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Exposure to Traffic and the Onset of Myocardial Infarction

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ABSTRACT

BACKGROUND

An association between exposure to vehicular traffic in urban areas and the exacerbation of cardiovascular disease has been suggested in previous studies. This study was designed to assess whether exposure to traffic can trigger myocardial infarction.

METHODS

We conducted a case–crossover study in which cases of myocardial infarction were identified with the use of data from the Cooperative Health Research in the Region of Augsburg Myocardial Infarction Registry in Augsburg, in southern Germany, for the period from February 1999 to July 2001. There were 691 subjects for whom the date and time of the myocardial infarction were known who had survived for at least 24 hours after the event, completed the registry's standardized interview, and provided information on factors that may have triggered the myocardial infarction. Data on subjects' activities during the four days preceding the onset of symptoms were collected with the use of patient diaries.

RESULTS

An association was found between exposure to traffic and the onset of a myocardial infarction within one hour afterward (odds ratio, 2.92; 95 percent confidence interval, 2.22 to 3.83; P<0.001). The time the subjects spent in cars, on public transportation, or on motorcycles or bicycles was consistently linked with an increase in the risk of myocardial infarction. Adjusting for the level of exercise on a bicycle or for getting up in the morning changed the estimated effect of exposure to traffic only slightly (odds ratio for myocardial infarction, 2.73; 95 percent confidence interval, 2.06 to 3.61; P<0.001). The subject's use of a car was the most common source of exposure to traffic; nevertheless, there was also an association between time spent on public transportation and the onset of a myocardial infarction one hour later.

CONCLUSIONS

Transient exposure to traffic may increase the risk of myocardial infarction in susceptible persons.

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Myocardial infarction is one of the main causes of death from cardiovascular disease. A myocardial infarction has a sudden onset, and factors related to lifestyle have been identified as potential triggers of myocardial infarction. These include strenuous exercise,[1-3] anger,[4] and the use of cocaine[5] and marijuana.[6] Recently, environmental factors such as elevated concentrations of ambient particulate matter have been added to the list of triggers.[7]

Traffic is an important concern in urban areas as a potential risk factor for cardiovascular disease.[8] In a cohort study, the risk of death from cardiopulmonary causes was twice as high among persons living close to a major road or highway, after adjustment for risk factors such as age, sex, and smoking status, than among those living farther from a major road or highway.[9] In addition, case–control studies have indicated that the work environment of professional drivers may contribute to their risk for myocardial infarction.[10,11]

In this study we assessed the association between the onset of a nonfatal myocardial infarction and exposure to traffic. The study assessed the effect of exposure on the basis of a complete case series of survivors of myocardial infarction, with the use of the case–crossover method.[12] The cases were drawn from the complete case series of the Cooperative Health Research in the Region of Augsburg (KORA) Myocardial Infarction Registry in Augsburg, southern Germany, for a period of 2.5 years. A study diary was used to collect information on the four days before the onset of symptoms, including information on the number of hours spent in traffic.

METHODS

STUDY SUBJECTS

We identified 906 cases of nonfatal myocardial infarction in the KORA registry, of which 691 were included in our study. Hospitalized survivors of myocardial infarction who are 25 to 74 years of age are routinely entered into this registry.[13] Cases are identified daily at the Central Hospital and once a week at six hospitals in the city of Augsburg and the two adjacent rural districts and at four hospitals near the study area. The diagnosis of a myocardial infarction was made with use of the algorithm of the World Health Organization's Multinational Monitoring of Trends and Determinants in Cardiovascular Disease (MONICA) project. The criteria of the algorithm include chest pain lasting more than 20 minutes that is not relieved by the administration of nitrates and either Q waves on electrocardiographic examination that suggest an evolving myocardial infarction, subsequent increases in the level of creatine kinase, aspartate aminotransferase, or lactate dehydrogenase to more than twice the upper limit of normal, or both.

All subjects gave written informed consent for participation; the protocol was approved by the KORA review board. Persons were excluded from the study if they were in poor health (e.g., if they had a critical illness or were in a moribund condition) and were unable to communicate with the investigators. Interviews took place on the general ward as soon as possible after the index event (median, nine days). Data on the sociodemographic characteristics, medical history, and smoking status of the subjects were collected by a trained research nurse as part of the registry's routine interview. After the subject's discharge, clinical data were abstracted from the medical records according to a standardized protocol.

The time of onset of the myocardial infarction was defined as the time of the onset of chest pain that lasted at least 20 minutes. In cases of subjects with atypical chest pain (27 subjects) or with other symptoms (17), the time of the severest symptoms was used. Supporting data were retrieved from the patient's medical record (e.g., a history of symptoms recorded by the physician in the ambulance or the emergency room). If the data conflicted, medical reports were considered to be more reliable than information provided by the patient.

DIARY OF ACTIVITIES

The activities of the subjects on the day of the myocardial infarction and during the four days preceding the symptoms were recorded by registry nurses in a standardized, interview-based diary after completion of the registry's routine interview. Information recorded in the diary included time (hours) spent sleeping, levels of activity during the day, periods spent outdoors, means of transportation, location (according to postal codes) within the study area, the presence or absence of symptoms of angina pectoris, the occurrence of extreme anger or joy, and any exposure to dust or solvents. Activities occurring within 0 and 59 minutes after a particular hour were ascribed to that particular hour. The same importance was given to all four days preceding the event.

During a pilot phase in which the diary was tested, we interviewed 26 patients in the central hospital between October 3 and November 13, 1999, and afterward the diary was revised to improve its clarity, minimize redundancy, and facilitate the statistical analysis. Adherence to standardized procedures for the interview and coding was ensured by careful training of three research nurses, who had extensive clinical experience with cardiovascular disease, subsequent routine supervision of the interviews, and a policy of asking the nurses to contact the study investigators immediately in the event of unforeseen problems.

STATISTICAL ANALYSIS

Conditional logistic-regression models were used to assess the association between transient exposure to various levels and types of traffic and the onset of the myocardial infarction, as proposed by Mittleman and colleagues.[14] With the use of descriptive analyses, we calculated the frequency of exposure to traffic for a particular period of time by dividing the number of person-hours of exposure by the total number of person-hours within that period. For each subject included in the study, one-hour periods during the six hours before the onset were selected as the case periods. A "control period" of exposure was defined as an exposure to traffic by the same subject 24 to 71 hours before the hour of the onset of the myocardial infarction. Thus, each subject represented a matched set of data for case and control exposures, and different case periods were tested against the set of control periods for the same subject. Only subjects for whom there were discordant sets of data on exposure were included in the analysis — that is, either subjects who were exposed to traffic in the case period but not in a control period, or those who were not exposed to traffic in the case period but were exposed in a control period.

RESULTS

PATIENTS

Of 906 persons who had a confirmed myocardial infarction and who survived for at least 24 hours, 215 (23.7 percent) were unable to provide diary information, information on the hour of the onset of the myocardial infarction, or both (Table 1). The remaining 691 patients with a confirmed myocardial infarction, who were included in the diary study, were predominantly male, and 70 percent of them

Table 1. Characteristics of Survivors of Myocardial Infarction (MI) Recruited between February 1999 and July 2001, According to Data from the KORA Myocardial Infarction Registry.*

Characteristic	Diary Data (N=691)	No Diary Data (N=215)	P Value
Mean age — yr	60	62	0.01†
Age group — no. (%)			
25–34 yr	6 (1)	1 (<1)	
35–44 yr	58 (8)	6 (3)	
45–54 yr	141 (20)	43 (20)	
55–64 yr	224 (32)	68 (32)	
65–74 yr	262 (38)	97 (45)	0.04‡
Male sex — no. (%)	532 (77)	172 (80)	0.35‡
German nationality — no. (%)	656 (95)	201 (93)	0.41‡
Employment status — no. (%)			
Employed	280 (41)	60 (28)	
Not employed§	411 (59)	155 (72)	<0.001‡
Educational level— no. (%)			
Low (8 to 11 yr)	532 (77)	155 (72)	
High (>11 yr)	132 (19)	50 (23)	0.17‡
First MI — no. (%)	595 (86)	171 (80)	0.04¶
Survival to 28 days — no. (%)	687 (99)	214 (>99)	1.00¶
Symptoms of MI — no. (%)			
Typical	647 (94)	191 (89)	
Atypical	27 (4)	10 (5)	
Other	17 (2)	14 (7)	0.01‡
History of disease — no. (%)			
Angina pectoris	163 (24)	69 (32)	0.01‡
Hypertension	457 (66)	165 (77)	0.003‡
Diabetes	143 (21)	69 (32)	<0.001‡
None	173 (25)	29 (13)	<0.001‡
Smoking status — no. (%)			
Smoker	248 (36)	51 (24)	
Nonsmoker	235 (34)	78 (36)	
Former smoker	208 (30)	86 (40)	0.002‡
Hospital at which patient was seen — no. (%)			
Central Hospital	559 (81)	164 (76)	
Other	132 (19)	51 (24)	0.14‡
Interval between MI and interview — days			<0.001‖
Median	9	11	
Range	3–54	3–351	

* Data on educational level were missing for 37 subjects — 27 for whom diary data were available and 10 without diary data. Subjects without diary data were not included in the case–crossover study.
† The P value was calculated with the use of Tukey's test.
‡ The P value was calculated with the use of the chi-square test.
§ Retired persons and housewives were included in this group.
¶ The P value was calculated with the use of Fisher's exact test.
‖ The P value was calculated with the use of the Wilcoxon rank-sum test.

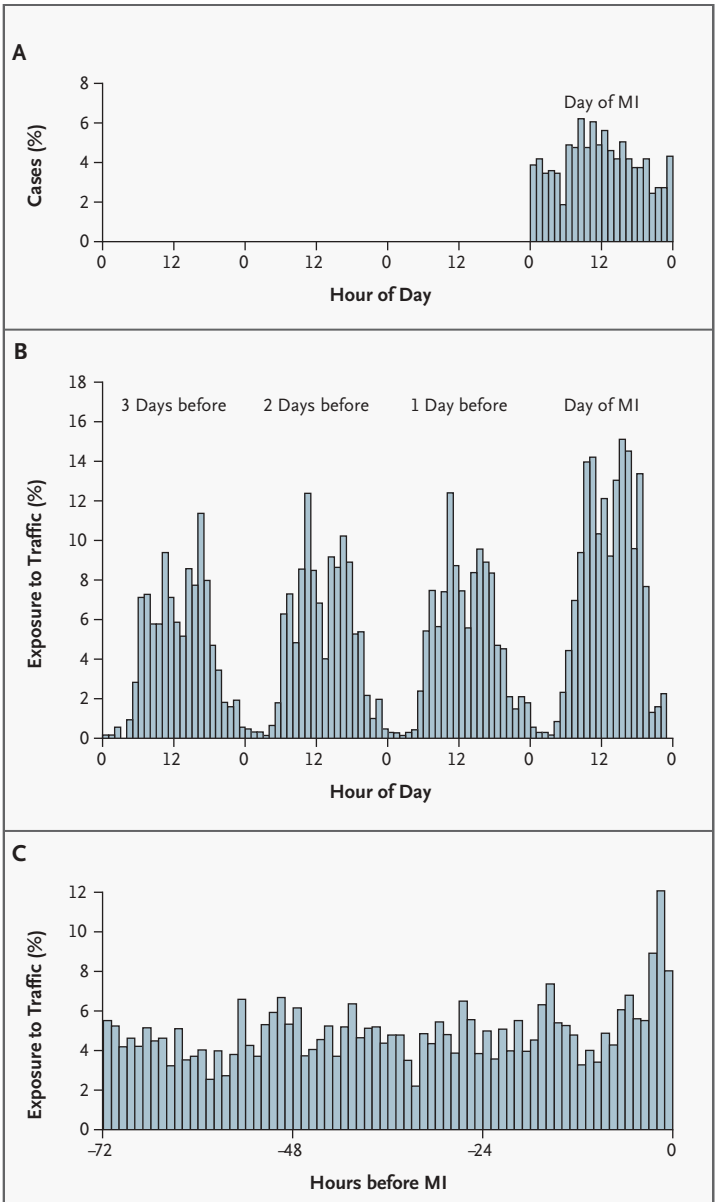

Figure 1. The Onset of 691 Nonfatal Myocardial Infarctions (MI) in Relation to Exposure to Traffic, According to the Amount of Time Spent in Traffic, February 1999 to July 2001, in the Region of Augsburg, Germany.

Panel A shows the distribution of times of onset of the myocardial infarctions over the day of the event, Panel B the time subjects spent in traffic on the day of the event and during the three days before it, and Panel C the time spent in traffic during the 72 hours preceding the onset of the myocardial infarction. The percentages are the proportions of subjects with exposure during the hour in question. Data are from the KORA Myocardial Infarction Registry.

were 55 years of age or older. For most of these subjects, this was their first myocardial infarction, and most of them survived to 28 days.

ASSOCIATION OF EXPOSURE TO TRAFFIC AND ONSET OF MYOCARDIAL INFARCTION

Exposure to traffic was more frequent on the day of the onset of the myocardial infarction (469 person-hours with exposure to traffic out of 8162 person-hours, or 5.7 percent) than during the previous three days (for the day before the onset of the myocardial infarction, 756 person-hours of 15,777 person-hours, or 4.8 percent; for the second day before the onset, 670 person-hours of 14,154 person-hours, or 4.7 percent; and for the third day before the onset, 528 person-hours of 11,478 person-hours, or 4.6 percent) (Fig. 1A and 1B). On the day of the myocardial infarction, of all the hours the subjects spent in traffic, 72 percent were spent in a car, 16 percent on a bicycle, 10 percent on public transportation (buses, trolley cars, and trains), and 2 percent on motorcycles. The percentages of hours spent in a vehicle were similar on the four days preceding the day of the myocardial infarction. One hour before the onset of the myocardial infarction, exposure to traffic was twice as frequent as at any other time (Fig. 1C).

Exposure to traffic was associated with an increase by a factor of 2.60 to 3.94 in the risk of the onset of a myocardial infarction within one hour (Table 2). Such exposure was not rare; for example, of the 625 subjects who reported exposure to traffic in the hours before the onset of the myocardial infarction, 75 who were exposed to traffic one hour before the onset and 375 for whom there were discordant matched sets of exposure were included in the analysis (Table 2). The odds ratio for exposure to traffic one hour before a myocardial infarction was 2.73 (95 percent confidence interval, 2.06 to 3.61) after adjustment for severe exertion, being outside, and getting up in the morning. The odds ratio associated with severe exertion was 6.38 (95 percent confidence interval, 3.89 to 10.46); for being outside, 2.21 (95 percent confidence interval, 1.61 to 3.03); and for getting up in the morning, 1.69 (95 percent confidence interval, 1.24 to 2.30). The odds ratio associated with travel by bicycle was 1.83 (95 percent confidence interval, 0.93 to 3.61) after adjustment for severe exertion, being outside, and getting up in the morning.

SENSITIVITY ANALYSES

We used sensitivity analyses to assess whether the results depended on the selection of the control period, and we compared the results of the different analyses (Table 2) with the results of the final model (Table 3, model A). The estimate was slightly larger in the sensitivity analysis (Table 3, models B and C) than in the main analysis. Slightly smaller estimates were observed when only one control exposure 24 hours before the onset was included in the analysis (Table 3, model D). The equivalent of model D was the analysis of discordant pairs with the use of McNemar's test. The odds ratio of 2.86 was derived by dividing 60 cases (of exposure to traffic during the case period but not during the control period) by 21 cases (of exposure to traffic during the control period but not during the case period) (P<0.001). The estimated odds ratios were slightly larger if the case–crossover analyses made use of three control periods that were matched with the case period for time of day (Table 3, models E and F).

The patients' differential recall of their activities before the onset of the myocardial infarction was a major concern. Information on exposure to traffic for the period from 0 (the onset of myocardial infarction) to −23 hours was available for 99 percent of the subjects, for −24 to −47 hours for 94 percent, for −48 to −71 hours for 82 percent, and for −72 to −95 hours for 38 percent. To assess the potential for recall bias within the data, we conducted analyses within the nonrisk periods defined a priori. We selected case periods and control periods from the 24 to 96 hours before onset (Table 3, models G through J). No association was observed between exposure to traffic and the onset of the myocardial infarction when case periods 25 hours before onset and control periods 49 hours before onset were considered (model G). A nonsignificant elevation in risk (P=0.13) was observed for the case period of 49 hours before onset and the control period of 73 hours before onset (model H), indicating that recall of activities may be biased 72 to 95 hours before the onset of a myocardial infarction. Models I and J indicate that with the period considered in the main analyses, no evidence of differential recall was found during control periods.

SUBGROUP ANALYSES

Exposure to traffic appeared to be associated with larger risks among women than among men and among patients 60 years of age or older than among

Table 2. Odds Ratios for the Onset of Myocardial Infarction (MI) after Time Spent in Traffic, According to the Means of Transportation.*

Type of Transportation and Hours before MI	No. of Subjects	Frequency of Exposure in Case Period on Day of MI (%)	Odds Ratio (95% CI)	P Value
Any means of transportation†				
Concurrent	585	8.0	1.50 (1.07–2.09)	0.02
1 hr	625	12.1	2.92 (2.22–3.83)	<0.001
2 hr	634	8.9	2.01 (1.49–2.72)	<0.001
3 hr	635	5.5	1.15 (0.79–1.66)	0.47
4 hr	638	5.6	1.27 (0.89–1.83)	0.19
5 hr	639	6.8	1.64 (1.17–2.30)	0.004
6 hr	640	6.1	1.34 (0.93–1.92)	0.11
Cars				
Concurrent	585	5.6	1.33 (0.90–1.99)	0.15
1 hr	625	8.3	2.60 (1.89–3.57)	<0.001
2 hr	634	6.5	1.94 (1.37–2.76)	<0.001
3 hr	635	4.2	1.16 (0.76–1.78)	0.49
4 hr	638	4.0	1.21 (0.79–1.86)	0.38
5 hr	639	5.3	1.73 (1.19–2.54)	0.005
6 hr	640	5.0	1.55 (1.04–2.30)	0.03
Bicycles				
Concurrent	585	1.8	2.59 (1.27–5.29)	0.009
1 hr	625	2.4	3.94 (2.14–7.24)	<0.001
2 hr	634	1.6	2.70 (1.37–5.33)	0.004
3 hr	635	1.0	1.66 (0.74–3.74)	0.22
4 hr	638	0.7	1.16 (0.45–2.96)	0.76
5 hr	639	0.9	1.49 (0.63–3.54)	0.37
6 hr	640	0.7	1.02 (0.36–2.87)	0.97
Public transportation				
Concurrent	585	0.5	1.08 (0.33–3.55)	0.90
1 hr	625	1.2	3.09 (1.41–6.75)	0.005
2 hr	634	0.9	2.13 (0.91–5.23)	0.08
3 hr	635	0.3	0.69 (0.17–2.88)	0.62
4 hr	638	0.9	2.27 (0.95–5.41)	0.06
5 hr	639	0.6	1.54 (0.55–4.37)	0.41
6 hr	640	0.3	0.73 (0.17–3.06)	0.67

* Analyses have been adjusted for the time of day to control for the potential effects of circadian variation with the use of 23 indicator variables. Vulnerable case periods were 0 to 6 hours before the onset of myocardial infarction, and control periods 24 to 71 hours before onset. The analyses were restricted to time (hours) spent within the study area (defined as the city of Augsburg and two adjacent rural districts) during the case periods and the control periods, to exclude time spent in long-distance travel. Data are from the KORA Myocardial Infarction Registry, February 1999 to December 2001. CI denotes confidence interval.

† "Any means of transportation" combines times spent in cars, in public transportation, and on motorcycles or bicycles.

Table 3. Sensitivity Analyses of the Effect of Different Control-Selection Strategies on the Association of Exposure to Traffic and the Onset of a Myocardial Infarction (MI).*

Sensitivity-Analysis Model	Case Exposure	Control Exposure	No. of Patients	Odds Ratio (95% CI)
		hr before MI		
A†	1	24–71	625	2.92 (2.23–3.84)
B†	1	24–95	625	2.98 (2.27–3.90)
C†‡	1	24–95	404	3.47 (2.51–4.79)
D	1	25	613	2.86 (1.74–4.70)
E	1	25, 49, 73	623	3.11 (2.10–4.60)
F‡	1	25, 49, 73	407	3.50 (2.21–5.53)
G§	25	49	558	0.83 (0.45–1.52)
H§	49	73	451	1.69 (0.85–3.36)
I†§	25	49–72	579	1.20 (0.83–1.74)
J†§	73	25–48	458	0.94 (0.61–1.44)

* Complete sets of data were available for subjects in models C and F. For models B and E, all available data were used, but some values were missing. CI denotes confidence interval. Hour 0 is considered the time of the myocardial infarction.

† The analysis was adjusted for time of day with the use of 23 indicator variables, to control for the possible influence of circadian variation.

‡ There were no missing values in the control periods.

§ The analysis was performed for nonrisk periods (control periods defined a priori) to assess the potential for recall bias; in the absence of bias, the expected odds ratio was 1.00.

those younger than 60 (Table 4). Effect estimates were larger for subjects with diabetes and those who were unemployed, but only employment status significantly modified the association between the risk of a myocardial infarction and exposure to traffic. The frequency of exposure to traffic differed according to the time of day (morning, 8.3 percent; afternoon, 7.1 percent; and night, 0.9 percent; P<0.001) and according to day of the week (Monday, 6.0 percent; Tuesday, 5.8 percent; Wednesday, 5.7 percent; Thursday, 4.7 percent; Friday, 5.7 percent; Saturday, 4.4 percent; and Sunday, 2.9 percent; P<0.001). Only the time of day showed an effect modification of borderline significance (Table 4).

DISCUSSION

We observed an association between exposure to traffic while traveling in cars, buses, and trolley cars and while riding on a bicycle or motorcycle and the onset of a myocardial infarction within one hour afterward. Travel in a car was the most common source of exposure, but travel by public transportation was also associated with the onset of a myocardial infarction within one hour afterward.

We used a case–crossover design that made possible the assessment of transient risk factors — that is, risk factors that may trigger acute events in susceptible patients. These risk factors include strenuous exercise,[1-3] anger,[4] and the use of cocaine[5] or marijuana.[6] Transient risk factors have only a short-term effect, whereas chronic risk factors, such as smoking, the presence of dyslipidemia, and a sedentary lifestyle, which promote atherosclerosis and prothrombotic conditions and may result in an impaired myocardium, have a long-term effect and determine vulnerability to acute coronary events.[15]

By virtue of the case–crossover design, exposure during the case periods and the control periods was determined for the same individual subject. The strategy for selecting the control periods and the potential for recall bias are of primary concern in judging the validity of the analyses. We used data on activities in each hour from the hour of onset of the myocardial infarction up to 71 hours before onset that were collected by means of bedside interviews. We included multiple control periods and controlled for the time of day in multivariate analyses. The restriction of the comparison to periods at the same time of day was designed to control for circadian patterns, but if daily routines are slightly modified, the restriction might result in an underestimation of exposure to traffic during the control periods and might therefore lead to an overestimation of the effect of exposure, as suggested in the sensitivity analyses. The possibility that patients may have better recall of the hours before the onset of the myocardial infarction than of the days before the event cannot be excluded. Consequently, an underestimation of exposure to traffic during the control periods would have inflated the estimates of the effect of such exposure as a trigger in individual cases. Sensitivity analyses in which different control-selection strategies were applied showed remarkably similar results. Comparison analyses of traffic exposures at nonrisk periods (control periods defined a priori) suggested there was no substantial recall bias with regard to the periods 24 to 71 hours before the onset of the myocardial infarction.

In the case–crossover design, conditions that do not vary over time do not induce confounding. Other transient risk factors such as strenuous exercise or stress (e.g., anger) might confound the associations we observed. However, multivariate analyses

Table 4. Subgroup Analyses of the Association of Exposure to Traffic with the Onset of the Myocardial Infarction (MI) within the Next Hour, with Case–Crossover Analyses Restricted to Activities within the Study Area.*

Characteristic	No. of Subjects (%)	Odds Ratio (95% CI)†	P Value	P Value for Heterogeneity of Subgroups
Total	625 (100)	2.92 (2.22–3.83)	<0.001	—
Male	474 (76)	2.59 (1.90–3.53)	<0.001	—
Female	151 (24)	4.51 (2.55–8.00)	<0.001	0.09
Age				
<60 yr	268 (43)	2.36 (1.59–3.51)	<0.001	—
≥60 yr	357 (57)	3.91 (2.66–5.73)	<0.001	0.07
Employment status				
Employed	246 (39)	2.20 (1.47–3.28)	<0.001	—
Not employed‡	379 (61)	4.20 (2.88–6.12)	<0.001	0.02
First MI	536 (86)	2.93 (2.20–3.92)	<0.001	0.92
Survival >28 days	621 (99)	2.94 (2.24–3.86)	<0.001	1.00
Other conditions				
Diabetes	130 (21)	4.63 (2.57–8.33)	<0.001	0.07
Hypertension	416 (67)	3.34 (2.38–4.67)	<0.001	0.21
Angina	148 (24)	4.07 (2.26–7.32)	<0.001	0.14
None	158 (25)	2.23 (1.31–3.82)	0.003	—
Located in Augsburg§	298 (48)	2.84 (1.88–4.29)	<0.001	0.55
Smoking status				
Current smoker	228 (36)	2.35 (1.47–3.76)	<0.001	—
Former smoker	185 (30)	2.73 (1.66–4.52)	<0.001	—
Nonsmoker	212 (34)	4.04 (2.54–6.43)	<0.001	0.25
Symptoms¶				
Symptoms recorded	152 (24)	2.31 (1.26–4.21)	0.007	—
No symptoms recorded	473 (76)	3.12 (2.30–4.24)	<0.001	0.38
Cold during the wk before MI				
Yes	40 (6)	5.48 (1.92–15.6)	0.002	—
No	585 (94)	2.83 (2.13–3.75)	<0.001	0.23
Time of day				
Morning (6 a.m.–12:59 p.m.)	241 (39)	3.58 (2.38–5.37)	<0.001	—
Afternoon (1 p.m.–8:59 p.m.)	192 (31)	3.03 (1.95–4.70)	<0.001	—
Night (9:00 p.m.–5:59 a.m.)	192 (31)	1.03 (0.36–2.92)	0.96	0.09
Day of MI				
Monday	89 (14)	3.46 (1.69–7.06)	<0.001	—
Tuesday	80 (13)	1.62 (0.55–4.81)	0.38	—
Wednesday	84 (13)	3.63 (1.77–7.42)	<0.001	—
Thursday	85 (14)	2.96 (1.42–6.16)	0.004	—
Friday	101 (16)	2.97 (1.55–5.69)	0.001	—
Saturday	92 (15)	3.77 (2.00–7.14)	<0.001	—
Sunday	94 (15)	2.30 (1.05–5.04)	0.04	0.86

* Exposure to traffic comprises time spent in cars, on public transportation, and on motorcycles and bicycles. CI denotes confidence interval.
† The analyses were adjusted with the use of 23 indicator variables for time of day, to control for the potential influence of circadian variation.
‡ Retired persons and housewives were included in this group.
§ Patients were located within the boundaries of the city of Augsburg at all times in the case and control periods.
¶ Symptoms included angina pectoris, chest pain, cold sweat, dizziness, nausea, shortness of breath, vomiting, and unconsciousness.

involving information on other triggers did not produce evidence of strong within-person confounding. Strenuous activity was confirmed as a substantial risk factor for the onset of a myocardial infarction in this study, as suggested earlier.[1-3] Riding a bicycle might be considered strenuous activity; indeed, the risk estimates associated with the use of a bicycle were reduced when we controlled for exercise, but there was no change in the overall effect estimate for exposure to traffic. Studies that assessed the role of anger as a trigger for myocardial infarction identified major life events as potential triggers but not moderate levels of psychological stress,[4] which are instead related to an elevation in long-term risk.[16] The estimates for traffic exposure might be confounded by the stress associated with getting up in the morning, which is itself a risk factor for myocardial infarction.[2] Getting up in the morning was an independent risk factor in our study, but it did not confound the association between exposure to traffic and the onset of a myocardial infarction.

The association between exposure to traffic and the onset of a myocardial infarction was stronger in the subgroup of subjects who were unemployed than in the subgroup of those who were employed. This finding indicates that the associations we observed were not due to commuting regularly to work. The subjects in this study used a car for transportation most of the time. We had no data on whether the individual subject had been driving the car or on the reasons for driving. Driving in different volumes of traffic might also be a factor to consider. Unfortunately, data on the circumstances of driving could not be collected reliably in retrospective interviews. However, because the association was also observed for persons who used public transportation, it is unlikely that the effect is entirely attributable to the stress linked with driving a car. No evidence for a statistically significant effect modification according to the day of the week was observed, but the estimated risks were larger for morning and afternoon hours than for night hours, when the density of the traffic is low. When only subjects who had no typical or atypical symptoms during the four days before the onset of the myocardial infarction were considered, no difference in the estimates was observed. Therefore, the possible effects of car trips undertaken to consult a doctor because of an evolving myocardial infarction could be ruled out.

Subjects who had had nonfatal myocardial infarctions were recruited on the basis of the nearly complete records of a myocardial-infarction registry.[13] Of the cases of myocardial infarction included in this study, 8 percent were attributable to exposure to traffic. The subgroup analyses indicated that women, persons 60 years of age or older, and patients with diabetes are at higher risk for the onset of a myocardial infarction after exposure to traffic than are men, persons younger than 60 years of age, and persons without diabetes. These results suggest that other persons in the KORA registry who were unable to provide diary information and who were therefore not included in our study might have been more susceptible to the risk of myocardial infarction after exposure to traffic than the subjects who were included.

A rather crude measure of exposure to traffic was used in this study. Potentially, a combination of different factors, such as stress, noise, and traffic-related air pollution, may contribute to the observed associations. While persons are driving a car, symptoms of a possible arrhythmia may be common among those who are eligible for treatment with an implantable cardiac defibrillator.[17] Chronic exposure to stress and noise is a well-documented risk factor for cardiovascular diseases, since such exposure can lead to elevated stress hormone concentrations.[18] A recently published study from the Netherlands indicates that among people who live near major roads, the risk of death due to cardiopulmonary diseases is nearly twice as high as that among those who do not live near major roads.[9] An increase in the risk of death due to ischemic heart disease has been documented in those whose occupations expose them to traffic, such as police officers who regulate traffic.[19] The short-term health effects of air pollution on the cardiovascular system have been studied intensively in the past decade. Particulate matter is considered to be of primary concern.[20,21] Studies of exposure to ambient particles have indicated that passengers in cars and buses have a greater exposure than is measured at a distance of 100 m or more from vehicular traffic.[22,23] The concentrations of particulate matter varied according to the route and the density of the traffic and might resemble concentrations at urban curbsides. For people traveling by car or bus, exposure to particulates is about two times as high as for cyclists.[22,24-26] Although high rates of ventilation increase the amount of particles deposited in

the airways,[22,25,26] cyclists may be able to leave congested situations (i.e., polluted microenvironments) more quickly than people in cars or buses.[22]

The disruption of a vulnerable but not necessarily stenotic atherosclerotic plaque in response to hemodynamic stress has been suggested as a mechanism that triggers a myocardial infarction; thereafter, the hemostatic and vasoconstrictive forces determine whether the resultant thrombus will become occlusive.[27] Particulate air pollution has been associated with transient increases in plasma viscosity,[28] acute-phase reactants,[29-31] and endothelial dysfunction,[32] as well as with altered autonomic control of the heart.[33-37] These changes have also been observed in healthy officers of the highway patrol in association with the concentration of particulate matter in their vehicles[38] and might be consistent with an increased risk of a myocardial infarction after a transient elevation in the concentrations of ambient particles in vulnerable subjects.[39]

Given our current knowledge, it is impossible to determine the relative contribution of risk factors such as stress and traffic-related air pollution. Nevertheless, patients who are at risk for acute coronary events are likely to profit from recent efforts to improve the air quality in urban areas with the use of cleaner vehicles and improved city planning.

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