------|------|------|------|
| Patients   | 30-day mortality | 1-year mortality | 1-year mortality -- ischaemic heart disease | Patients | 30-day mortality | 1-year mortality | 1-year mortality -- ischaemic heart disease | Patients | 30-day mortality | 1-year mortality | 1-year mortality -- ischaemic heart disease |
| n          | %    | n    | %    | n    | %    | n    | %    | n    | %    | n    | %    | n    | %    | n    | %    | n    | %    | n    | %    |
| 18–49      | 809  | 14   | 2    | 15   | 2    | 779  | 15   | 2    | 18   | 2    | 13   | 2    | 793  | 19   | 2    | 22   | 3    | 18   | 2    |
| 50–66      | 3098 | 89   | 3    | 146  | 5    | 2969 | 83   | 3    | 141  | 5    | 79   | 3    | 2905 | 85   | 3    | 137  | 5    | 80   | 3    |
| 67–79      | 2582 | 193  | 7    | 361  | 14   | 2789 | 195  | 7    | 373  | 13   | 160  | 6    | 2747 | 204  | 7    | 389  | 14   | 165  | 6    |
| 80–89      | 1890 | 328  | 17   | 638  | 34   | 1860 | 317  | 17   | 591  | 32   | 260  | 14   | 1871 | 319  | 17   | 602  | 32   | 267  | 14   |
| ≥90        | 553  | 151  | 27   | 275  | 50   | 615  | 167  | 27   | 343  | 56   | 162  | 26   | 704  | 206  | 29   | 371  | 53   | 177  | 25   |
| 2016       | 798  | 12   | 2    | 24   | 3    | 660  | 10   | 2    | 13   | 2    | 6    | 1    | 677  | 9    | 1    | 17   | 3    | 13   | 2    |
| 50–66      | 2903 | 87   | 3    | 140  | 5    | 2921 | 83   | 3    | 134  | 5    | 70   | 2    | 2762 | 87   | 3    | 128  | 5    | 79   | 3    |
| 67–79      | 2775 | 180  | 6    | 357  | 13   | 2886 | 205  | 7    | 379  | 13   | 161  | 6    | 2811 | 161  | 6    | 340  | 12   | 133  | 5    |
| 80–89      | 1826 | 322  | 18   | 591  | 32   | 1708 | 297  | 17   | 528  | 31   | 207  | 12   | 1736 | 276  | 16   | 529  | 30   | 199  | 11   |
| ≥90        | 621  | 188  | 30   | 331  | 53   | 597  | 172  | 29   | 296  | 50   | 144  | 24   | 592  | 160  | 27   | 296  | 50   | 122  | 21   |
Outcome

All-cause mortality after a first AMI in different age groups is presented in Table 3 and Figure 3. We found no changes in age-adjusted 30-day mortality during the period, but age-adjusted 1-year mortality was reduced by 1.6% (95% CI 0.4, 2.7) per year from 16.4% in 2013 to 15.1% in 2018. The reduction in mortality was found in patients with non-STEMI: age-adjusted 1-year mortality after non-STEMI was reduced from 17.8% in 2013 to 15.2% in 2018, while it was unchanged at 14% after STEMI. Information regarding 1-year mortality after STEMI and non-STEMI in different age groups is presented in Supplementary material online, Table S1. With respect to gender differences, the reduction was seen only in men; age-adjusted 1-year mortality for men was reduced by 2.6% (95% CI 0.4, 4.8) per year, but we found no corresponding change for women.

Ischaemic heart disease (ICD-10 code I20-I25) was reported as the cause of death in 47% of patients who died within 1 year in 2013. The proportion was reduced to 43% in 2018.

Discussion

This nationwide study of patients with a first AMI admitted to hospitals in Norway from 2013 to 2019 revealed a reduction in hospitalizations due to a first AMI and a gradual increase in the proportion of patients who were examined with coronary angiography and prescribed guideline-recommended secondary preventive therapy. The age-adjusted 1-year mortality decreased during the period. The changes over time were primarily seen in the oldest groups.

A reduced number of hospital admissions and a reduced incidence of AMI in Norway in the period 1991–2014 has been described previously. Our study from a national medical quality register shows a further reduction in the number of admissions for incident AMIs until 2019. The relatively high proportion of STEMI vs. non-STEMI patients can be explained by inclusion of patients with first-time AMI only.

In another Norwegian study, the Tromsø study, the declining incidence of acute coronary syndrome was largely attributed to changes in coronary risk factors such as lower cholesterol and blood pressure levels, fewer smokers and more physical activity in the population. The present study includes only patients admitted to hospitals with an AMI and cannot be used to assess changes in risk factors in the general population. However, in our study, the proportion of patients with a first AMI who smoked was higher than in the general population [2013: 15%; 2019: 9% (age 16–74 years)], suggesting that smoking is still an important modifiable risk factor for AMI, especially in younger patients.

The guidelines from the European Society of Cardiology recommended early coronary angiography in most patients with non-STEMI. Although the proportion of patients with non-STEMI who underwent coronary angiography increased from 58 to 68% during the period, the proportion is still lower in Norway than in other countries in Europe with national AMI registries. Although the proportion undergoing coronary angiography increased most in the older age groups, it was still significantly lower in these groups compared with younger age groups. Increasing comorbidity with increasing age may have had an impact on the choice of treatment strategy. The gender difference in the proportion of women and men who were...
examined with coronary angiography is also noteworthy and persisted during the study period. Possible differences in symptoms and clinical findings in suspected AMI in younger and older patients and in women and men cannot explain the differences, since only patients with the diagnosis of AMI were registered in the NORMI and consequently were included in this study. We have not investigated geographical differences in treatment strategy, but distance to hospitals offering coronary angiography has probably also been of importance.

Secondary preventive drugs such as antiplatelet therapy and statins are important in preventing new cardiovascular events and are recommended as secondary prevention after AMI. The proportions of patients prescribed these drugs after AMI in Norway were comparable with other countries in Europe. However, several studies have demonstrated a remaining gap between the guidelines and the achievement of recommended targets for cardiovascular risk factors and medication use after myocardial infarction. Early combination of statin, ezetimibe, and in some cases also inhibitors of proprotein convertase subtilisin/kexin type 9 is recommended in patients with high risk of new events.

Mortality after AMI has shown a declining trend in Norway for many years. The present study shows a further reduction in all-cause mortality after AMI for the period 2013–19. The NORMI does not have follow-up data for secondary preventive therapy, but more favourable risk profiles, improved acute treatment with an increasing proportion of patients examined with coronary angiography and treated with PCI, and increased prescription of secondary preventive drugs may have contributed to the improved survival. Changes in the general mortality in the population as well as changes in the use of medical diagnostic codes and procedure codes may also have affected the results, which must therefore be interpreted with caution.

The main strengths of this study are the large and unselected population comprising nearly all patients hospitalized with a first AMI in Norway from 2013 to 2019, and a nearly complete follow-up. However, there are some important limitations associated with the study design and the NORMI. This study was an observational study, making it impossible to demonstrate causal associations between treatment and outcomes. Only AMIs that led to hospitalization were registered in the NORMI. A few hospitals did not deliver complete data for the whole period, but the coverage compared with the Norwegian Patient Register was >90%. We only obtained deidentified data from the NORMI and the Norwegian Cardiovascular Disease Registry and could not verify the information through medical records at the individual patient level. Nevertheless, the degree of completeness and correctness of most variables in the NORMI have been shown to be high. The findings of the study must be interpreted with caution and generalization of the results should be avoided.

**Conclusion**

In conclusion, in the time period 2013–19 in Norway, we found a reduction in the number of patients admitted with a first AMI. Furthermore, more patients with a first AMI underwent coronary angiography, more patients were prescribed secondary preventive therapy at discharge, and the age-adjusted 1-year mortality after AMI was reduced in this period. The national myocardial infarction registry provides important information about AMI and may have contributed to better adherence to guideline recommendations.

**Lead author biography**

Jarle Jortveit is a senior researcher and cardiologist at Sørlandet Hospital Arendal, Norway. He is also cofounder and chief medical officer in ECG247 Smart Heart Sensor.

**Authors’ contributions**

J.J. and S.H. were responsible for the conception of the study, and the analysis and interpretation of data. J.J. drafted the manuscript. A.H.P. contributed to the analysis and interpretation of the data and critically revised the manuscript. J.J. and S.H. critically revised the manuscript. All gave final approval and agreed to be accountable for all aspects of work ensuring its integrity and accuracy.

**Data availability**

The data underlying this article were provided by the Norwegian Institute of Public Health under license by permission. Data will be shared on request to the corresponding author with permission of the Norwegian Institute of Public Health.

**Supplementary material**

Supplementary material is available at European Heart Journal Open online.

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**Conflict of interest:** J.J. has received speaking fees from Amgen, AstraZeneca, BMS, Boehringer Ingelheim, Novartis, Pfizer, and Sanofi. He is also a chief medical officer in ECG247 Smart Heart Sensor. S.H. has received speaking fees from Boehringer Ingelheim, BMS, Pfizer, and Sanofi. All other authors no conflict of interest.

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