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Socioeconomic environment and survival in patients after ST-segment elevation myocardial infarction (STEMI): a longitudinal study for the City of Vienna

Sonja Spitzer ,[1] Vanessa di Lego,[2] Michael Kuhn ,[2,3] Christian Roth,[4] Rudolf Berger[4,5]

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For numbered affiliations see end of article.

Correspondence to
Dr Sonja Spitzer;
sonja.spitzer@univie.ac.at

ABSTRACT

Objectives This study investigates the relationship between socioeconomic environment (SEE) and survival after ST-segment elevation myocardial infarction (STEMI) separately for women and men in the City of Vienna, Austria.

Design Hospital-based observational data of STEMI patients are linked with district-level information on SEE and the mortality register, enabling survival analyses with a 19-year follow-up (2000–2018).

Setting The analysis is set at the main tertiary care hospital of the City of Vienna. On weekends, it is the only hospital in charge of treating STEMIs and thus provides representative data for the Viennese population.

Participants The study comprises a total of 1481 patients with STEMI, including women and men aged 24–94 years.

Primary and secondary outcome measures Primary outcome measures are age at STEMI and age at death. We further distinguish between deaths from coronary artery disease (CAD), deaths from acute coronary syndrome (ACS), and other causes of death. SEE is proxied via mean individual gross income from employment in each municipal district.

Results Results are based on Kaplan-Meier survival probability estimates, Cox proportional hazard regressions and competing risk models, always using age as the time scale. Descriptive findings suggest a socioeconomic gradient in the age at death after STEMI. This finding is, however, not supported by the regression results. Female patients with STEMI have better survival outcomes, but only for deaths related to CAD (HR: 0.668, 95% CIs 0.452 to 0.985) and other causes of deaths (HR: 0.627, 95% CIs 0.444 to 0.884), and not for deaths from the more acute ACS.

Conclusions Additional research is necessary to further disentangle the interaction between SEE and age at STEMI, as our findings suggest that individuals from poorer districts have STEMI at younger ages, which indicates vulnerability in regard to health conditions in these neighbourhoods.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study is based on high-quality data from patients with ST-segment elevation myocardial infarction (STEMI) that is representative for the City of Vienna and allows us to explore the hitherto neglected relationship between socioeconomic environment (SEE), age at STEMI, and age at death after STEMI.
⇒ The fact that all patients—irrespective of SEE—are treated in the same hospital enables us to study differences in survival that go beyond spatial differences in healthcare provision.
⇒ By using age as time scale instead of time-on-study, we are able to model mortality hazards while controlling for composition effects due to age variance across SEE.
⇒ SEE is only observed at the district level, which prevents us from considering important variations in income at the subdistrict and individual level.
⇒ Since the data set is restricted to patients with STEMI, we can explore mortality risk conditional on having STEMI, but cannot analyse risk factors associated with STEMI.

INTRODUCTION

Socioeconomic environment (SEE) has been linked to a variety of health and survival outcomes.[1–6] This association is mediated through individual-level health status and behaviour as well as population-level and neighbourhood characteristics, including the supply of resources and services to promote and maintain healthy lifestyles.[7–10] The SEE–health relationship is highly complex and varies depending on the health condition in question.[11–14] Overall, studies have documented a link between low SEE and increased cardiovascular morbidity and mortality,[15 16] with conditions like myocardial infarction[2] and coronary artery

disease (CAD)[17] being particularly neighbourhood sensitive. For acute coronary syndrome (ACS), SEE affects treatment modalities, outpatient cardiac rehabilitation, medication at discharge, and consequently survival outcomes across patients.[18]

The association between SEE and outcomes after ST segment elevation myocardial infarction (STEMI), however, is less well understood.[19] Most studies do not investigate overall SEE effects but focus on individual-level socioeconomic status (SES) instead. Even for SES, the evidence is mixed, with some results showing no significant association between SES and clinical outcomes after STEMI,[20] while others indicate poorer cardiovascular outcomes after percutaneous coronary intervention (PCI) for patients with lower SES.[21] The available evidence to date linking SEE to STEMI has focused on differences in treatment and secondary prevention measures, with increased mortality risk observed among STEMI patients from lower SEE, especially as regards timely reperfusion therapy and door-to-balloon delay.[18 22 23] Other analysis has shown that survival among STEMI patients was significantly related to their district of residence, but not in a systematic way to the SEE of these districts.[24] Overall, the link between SEE and STEMI is still largely underexplored, thus meriting further investigation.

A better understanding of the drivers of cardiovascular morbidity and mortality is crucial given their negative impact on public health. According to the WHO, ischaemic heart disease is responsible for 16% of the world's total deaths, with CAD being the most common cause of death worldwide.[25] The total prevalence of CAD in the USA is 6.2% in adults aged 20 years and over, 7.6% in men, and 5.0% in women.[26] In Europe, every sixth man and every seventh woman die from myocardial infarction.[27] Also in Austria, diseases of the cardiovascular system are the most frequent cause of death. Recent data from Statistics Austria show that 15.9% of all male decedents and 13.4% of all female decedents die because of CAD.[28] This makes CAD a major health burden that warrants further analyses concerning its distribution and drivers.

This study aims at investigating the relationship between SEE and STEMI-related morbidity and mortality in the City of Vienna, capital of Austria. The city has close to 1.9 million residents and is divided into 23 geographical sections, called districts, which vary substantially in their SEE. Our analysis is based on an exclusive data set from the city's main tertiary care hospital, which is representative for the Viennese population. It allows us to link SEE at residential district level to (1) age at STEMI as well as (2) longer term survival outcome of patients with STEMI. A better understanding of the role of socioeconomic inequalities for medical outcomes is important to better target healthcare resources and to provide optimal medical treatment for patients undergoing PCI after STEMI.

MATERIALS AND METHODS

Data and sample

We explore a high-quality data set of patients with STEMI provided by the coronary catheter laboratory of the Medical University of Vienna (MUW) in cooperation with the MUW IT department.

Healthcare in Austria is primarily publicly organised and based on a social insurance model financed via compulsory insurance contributions. STEMIs in Vienna are treated in six public hospitals, which are equipped with coronary catheter laboratories. These hospitals are part of the Vienna STEMI network and are responsible for patients with STEMI on specific days of the week, according to a rotation schedule. On weekends, the General Hospital of Vienna is the only hospital in charge of treating STEMIs and, thus, provides representative data for the Viennese population on those days. During the week, the allocation of patients with STEMI is less strict and more selected according to—for example—proximity and, thus, the patient's district of residence. For this reason, we analyse patients who presented with STEMI on weekends only. This allows us to study differences in survival that go beyond district-level differences in tertiary healthcare provision, since all patients are initially treated in the same hospital.

Overall, a total of 1481 individuals who presented with STEMI[27] on Saturdays and Sundays at the General Hospital of Vienna between the years 2000 and 2012 are included in the analysis. Revascularisation of all patients in the sample was done by primary PCI within 1 hour from symptom onset, according to contemporary guidelines.[27] Non-STEMI, unstable angina pectoris, and elective patients are not considered in this study.

All patients with STEMI were matched with the Austrian Death Registry to obtain date and cause of death for each observation until 31 December 2018, leading to a non-informative administrative right-censoring data setup. District-level information on SEE was provided by Statistics Austria, the Austrian National Public Health Institute, the Viennese Municipal Department on Economic Affairs, Labour and Statistics as well as the Public Employment Service Austria.

Measures

The primary outcome variables of interest are age at STEMI and age at death after STEMI. We consider all-cause mortality and further differentiate between deaths related to CAD, deaths related to ACS, and all other causes of deaths. Throughout the paper, we present results for the entire study population as well as separately for women and men.

SEE and SES are usually conceptualised as a combination of economic, social, and employment aspects and typically measured using information on income, wealth, education, and occupational position as well as their aggregates.[10 17 29] Depending on their focus and data availability, studies may also consider further aspects to describe SEE, such as an area's political climate, access

to healthcare, or transportation.[1 24] By contrast, SEE and SES are frequently proxied using one dimension only, thereby often relying on household or average neighbourhood income.[6 15]

In the present study, we start by using a set of SEE dimensions to explore SEE at the district level, and then proxy SEE using each district's mean individual income for the remainder of the paper. As shown in the below results, income is highly correlated with all other SEE dimensions and, thus, a reliable proxy for the purpose of this study. Moreover, the use of only one dimension facilitates the interpretation of our results. In particular, neighbourhoods are split into three groups according to their mean individual gross income from employment, namely, high-income districts (districts 1, 13, 19, 4, 18, 8 and 23), medium-income districts (districts 7, 9, 3, 6, 22, 14, 21, 17 and 2), and low-income districts (districts 11, 5, 12, 16, 10, 20 15) (see online supplemental figure A.1 for a detailed map). Viennese districts also have names but are most commonly referred to by numbers that reflect their postcodes.

For the descriptive analysis, we further explore SEE dimensions that are frequently considered in the context of non-communicable diseases and available for the observation period at the district level. More specifically, we analyse the (1) share with compulsory education in the age group 15–64, (2) share with tertiary education in the age group 15–64, (3) unemployment rate, (4) share with non-EU country of origin, (5) inhabitants per general practitioner (GP), and (6) inhabitants per internist. All district-level information is taken from 2012 since this is the final year in which patients with STEMI are considered in the database. In addition, we analyse district-level mean age provided by the 2011 population census.

The dataset also includes a range of potential risk factors associated with STEMI in the first place. The distribution of these risk factors among patients with STEMI and their impact on survival was already investigated in an earlier study.[24] Since the aim of the present study is to evaluate survival conditional on having STEMI, and not the determinants of STEMI, risk factors are only discussed briefly in this article. More specifically, we provide SEE-specific prevalence of hypertension, hyperlipidaemia, diabetes mellitus (type 1 and type 2), whether the patient has a body mass index larger than 25 and is, thus, classified as overweight, current and previous smoking, a family history of STEMIs, cerebrovascular disease, and peripheral vascular disease.

Statistical analyses

First, we estimate non-parametric Kaplan-Meier survival curves by SEE and sex. We then employ semiparametric Cox proportional hazard regressions to quantify the effect of SEE on survival. Finally, we conduct competing risk analyses to account for the interaction of age at death and causes of deaths from CAD, ACS, and other causes. This is especially important since in long-term analyses the chance that someone dies from causes unrelated to STEMI increases with each year of observation. Not only does dying from one specific cause prevent death from another, but each cause may also interact differently with age, biasing the interpretation of morality risks by each cause.[30 31]

In most survival analyses, time-on-study is used as the time scale, with duration until the event—in our case death—being the outcome of interest.[32 33] It has, however, also been shown that in long-term epidemiologic cohort studies of chronic diseases—such as heart disease or cancer—the estimated risk factors can be confounded by the age effect. In the context of CAD or, indeed, of any disease for which the outcome of interest is correlated with age, the mortality hazard might change more as a function of age than as a function of time.[34–37] The effect is more important the longer the follow-up, or if the interest is in long-term outcomes. For example, one would expect a larger difference in survival between a 50-year-old and an 80-year-old patients with STEMI with the same follow-up time than between two 80-year-old patients with STEMI with different follow-up time. As higher age itself is a risk factor not only for overall mortality but also for mortality due to STEMI, comparing the same follow-up time among patients with different ages could potentially confound the factors associated with STEMI survival in the long term. We, thus, use age as the time scale for all analyses, which implies that patients enter the analysis at their age at STEMI and exit at their age at death or study period. This also allows us to account for differences in the age structure across districts as well as potential age differences in patients with STEMI across districts, since we always compare outcome status among individuals of the same age.

Using age and not time-to-event as the time scale may, however, affect conclusions regarding short-term survival. We, thus, also employ time-to-event models as a sensitivity analyses (see online supplemental tables A.1 and A.2). As the focus of this study is on the effect of SEE on long-term survival, while accounting for age as a factor that is related to the outcome itself, we choose a Cox semiparametric regression setting for estimating hazards, instead of using alternative methods like Laplace regressions that focus on percentiles of age at death rather than HRs.[38]

All analyses are conducted for the entire study population while controlling for sex as well as for women and men in separate. Moreover, all models are stratified on the year of STEMI to account for structural, institutional, or data collection changes over time.

Patient and public involvement

Data for this study are provided by the MUW and do not contain personal medical information about identifiable living individuals. Patients with STEMI or the public were not directly involved in the design, conduct or reporting of this study. Results will, however, be disseminated to the public via various channels once this research article is publicly available.

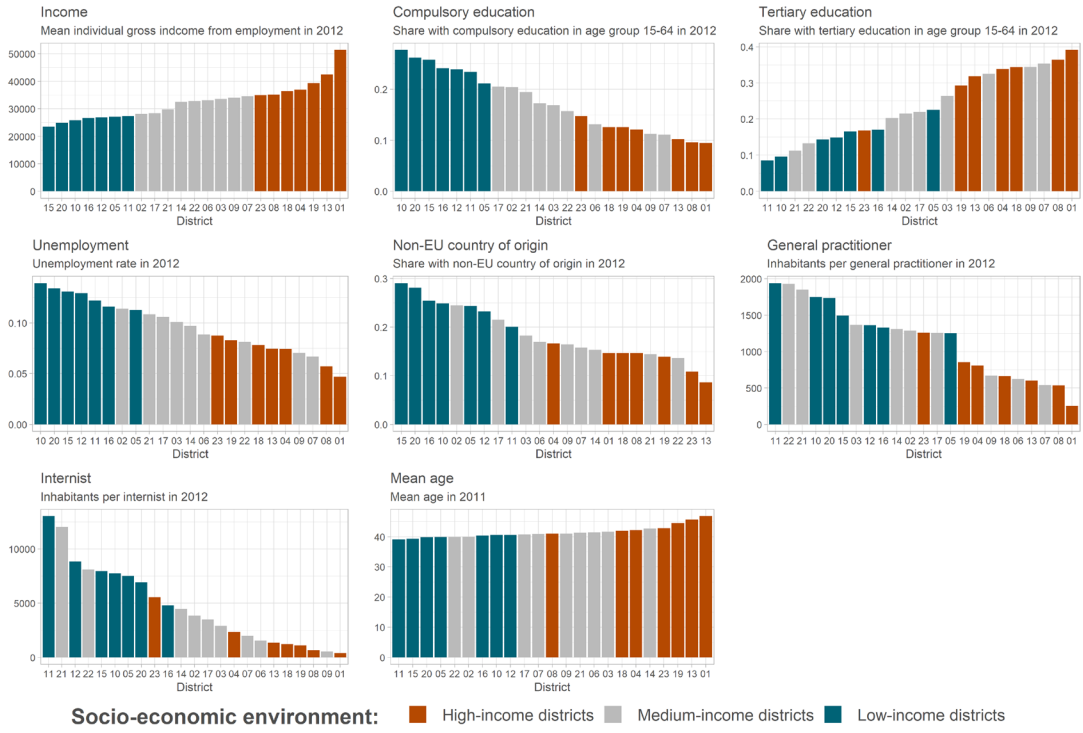

Figure 1 Socioeconomic environment and age structure per district in 2012 and 2011. Income data were provided by Statistics Austria and the Viennese Municipal Department on Economic Affairs, Labour and Statistics. Information on education and unemployment was provided by the Viennese Municipal Department on Economic Affairs, Labour and Statistics. Data on Non-EU country of origin were extracted from the Statistics Austria website. Information on general practitioners and internists was provided by the Austrian National Public Health Institute, and mean age was taken from the 2011 population census.

RESULTS

Descriptive results on socioeconomic environment

Figure 1 describes the SEE of the 23 Viennese municipal districts using seven dimensions and also shows differences in the age structure. The districts are colour coded based on the mean individual gross income from employment, which is highly correlated with the other SEE dimensions. In particular, we differentiate between low-income districts, medium-income districts, and high-income districts.

The shares of residents with compulsory education and tertiary education in the age group 15–64 are closely related to the districts' mean individual income–the higher the average educational attainment, the higher the mean individual income in each district. The correlation coefficient is 0.739 for mean individual income and the share of individuals with tertiary education, and −0.861 for the share of individuals with compulsory education. One exception is the 23rd district, which has high income but a low share of individuals with tertiary education. By contrast, the fifth district has low mean income, but the share of individuals with tertiary education is in the middle-field.

The unemployment rate as well as the share with non-EU country of origin are negatively correlated with the neighbourhoods' mean individual gross income (correlation coefficients of −0.873 and −0.774, respectively). The only exception is the fourth district, which has high income and a high share of individuals with non-EU country of origin. This district hosts many international embassies and, thus, potentially many individuals with non-EU country of origin but high socioeconomic status.

Other dimensions of SEE are the number of inhabitants per GP and internists, which also vary with district mean income and are highest in poor areas (correlation coefficient of −0.738 and −0.662, respectively). Two exceptions are, again, the 23rd district, which has high income but relatively low numbers of GPs and internists as well as the fifth district, which has a high number of GPs given its mean income.

The final panel in figure 1 shows that, overall, mean age is also related to income across Viennese neighbourhoods. On average, poorer districts are younger and richer districts are older. This finding reinforces our choice of using age as the time scale when performing the survival analyses. Online supplemental figure A.2 shows that age at STEMI and time until death are negatively correlated, that is, younger patients with STEMI survive longer than older patients. Since district mean age as well as mean age at STEMI (see table 1) vary across SEE, this relationship could obscure SEE differentials in survival when using time-on-study as the time scale instead.

Descriptive statistics of patients with STEMI

Table 1 provides summary statistics for our study population of patients with STEMI. The observed patients are aged 24–94 with mean age at STEMI 60.6year and mean age at death 73.8 years. Both age at STEMI and

Table 1 Summary statistics STEMI patients 2000 to 2012

Sex	Total	Women				Men			
SEE	**Total**	**High**	**Medium**	**Low**	**P value**	**High**	**Medium**	**Low**	**P value**
STEMI patients (N)	1481	84	167	165		207	425	433	
Died (N)	479	37	60	60		64	130	128	
Died (%)*	32.3	44.0	35.9	36.4		30.9	30.6	29.6	
Cause of death									
ACS (N)	126	11	16	18		18	28	35	
ACS (%)†	26.3	29.7	26.7	30.0		28.1	21.5	27.3	
CAD (N)	141	13	21	19		15	34	39	
CAD (%)†	29.4	35.1	35.0	31.7		23.4	26.2	30.5	
Other (N)	212	13	23	23		31	68	54	
Other (%)†	44.3	35.1	38.3	38.3		48.4	52.3	42.2	
Age at STEMI									
Mean	60.6	70.2	67.0	64.6	0.008	60.2	58.4	57.3	0.022
SD	13.4	13.7	13.4	14.0		12.7	12.1	12.7	
Median	59.9	72.7	67.2	65.4		59.5	58.2	56.5	
Minimum	24.6	34.7	37.8	33.1		26.1	27.2	24.6	
Maximum	94.3	94.3	94.1	93.7		89.6	89.8	91.6	
Age at death									
Mean	73.8	81.0	79.6	78.2	0.412	74.2	70.1	70.4	0.047
SD	11.6	9.7	10.2	10.2		9.0	11.6	11.8	
Median	73.9	83.2	79.2	80.4		72.9	69.7	71.4	
Minimum	36.4	57.8	57.6	56.1		50.8	40.3	36.4	
Maximum	99.5	99.5	97.5	97.9		91.8	94.5	94.4	
Risk factors (%)*									
Hypertension	57.7	64.3	54.5	64.2		57.5	56.7	56.1	
Hyperlipidaemia	61.2	56.0	52.7	56.4		67.6	62.6	62.8	
Diabetes	19.2	20.2	19.2	22.4		19.3	16.2	20.6	
Overweight	70.3	58.2	62.6	57.3		72.5	71.9	77.5	
Smoking	49.9	32.1	35.3	40.0		53.6	54.8	56.1	
Family history	17.5	8.3	14.4	17.6		18.8	19.8	17.6	
CVD	6.7	8.3	5.4	8.5		8.2	6.1	6.0	
PVD	5.3	7.1	5.4	6.1		5.3	5.9	4.2	

Based on patients presented with STEMI in the General Hospital of Vienna on weekends between the years 2000 and 2012. Individuals were followed and thus their deaths registered until 31 December 2018. P values are based on an analysis of variance (ANOVA) comparing differences in mean values across SEE separately for women and men.
*100% = 'N STEMI patients'.
†100% = 'Died (N)'.
ACS, acute coronary syndrome; CAD, coronary artery disease; CVD, cerebrovascular disease; n, number of observations; PVD, peripheral vascular disease; SEE, socioeconomic environment; STEMI, ST-segment elevation myocardial infarction.

age at death vary substantially across SEE. Patients with STEMI from low-income districts are much younger than patients with STEMI from high-income districts, which holds for both women and men. The proportion of STEMI patients younger than 50 compared with all STEMI patients is highest in low-income districts (26.8%), followed by medium-income districts (22.5%), and high-income districts (19.2%) (see online supplemental table A.3 for the detailed table). Online supplemental figure A.3 shows the age distribution of patients with STEMI for each district individually and suggests an SEE gradient in the age at STEMI.

Age at death, considering all causes, also varies substantially across SEE in Vienna, but more so for men than for women. The proportion of young deaths (age at death<60) compared with all deaths after STEMI is

again highest in low-income districts (14.4%), followed by medium-income districts (12.1%), and high-income districts (4.0%). This finding also holds when considering each district individually (online supplemental figure A.4) as well as when analysing deaths from CAD and ACS only (online supplemental figure A.5). The share of patients with STEMI dying from CAD and ACS before their 60th birthday is also highest in low-income districts (14.4%), followed by medium-income districts (13.1%), and high-income districts (5.3%).

Most of the 1481 patients are men (71.9%), which is in line with other studies on STEMI.[24 39–41] While male patients with STEMI die mostly from other causes, female patients with STEMI have high shares of deaths related to ACS and CAD.

In summary, the descriptive evidence suggests that both female and male patients with STEMI from rich districts have STEMI later in life and die at older ages, while patients with STEMI from poor districts have STEMI earlier in life and die at younger ages.

Overview of STEMI-related risk factors

Table 1 also provides an overview of the most important STEMI risk factors across SEE. Most risk factors show a high prevalence among patients with STEMI in our sample. For example, 70.3% of the patients are overweight, 61.2% suffer from hyperlipidaemia, and 49.9% smoke or have smoked in the past. The SEE gradient in these risk factors is, however, not always as expected, that is, risk factors are not necessarily more widespread in low-income districts. For example, the prevalence of diabetes and being overweight is highest among male patients from low-income districts, which could partly explain why STEMI occurs at younger ages in this subgroup. By contrast, hyperlipidaemia is most prevalent among male patients from high-income districts. This curious finding is again likely related to the different age compositions across SEE—since the risk factors increase with age, and richer districts are—on average—older than poorer districts, the relationship between individual SES and STEMI risk factors could be obscured.

For a detailed analysis of risk factors and their association with individual survival in the MUW STEMI data set, see Roth *et al*.[24]

Kaplan-Meier survival probability estimates considering all-cause mortality

Figure 2 provides Kaplan-Meier survival probability estimates for women and men from high, medium, and low SEE with age as time-scale, considering all-cause mortality. The survival probability as well as the median survival for male patients from rich districts appears to be much higher than that of male patients from other SEEs. By contrast, the graph suggests no difference in survival across SEE for women.

Determining whether the curves in figure 2 are statistically different from one another is best possible by running a Cox proportional hazard model including only SEE as explanatory variable and then conducting simultaneous tests for general linear hypotheses. These tests suggest that the survival probability is not actually significantly different across income groups in our sample, neither for women nor for men.

Cox proportional hazard regression analysis considering all-cause mortality

Table 2 presents estimated effects of SEE on survival based on semiparametric Cox proportional hazard regressions

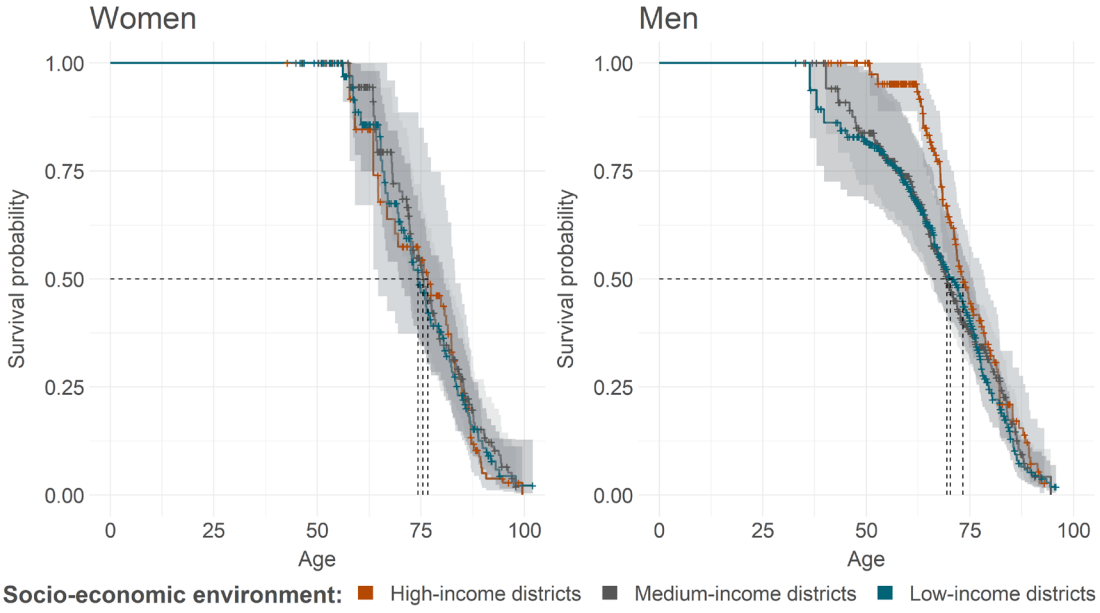

Figure 2 Kaplan-Meier survival probability estimates, using age as time scale; based on patients presented with STEMI in the General Hospital of Vienna on weekends between the years 2000 and 2012 (416 women and 1065 men). Individuals were followed and thus their deaths registered until 31 December 2018. Dashed lines indicate median survival and the grey area represents 95% CIs. STEMI, ST-segment elevation myocardial infarction.

Table 2 Cox proportional hazard estimates

		Coefficient	95% CIs	HR	95% CIs	P value
Full sample	SEE=medium	−0.033	−0.286 to 0.221	0.968	0.751 to 1.247	0.801
(N=1481)	SEE=low	0.039	−0.215 to 0.293	1.040	0.807 to 1.340	0.761
	Sex=women	−0.29	−0.505 to −0.08	0.748	0.604 to 0.928	0.008
Women only	SEE=medium	−0.061	−0.529 to 0.407	0.941	0.589 to 1.502	0.798
(N=416)	SEE=low	0.051	−0.415 to 0.517	1.052	0.660 to 1.677	0.830
Men only	SEE=medium	0.063	−0.262 to 0.389	1.065	0.770 to 1.476	0.703
(N=1065)	SEE=low	0.109	−0.213 to 0.431	1.115	0.808 to 1.539	0.506

Cox proportional hazard estimates, using age as time scale and stratified on the year variable; based on patients presented with STEMI in the General Hospital of Vienna on weekends between 2000 and 2012. Individuals were followed and thus their deaths registered until 31 December 2018. High-income districts serve as a reference category for SEE and men serve as a reference category for sex in the full sample.
N, number of observations; SEE, socio-economic environment; STEMI, ST-segment elevation myocardial infarction.

for the full sample as well as for women and men separately, considering all-cause mortality. Sex is controlled for when analysing the full sample and all three models are stratified on the year variable. The proportional hazard assumption holds for all three models and a visual interpretation of the Schoenfeld residuals suggests no time pattern in the HRs either. Although point estimates suggest that patients with STEMI from poorer districts have a 4% higher risk of dying relative to patients with STEMI from rich districts (HR 1.040, 95% CIs 0.807 to 1.340 for the full sample), these effects are not statistically significant in any of the three models and have large CIs. We find, however, that female patients with STEMI in this sample have significant better survival outcomes than male patients with STEMI, with a risk of dying that is almost 25% lower (HR 0.748, 95% CIs 0.604 to 0.928 for the full sample).

In the online supplemental material, we provide and discuss estimates based on Cox regressions using time-to-event as the time scale, with and without adjusting for age at STEMI (online supplemental tables A.1 and A.2, figure A.6). Results suggest that higher age is mediating the sex link to mortality in case of STEMI. Along with the evident heterogeneities in the age structure across districts, this finding supports our approach of using age as time scale for the main analyses. This way, we are performing a more robust comparison for longer term follow-up and considering not only the percent increase in mortality risk with a 1-year increase in age, but also comparing individuals of the same age in terms of their mortality risk.

Competing risk analysis: differentiating between deaths from ACS, CAD, and other causes

Table 3 displays results from the competing risk analyses, where we differentiate between deaths from ACS, deaths from CAD, and other causes of death. All three models are again stratified on the year variable. They satisfy the proportional hazard assumption and the Schoenfeld residuals are inconspicuous.

We find no clear effects of SEE on survival for any of the causes of deaths, neither in the full sample nor in the sex-specific subsamples. Interestingly, however, the female survival advantage appears to be present only for deaths related to CAD (HR: 0.668, 95% CIs 0.452 to 0.985 for the full sample) and other causes of deaths (HR: 0.627, 95% CIs 0.444 to 0.884 for the full sample), but not for deaths from ACS (HR: 1.083, 95% CIs 0.732 to 1.602 for the full sample). This result is in line with the literature, which shows that women with ACS who are hospitalised have a higher risk of mortality compared with men, especially if undergoing coronary revascularisation, and even after 1 year of follow-up.[42–45]

DISCUSSION

We explored an exclusive data set for the City of Vienna to investigate the relationship between SEE, age at STEMI and survival after STEMI separately for women and men. The descriptive evidence suggested a socioeconomic gradient in the age at STEMI as well as the age at death after STEMI for both sexes, with patients with STEMI from low-income districts having STEMI earlier in life and dying at younger ages, while patients with STEMI from high-income districts have STEMI later in life and die at older ages. The descriptive findings regarding survival after STEMI were, however, not supported by the Kaplan-Meier survival probability estimates, the Cox proportional hazard regressions, or the competing risk analysis. This result is aligned with other studies that have not found a significant relationship between STEMI survival and SEE, especially when the healthcare system was universal,[46] or when population composition was accounted for.[47]

Nonetheless, we found important differences in survival between female patients with STEMI and male patients with STEMI. Female patients with STEMI have better survival outcomes, which might be related to their overall survival advantage. This survival advantage is, however, only present for deaths related to CAD and

Table 3 Competing risk analysis

			ACS deaths	CAD deaths	Other deaths
Full sample	SEE=medium	Coefficient	−0.204	0.083	−0.002
(N=1481)		Hazard ratios	0.815	1.087	0.998
		P-value	0.413	0.737	0.992
	SEE=low	Coefficient	−0.020	0.227	−0.053
		Hazard ratios	0.980	1.255	0.948
		P-value	0.935	0.355	0.790
	Sex=women	Coefficient	0.080	−0.404	−0.467
		Hazard ratios	1.083	0.668	0.627
		P-value	0.691	0.042	0.008
Women only	SEE=medium	Coefficient	0.001	−0.230	0.053
(N=416)		Hazard ratios	1.001	0.795	1.054
		P-value	0.998	0.565	0.893
	SEE=low	Coefficient	0.198	−0.121	0.100
		Hazard ratios	1.219	0.886	1.105
		P-value	0.665	0.763	0.797
Men only	SEE=medium	Coefficient	−0.188	0.443	−0.009
(N=1065)		Hazard ratios	0.829	1.557	0.991
		P-value	0.572	0.194	0.968
	SEE=low	Coefficient	0.067	0.453	−0.059
		Hazard ratios	1.069	1.573	0.943
		P-value	0.835	0.173	0.803

Competing risk analysis, using age as time scale and stratified on the year variable; based on patients presented with STEMI in the General Hospital of Vienna on weekends between 2000 and 2012. Individuals were followed and thus their deaths registered until 31 December 2018. High-income districts serve as a reference category for SEE and men serve as a reference category for sex in the full sample.
ACS, acute coronary syndrome; CAD, coronary artery disease; N, number of observations; SEE, socio-economic environment; STEMI, ST-segment elevation myocardial infarction.

other causes of deaths, but not for deaths from the more acute ACS. This is in line with other evidence that report poorer outcomes among women with ACS who are hospitalised compared with men, especially if hospitalised and undergoing coronary revascularisation.[45 48 49] Hence, the higher mortality among women may be connected to in-hospital treatment or the level of severity of their condition. Another potential explanation for this finding could be the older ages and higher number of comorbidities among women suffering myocardial infarction.[39 50 51] Although ACS occurs three to four times more in men than in women below the age of 60 years, women represent the majority of patients after the age of 75.[50] Moreover, women have atypical symptoms up to 30% more often,[52] but tend to present them later than men.[53 54] Compared with men, they also experience a greater amount of ischaemic time related to STEMI, which is related to further patient delays.[55] Relatedly, women undergo fewer ACS-related interventions than men and receive reperfusion therapy less frequently.[50 56 57] Finally, they have a higher risk of bleeding complications from PCI—an important treatment for STEMI that increases survival rates and is an important part of medical guideline procedures.[27 58 59] All of this previous evidence could help explain why the female survival advantage is not present for ACS in our study.

Overall, SEE may be more important to explain risk factors among patients with STEMI, but not their survival, especially in the context of universal healthcare systems such as in Austria. However, results from this sample suggest that differences in the age structure across districts may obscure the relationship between individual-level risk factors and district-level morbidity and mortality. In addition, despite the fact that ischaemic heart disease develops on average 7–10 years later in women compared with men, STEMI remains a leading cause of death in women. Our finding signals that further research on the risk factors, treatment and characteristics of STEMI outcomes by sex is needed as well as a deeper understanding of the role of SEE in shaping the pathways through which women and men differ in their health and mortality outcomes. These considerations may enlighten treatment guidelines as stated by the European Society of Cariology.[58]

Moreover, future research could fruitfully explore the relationship between SEE and survival after STEMI on

the subdistrict or individual level for the City of Vienna, for example, by accounting for social housing, which is prevalent in all Viennese districts. Moreover, this study has suggested that individuals from low SEE have STEMI at younger ages and individuals from high SEE have STEMI at older ages, which warrants further investigations. Since our data set is restricted to patients with STEMI only, we cannot directly analyse factors related to the risk of having STEMI. Hence, further studies should investigate differences in STEMI risks across Viennese districts. Finally, since patients with STEMI from low SEE are often younger, they live relatively longer after STEMI and, thus, have a longer time until death. Future work should, thus, investigate if this relationship has the potential to obscure the link between SEE and survival after STEMI when time-on-study is considered as the time scale instead of age, and whether the effects that are being observed are capturing ageing effects instead of a specific mortality risk.

In this regard, a key strength of this study is the use of age as the time scale for all analyses, which allowed us to compare patients with similar underlying risk of dying with respect to their age, and the overall higher female longevity. Moreover, this approach accounted for differences in overall population age structure and mean age at STEMI across districts. Another important contribution of this research is its focus on the relationship between SEE, age at STEMI and age at death after STEMI, which has not been studied in detail before for a Central European City like Vienna.[18 24]

The main limitations of this study are data related. First, SEE is only observed at the district level and, thus, prevents the analysis of variations in income and mortality across sub-istrict entities, households or individuals. Second, the number of observations in some districts and especially in some district-sex cells are rather low, which is likely to cause the large uncertainty around the estimates. Finally, the data set is restricted to patients with STEMI, which allows us to explore mortality risk conditional on having STEMI, but prevents us from analysing risk factors associated with having STEMI in the first place.

CONCLUSIONS

This study suggests that, within our sample, SEE does not explain differences in survival among patients with STEMI. SEE may not be important for explaining mortality outcomes in the Viennese case, despite being important for explaining risk factors.[24] This may in part be due to Austria's universal healthcare coverage and the fact that patients with STEMI are all admitted in the same hospital, as has been reported in other contexts where universal healthcare is available.[46] STEMI has a high mortality rate and is intimately connected to the conditions, speed, and type of treatments a patient receives, which may explain why we do not observe SEE differentials in mortality outcomes.[60–62] In addition, the fact that patients coming from lower SEE are younger may play an important role in explaining survival, as age itself is an important risk factor and compositional effects have been shown to be important STEMI outcomes.[47] Patients with lower SEE present STEMI earlier, but are also younger, which may offset SEE effects in their survival. This shows how the pathways linking socioeconomic environments, risk factors, and survival are not straightforward, meriting further investigation into the mechanisms underlying different risk profiles, which are key for well-targeted policymaking. Medical guidelines, prognostic calculations, and management of cardiovascular disease should be targeted taking into account not only SEE indicators but also the distribution of risk factors across SEE groups, district-level characteristics, and the age distribution of the population.

Age in itself is an important risk factor for mortality. If certain districts have an older age distribution relative to others, this will also impact their survival rates. In this regard, using multiple approaches to survival models that use both age and duration as the time scale may be helpful for disentangling the age effect from other risk factors that may not be district-level specific. Finally, our findings suggest that further research on the risk factors, treatment, and characteristics of STEMI outcomes by sex is needed as well a deeper understanding of the role of SEE in shaping the pathways through which women and men differ in their health and mortality outcomes.

Author affiliations
[1]Department of Demography, University of Vienna, Wittgenstein Centre for Demography and Global Human Capital (IIASA, OeAW, University of Vienna), Wien, Austria
[2]Vienna Institute of Demography, Austrian Academy of Sciences, Wittgenstein Centre for Demography and Global Human Capital (IIASA, OeAW, University of Vienna), Wien, Austria
[3]Economic Frontiers Program, International Institute for Applied Systems Analysis, Laxenburg, Austria
[4]Department of Internal Medicine II, Cardiology, Medical University of Vienna, Wien, Austria
[5]Department of Internal Medicine I, Cardiology and Nephrology, Hospital of St. John of God, Eisenstadt, Austria

Twitter Sonja Spitzer @Sonja_Spitzer and Vanessa di Lego @v_dilego

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ORCID iDs
Sonja Spitzer http://orcid.org/0000-0002-2114-7947
Michael Kuhn http://orcid.org/0000-0003-0424-3221

REFERENCES

1 Cummins S, Stafford M, Macintyre S, *et al*. Neighbourhood environment and its association with self rated health: evidence from Scotland and England. *J Epidemiol Community Health* 2005;59:207–13.
2 Wen M, Christakis NA. Neighborhood effects on posthospitalization mortality: a population-based cohort study of the elderly in Chicago. *Health Serv Res* 2005;40:1108–27.
3 Graham GN. Why your ZIP code matters more than your genetic code: promoting healthy outcomes from mother to child. *Breastfeed Med* 2016;11:396–7.
4 Mackenbach JP, Valverde JR, Artnik B, *et al*. Trends in health inequalities in 27 European countries. *Proc Natl Acad Sci U S A* 2018;115:6440–5.
5 Mackenbach JP, Rubio Valverde J, Bopp M, *et al*. Progress against inequalities in mortality: register-based study of 15 European countries between 1990 and 2015. *Eur J Epidemiol* 2019;34:1131–42.
6 Addo J, Ayerbe L, Mohan KM, *et al*. Socioeconomic status and stroke: an updated review. *Stroke* 2012;43:1186–91.
7 Link BG, Phelan J. Social conditions as fundamental causes of disease. *J Health Soc Behav* 1995;Spec No:80–94.
8 Woolf SH, Braveman P. Where health disparities begin: the role of social and economic determinants--and why current policies may make matters worse. *Health Aff* 2011;30:1852–9.
9 Eschbach K, Ostir GV, Patel KV, *et al*. Neighborhood context and mortality among older Mexican Americans: is there a barrio advantage? *Am J Public Health* 2004;94:1807–12.
10 Oakes JM, Rossi PH. The measurement of SES in health research: current practice and steps toward a new approach. *Soc Sci Med* 2003;56:769–84.
11 Macintyre S, Ellaway A, Cummins S. Place effects on health: how can we conceptualise, operationalise and measure them? *Soc Sci Med* 2002;55:125–39.
12 Nandi A, Kawachi I. *Neighborhood effects on mortality*. Dordrecht: Springer, 2011: 413–39.
13 Subramanian SV, Kawachi I. Whose health is affected by income inequality? A multilevel interaction analysis of contemporaneous and lagged effects of state income inequality on individual self-rated health in the United States. *Health Place* 2006;12:141–56.
14 Subramanyam M, Kawachi I, Berkman L, *et al*. Relative deprivation in income and self-rated health in the United States. *Soc Sci Med* 2009;69:327–34.
15 Agarwal S, Garg A, Parashar A, *et al*. Outcomes and resource utilization in ST-elevation myocardial infarction in the United States: evidence for socioeconomic disparities. *J Am Heart Assoc* 2014;3:e001057.
16 Alter DA, Naylor CD, Austin P, *et al*. Effects of socioeconomic status on access to invasive cardiac procedures and on mortality after acute myocardial infarction. *N Engl J Med* 1999;341:1359–67.
17 Diez Roux AV, Merkin SS, Arnett D, *et al*. Neighborhood of residence and incidence of coronary heart disease. *N Engl J Med* 2001;345:99–106.
18 Kämpfer J, Yagensky A, Zdrojewski T, *et al*. Long-Term outcomes after acute myocardial infarction in countries with different socioeconomic environments: an international prospective cohort study. *BMJ Open* 2017;7:e012715–9.
19 Chew DP, Scott IA, Cullen L, *et al*. National Heart Foundation of Australia & Cardiac Society of Australia and New Zealand: Australian Clinical Guidelines for the Management of Acute Coronary Syndromes 2016. *Heart, Lung and Circulation* 2016;25:895–951.
20 Denvir MA, Lee AJ, Rysdale J, *et al*. Influence of socioeconomic status on clinical outcomes and quality of life after percutaneous coronary intervention. *J Epidemiol Community Health* 2006;60:1085–8.
21 Jakobsen L, Niemann T, Thorsgaard N, *et al*. Dimensions of socioeconomic status and clinical outcome after primary percutaneous coronary intervention. *Circ Cardiovasc Interv* 2012;5:641–8.
22 Lassen JF, Bøtker HE, Terkelsen CJ. Timely and optimal treatment of patients with STEMI. *Nat Rev Cardiol* 2013;10:41–8.
23 Terkelsen CJ, Sørensen JT, Maeng M, *et al*. System delay and mortality among patients with STEMI treated with primary percutaneous coronary intervention. *JAMA* 2010;304:763–71.
24 Roth C, Berger R, Kuhn M. The role of the socio-economic environment on medical outcomes after ST-segment elevation myocardial infarction. *BMC Public Health* 2019;19:1–14.
25 WHO. The top 10 causes of death 2018.
26 Writing Group Members, Mozaffarian D, Benjamin EJ, *et al*. Heart disease and stroke Statistics-2016 update: a report from the American heart association. *Circulation* 2016;133:e38–48.
27 Task Force on the management of ST-segment elevation acute myocardial infarction of the European Society of Cardiology (ESC), Steg PG, James SK, *et al*. ESC guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. *Eur Heart J* 2012;33:2569–619.
28 Statistics Austria. Todesursachen: absolute und relative Häufigkeit der Gestorbenen sowie durchschnittliches empirisches Sterbealter nach Todesursachen und Geschlecht 2020, 2020. Available: http://www.statistik.at/web_de/statistiken/menschen_und_gesellschaft/gesundheit/todesursachen/index.html [Accessed 21 Oct 2021].
29 Psaki SR, Seidman JC, Miller M, *et al*. Measuring socioeconomic status in multicountry studies: results from the eight-country MAL-ED study. *Popul Health Metr* 2014;12:8.
30 Geskus RB. *Data analysis with competing risks and intermediate states*. Boca Raton, FL: Taylor & Francis Group/Chapman and Hall/CRC, 2016.
31 Andersen PK, Geskus RB, de Witte T, *et al*. Competing risks in epidemiology: possibilities and pitfalls. *Int J Epidemiol* 2012;41:861–70.
32 Kalbfleisch JD, Prentice RL. *The statistical analysis of failure time data*, 2002.
33 Keiding N, Incidence A-S. And prevalence: a statistical perspective. *Journal of the Royal Statistical Society Series A* 1991;154:371.
34 Griffin BA, Anderson GL, Shih RA, *et al*. Use of alternative time scales in COX proportional hazard models: implications for time-varying environmental exposures. *Stat Med* 2012;31:3320–7.
35 Korn EL, Graubard BI, Midthune D. Time-to-event analysis of longitudinal follow-up of a survey: choice of the time-scale. *Am J Epidemiol* 1997;145:72–80.
36 Lamarca R, Alonso J, Gómez G, *et al*. Left-truncated data with age as time scale: an alternative for survival analysis in the elderly population. *J Gerontol A Biol Sci Med Sci* 1998;53:M337–43.
37 Cologne J, Hsu W-L, Abbott RD, *et al*. Proportional hazards regression in epidemiologic follow-up studies: an intuitive consideration of primary time scale. *Epidemiology* 2012;23:565–73.
38 Bellavia A, Discacciati A, Bottai M, *et al*. Using Laplace regression to model and predict percentiles of age at death when age is the primary time scale. *Am J Epidemiol* 2015;182:271–7.
39 Kytö V, Sipilä J, Rautava P. Gender and in-hospital mortality of ST-segment elevation myocardial infarction (from a multihospital nationwide registry study of 31,689 patients). *Am J Cardiol* 2015;115:303–6.
40 Tillmanns H, Waas W, Voss R, *et al*. Gender differences in the outcome of cardiac interventions. *Herz* 2005;30:375–89.

41 Khera S, Kolte D, Gupta T, *et al*. Temporal Trends and Sex Differences in Revascularization and Outcomes of ST-Segment Elevation Myocardial Infarction in Younger Adults in the United States. *J Am Coll Cardiol* 2015;66:1961–72.
42 Hochman JS, Tamis JE, Thompson TD, *et al*. Sex, clinical presentation, and outcome in patients with acute coronary syndromes. global use of strategies to open occluded coronary arteries in acute coronary syndromes IIb Investigators. *N Engl J Med* 1999;341:226–32.
43 Vaccarino V, Parsons L, Every NR, *et al*. Sex-based differences in early mortality after myocardial infarction. National Registry of myocardial infarction 2 participants. *N Engl J Med* 1999;341:217–25.
44 Berger JS, Elliott L, Gallup D, *et al*. Sex differences in mortality following acute coronary syndromes. *JAMA* 2009;302:874–82.
45 Udell JA, Koh M, Qiu F, *et al*. Outcomes of women and men with acute coronary syndrome treated with and without percutaneous coronary revascularization. *J Am Heart Assoc* 2017;6:e004319.
46 Biswas S, Andrianopoulos N, Duffy SJ, *et al*. Impact of socioeconomic status on clinical outcomes in patients with ST-segment-elevation myocardial infarction. *Circ Cardiovasc Qual Outcomes* 2019;12:e004979.
47 Ambugo EA, Hagen TP. A multilevel analysis of mortality following acute myocardial infarction in Norway: do municipal health services make a difference? *BMJ Open* 2015;5:e008764–10.
48 Graham G. Acute coronary syndromes in women: recent treatment trends and outcomes. *Clin Med Insights Cardiol* 2016;10:CMC. S37145–10.
49 Kostis JB, Wilson AC, O'Dowd K. Sex differences in the management and long-term outcome of acute myocardial infarction. *A statewide study. MIDAS Study Group. Myocardial Infarction Data Acquisition System. Circulation* 1994;90:1715–30.
50 EUGenMed Cardiovascular Clinical Study Group, Regitz-Zagrosek V, Oertelt-Prigione S, *et al*. Gender in cardiovascular diseases: impact on clinical manifestations, management, and outcomes. *Eur Heart J* 2016;37:24–34.
51 Kang S-H, Suh J-W, Yoon C-H, *et al*. Sex differences in management and mortality of patients with ST-elevation myocardial infarction (from the Korean acute myocardial infarction national registry). *Am J Cardiol* 2012;109:787–93.
52 Brieger D, Eagle KA, Goodman SG, *et al*. Acute coronary syndromes without chest pain, an underdiagnosed and undertreated high-risk group: insights from the global registry of acute coronary events. *Chest* 2004;126:461–9.
53 Kaul P, Armstrong PW, Sookram S, *et al*. Temporal trends in patient and treatment delay among men and women presenting with ST-elevation myocardial infarction. *Am Heart J* 2011;161:91–7.
54 Diercks DB, Owen KP, Kontos MC, *et al*. Gender differences in time to presentation for myocardial infarction before and after a national women's cardiovascular awareness campaign: a temporal analysis from the can rapid risk stratification of unstable angina patients suppress adverse outcomes with early implementation (crusade) and the National cardiovascular data registry acute coronary treatment and intervention outcomes Network-Get with the guidelines (NCDR action Registry-GWTG). *Am Heart J* 2010;160:80–7.
55 Meyer MR, Bernheim AM, Kurz DJ, *et al*. Gender differences in patient and system delay for primary percutaneous coronary intervention: current trends in a Swiss ST-segment elevation myocardial infarction population. *Eur Heart J Acute Cardiovasc Care* 2019;8:283–90.
56 Hvelplund A, Galatius S, Madsen M, *et al*. Women with acute coronary syndrome are less invasively examined and subsequently less treated than men. *Eur Heart J* 2010;31:684–90.
57 Nguyen JT, Berger AK, Duval S, *et al*. Gender disparity in cardiac procedures and medication use for acute myocardial infarction. *Am Heart J* 2008;155:862–8.
58 Ibanez B, James S, Agewall S. ESC guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. *European Heart Journal* 2017;2018:119–77.
59 Nanna MG, Hajduk AM, Krumholz HM, *et al*. Sex-based differences in presentation, treatment, and complications among older adults hospitalized for acute myocardial infarction: the SILVER-AMI study. *Circ Cardiovasc Qual Outcomes* 2019;12:e005691.
60 Kochar A, Chen AY, Sharma PP, *et al*. Long-Term mortality of older patients with acute myocardial infarction treated in US clinical practice. *J Am Heart Assoc* 2018;7. doi:10.1161/JAHA.117.007230. [Epub ahead of print: 30 06 2018].
61 Doost Hosseiny A, Moloi S, Chandrasekhar J, *et al*. Mortality pattern and cause of death in a long-term follow-up of patients with STEMI treated with primary PCI. *Open Heart* 2016;3:e000405.
62 Alabas OA, Jernberg T, Pujades-Rodriguez M, *et al*. Statistics on mortality following acute myocardial infarction in 842 897 Europeans. *Cardiovasc Res* 2020;116:149–57.