Reduction in Acute Myocardial Infarction Hospitalization after Implementation of a Smoking Ordinance

Gerrit Bruintjes, MPH, a Becki Bucher Bartelson, PhD, b,c Paul Hurst, MD, d Arnold H. Levinson, PhD, e John E. Hokanson, PhD, f Mori J. Krantz, MD g,h

aColorado School of Public Health, University of Colorado, Aurora; bDepartment of Biostatistics, Colorado School of Public Health, Aurora; cRocky Mountain Poison and Drug Center, Denver, Colo; dNorth Colorado Medical Center, Greeley; eDepartment of Community and Behavioral Health and fDepartment of Epidemiology, Colorado School of Public Health, University of Colorado, Aurora; gCardiology Division, Denver Health and Hospital Authority, Denver, Colo; hColorado Prevention Center, Aurora.

ABSTRACT

BACKGROUND: Smoking ordinances have been associated with reduced acute myocardial infarction rates, but nearly all studies lack patient-level data.

OBJECTIVE: We determined whether a smoking ordinance was associated with a reduction in hospitalizations for acute myocardial infarction, irrespective of smoking status and infarct presentation (ST elevation vs. non-ST elevation).

METHODS: Detailed chart abstraction of biomarkers to confirm first acute myocardial infarction events was performed from the single community hospital serving Greeley, Colorado and adjacent zip codes, 17 months before and 31 months after implementing a public smoking ordinance. Poisson regression analysis, adjusted for population growth, was used to assess changes in mean incidence rates.

RESULTS: A total of 706 hospitalizations were identified from July 2002 through June 2006: 482 among Greeley city residents and 224 within adjacent zip code areas. A postordinance reduction in hospitalizations was observed in Greeley (relative risk [RR] 0.73; 95% confidence interval [CI], 0.59-0.90). A smaller, nonsignificant decrease was noted in the area immediately surrounding Greeley (RR 0.83; 95% CI, 0.61-1.14). However, the comparison of relative risk reductions between Greeley and the surrounding area was not significant (P = .48). The reduction in Greeley was more pronounced among smokers (RR 0.44; 95% CI, 0.29-0.65) than nonsmokers (RR 0.86; 95% CI, 0.67-1.09) and did not differ by acute myocardial infarction presentation (P = .38).

CONCLUSIONS: A smoking ordinance was associated with a decrease in acute myocardial infarction hospitalizations of a magnitude similar to previous reports, but could not be distinguished from the adjacent geographic area. Reductions were greatest among smokers, despite previous studies suggesting that benefits accrue primarily among nonsmokers. Smoke-free policy may therefore exert a beneficial effect among smokers, who are disproportionately exposed to direct and sidestream smoke.

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A growing body of evidence suggests that public smoking ordinances may decrease acute myocardial infarction hospitalization rates. 1-12 Two recent meta-analyses, however, have obtained different pooled estimates of the reduction in acute myocardial infarction hospitalization (8% vs 19%), and one indicated that the results were heterogeneous. 1-3 The cardiovascular effects of smoke-free policy have been broadly documented in local (city), state, and country-wide smoking ordinance studies. 1-12 However, variability in the magnitude of the relative reduction in acute coronary events has been observed, ranging from no reduction to upwards of 40%. Some of this heterogeneity may reflect differences in

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Requests for reprints should be addressed to Mori J. Krantz, MD, Department of Cardiology, Denver Health Medical Center, 777 Bannock Street, Mailcode 0960, Denver, CO 80204.

E-mail address: mori.krantz@dhha.org

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analytic methods, secular trends, and smoking rates across communities studied. In addition, nearly all published studies did not require biomarker confirmation of acute myocardial infarction events.

The differential effects of smoke-free legislation in various population subgroups have not been extensively examined. To date, only 2 studies examined the clinical characteristics of individuals hospitalized for acute myocardial infarction. Both suggested that nonsmokers derive greater relative benefits, despite the fact that smoke-free policy reduces direct tobacco consumption among smokers. A study in Indiana found no significant decrease in event rates among smokers, but was limited by small sample size. A larger study in Scotland reported a 14% reduction among current smokers and a 21% reduction among never smokers. Although an association between institution of a public smoking ordinance and a reduction in acute coronary events is biologically plausible, the effects of smoke-free policy on the type of myocardial infarction have not been previously investigated, but could provide insights into secondhand smoke and coronary plaque disruption because ST-elevation events reflect total thrombotic occlusion of the infarct-related artery.

Given this background, we evaluated biomarker-proven acute myocardial infarction rates before and after implementation of a smoke-free ordinance in Greeley, Colorado. We investigated whether sub-populations experience variable reductions in hospitalization rates; specifically, we investigated differences in relative risk by smoking status and acute myocardial infarction presentation.

METHODS

Greeley is a geographically isolated rural community located in northern Colorado, with only one hospital (North Colorado Medical Center) that served the city and the surrounding areas during the study period. This allowed for a closed community analysis of the association between enactment of a smoking ordinance and acute myocardial infarction incidence.

The Greeley City Council enacted a smoking ordinance that became effective in December 2003 that prohibited smoking in all places of public assembly. This included restaurants, bars, bowling alleys, and bingo halls, but also banned smoking in outdoor public gathering places where seating was provided. Smoking was not allowed within 50 feet of such areas when a “no smoking” sign was posted. Areas outside the city limits were not subject to the ordinance and included Garden City, a community partially surrounded by the city of Greeley (Figure 1). Initially, the ordinance underwent legal challenges; however, a local vote in November 2004 reiterated the public desire for a smoke-free policy. Media reports indicate that there was variable ordinance compliance during the legal challenge period.

The Colorado Multiple Institutional Review Board approved the study protocol. In order to protect patient confidentiality, all information collected was de-identified before removal from the premises of the North Colorado Medical Center.

Study Population

All patients hospitalized with a primary diagnosis of acute myocardial infarction (International Classification of Diseases, 9th Revision Codes of 410.xx), and biomarker confirmation from July 2002 through June 2006 were included. Incidence rates were computed counting only first acute myocardial infarctions within the study period. Cases arriving before ordinance enactment (December 2003) were categorized as preordinance, and subsequent cases obtained through June 2006 were categorized as postordinance. Patients with zip codes outside of the study area and transfers from other facilities were excluded. The population was separated into individuals with a resident zip code within Greeley city limits (80631, 80634), where the ordinance was in effect, and those with a residential zip code adjacent to Greeley (80620, 80615, 80624, 80644, 80645, 80623, 80651, 80543, 80534, 80550) (Figure 1). The population estimates used for rate computations were obtained through the US Census Bureau and were utilized to adjust for population growth over the study period.

Data Collection

Patient-level demographic and clinical characteristics of all cases were ascertained by review of electronic medical records. Specifically, we assessed current smoking status and categorization of events as non-ST-elevation myocardial infarction (NSTEMI) and ST-elevation myocardial infarction (STEMI). STEMI was defined by the first emergency physician electrocardiographic interpretation and triage to primary percutaneous coronary intervention or thrombolysis on admission, and a discharge diagnosis of acute myocardial infarction. All other biomarker-proven events with discharge diagnosis of acute myocardial infarction were classified as NSTEMI. A single abstractor ascer-

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<td>● A public smoking ordinance reduced biomarker-proven acute myocardial infarction (AMI) rates by 27%, replicating prior administrative data.</td>
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<td>● Reductions in AMI were greatest among smokers, despite prior data suggesting that benefits accrue primarily among nonsmokers.</td>
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<td>● No differences were observed in the rate of ST elevation versus non-ST-elevation AMI.</td>
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<td>● Expanding smoke-free policy has the potential to reduce AMI rates regardless of smoking status.</td>
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tained age, sex, smoking status, and comorbidities (previous coronary artery disease, diabetes mellitus, and chronic obstructive pulmonary disease). Biomarker confirmation (troponin I or creatine phosphokinase MB isoenzyme elevation as defined by laboratory thresholds) was required for all cases. To ensure data integrity, all information was double entered into the study database and discrepancies between entries resolved before analysis. Once evaluated for completeness, chart abstraction data were screened for outliers and illogical cross comparisons, with 100% correction.

**Statistical Analysis**

Population-adjusted monthly hospitalization rates were examined in relation to geographic location (within and adjacent to Greeley city limits; [Figure 1](#)), time period (before and after ordinance), and their interaction using a Poisson regression model. We constructed the regression analysis in similar fashion as described previously to create risk ratios (RR) and associated 95% confidence intervals (CI) to quantify the magnitude of the ordinance effect.\(^5\) Due to seasonal imbalance for pre- and postordinance observation periods, we adjusted for seasonality (using harmonics); however, no significant effect was noted and the harmonics were removed from the final models. A recent meta-analysis\(^2\) suggested that the longer an ordinance is in place, the larger the decrease in event rates. To address this possibility, separate linear trends before and after the ordinance were added to the model. As the linear trends were not significant, they were removed from the final model. In addition to monthly summaries, the total event rate per person-year was calculated for both periods. The person-year denominator was adjusted for the differential period lengths and the 7.7% population growth within Greeley (82,704 to 89,046 residents from 2002 to 2006). Next, we completed 2 prespecified analyses on the population within Greeley examining the ordinance effect by current smoking status, as well as acute myocardial infarction presentation as ST elevation versus non-ST elevation. These models were developed in a manner similar to the primary model.

**RESULTS**

After excluding 15 cases transferred from outside facilities and cases with residential zip codes outside Greeley and its surrounding catchment area, a total of 706 acute myocardial infarction hospitalizations occurred during the study period. Overall, 482 hospitalizations among Greeley city limit residents were available for analysis, while 224 occurred among residents from the surrounding area. The characteristics of all patients are shown in the Table. Most patients were hospitalized directly from the Emergency Department. The Greeley population was predominantly male; 40% had a history of preexisting coronary artery disease, 28% had diabetes, and 27% were current smokers. Patients from the surrounding area had similar characteristics.
A significant decrease in the hospital incidence rates of acute myocardial infarction was observed in the city of Greeley after enactment of the ordinance (RR 0.73; 95% CI, 0.59-0.90). A numerically smaller decrease was observed in the area immediately surrounding Greeley (RR 0.83; 95% CI, 0.61-1.14). Importantly, the difference in the decrease between Greeley and the surrounding area was not statistically significant ($P = .48$), although power for this test was only 53%. Figure 2 displays the reduction in observed and predicted monthly events per 100,000 person-years before and after ordinance implementation. Figure 3 shows the temporal reduction in total events per 100,000 person-years.

Using regression analyses on monthly data, smokers experienced a statistically significant reduction in acute myocardial infarction hospitalizations within Greeley (RR 0.44; 95% CI, 0.29-0.65), while nonsmokers had a nonsignificant decrease in event rates (RR 0.86; 95% CI, 0.67-1.09) after ordinance implementation (Figure 4). However, the reduction in acute myocardial infarction rates among smokers in the surrounding area (RR 0.58; 95% CI, 0.35-0.97) did not differ from smokers within Greeley ($P = .38$). Figure 5 shows the decrease in total acute myocardial infarction hospitalizations after implementation of the smoke-free ordinance as a function of acute coronary syndrome presentation. The reduction in events was similar in patients with STEMI (RR 0.79; 95% CI, 0.34-1.83) and NSTEMI (RR 0.66; 95% CI, 0.37-1.17) myocardial infarction ($P = .38$).

**DISCUSSION**

The association between a reduction in acute myocardial infarction hospitalizations and enactment of public smoking ordinances has been evaluated in a variety of settings and utilizing a number of analytic designs. However, the total number of published studies is relatively small, and the possibility of publication bias was noted in a recent meta-analysis. This suggests the importance of replicating findings and quantifying effect sizes within similar communities.
through consistent analytic methods. In the current study, we observed a significant 27% reduction in rates with enactment of a smoking ordinance in Greeley, a city in northern Colorado. This reduction was identical in magnitude to previously observed findings in Pueblo, a city in southern Colorado (RR 0.73; 95% CI, 0.63-0.85), and suggests reproducibility across distinct geographic regions. However, because the reduction in acute myocardial infarction hospitalization rates did not differ significantly between Greeley and the surrounding area, the possibility that the decrease in Greeley reflects secular trends cannot be entirely excluded. Nonetheless, our findings fall within the range of published risk reductions ranging from no reduction to 40% following enactment of a smoke-free ordinance.1-3

**Figure 3**  Acute myocardial infarction rates in Greeley and the surrounding area before and after ordinance enactment. Preordinance period (before) is July 2002 through November 2003. Postordinance period (after) is from December 2003 through June 2006. PY = person-years.

**Figure 4**  Acute myocardial infarction rates in Greeley by smoking status before and after ordinance enactment. Preordinance period (before) is July 2002 through November 2003. Postordinance period (after) is December 2003 through June 2006. PY = person-years.
We also found a nonsignificant decrease in acute myocardial infarction hospitalizations among residents of the area immediately surrounding Greeley. This potential spill-over effect mirrors previous studies where a smaller magnitude reduction in event rates was observed in the area surrounding the cities of Helena, Montana and Pueblo, Colorado. The smaller observed decrease in the areas surrounding the ordinance zone suggests that residential zip codes are a relatively crude measure of ordinance exposure. In fact, the town of Garden City falls outside the ordinance zone, but is largely surrounded by Greeley (Figure 1). Established restaurants, bars, and other entertainment venues existed in both Greeley and the surrounding area, allowing residents to selectively patronize either smoke-free or unrestricted environments in close proximity.

From an inspection of the time series plot (Figure 2, left panel), there appears to be 3 distinct periods: preordinance, one of minimal decrease in the immediate postordinance period, and a further decrease in event rates in the latter period. This is consistent with media reports in Greeley suggesting that ordinance adherence was not uniform initially, yet became widely embraced after an outpouring of public support via referendum 1 year later. This relationship for secondhand smoke exposure has been previously demonstrated in a large case-control study, where a graded increase in acute coronary events was demonstrated among smokers and nonsmokers alike.

A second important observation is the greater reduction in acute myocardial infarction rates among current smokers. This decrease among current smokers was numerically greater in Greeley then in the surrounding area, although the difference did not reach statistical significance. This contrasts with results from Monroe County, Indiana, where the decrease in acute myocardial infarction hospitalizations was noted solely among nonsmokers. However, that study is potentially confounded by exclusion of individuals with preexisting cardiovascular disease, hypertension, and hypercholesterolemia, effectively eliminating the population at highest risk for acute myocardial infarction. Moreover, the analysis cohort in Indiana included just 23 cases spanning a 3-year period, limiting statistical power to detect differences by smoking status. More recently, a smoking ban in Scotland was associated with a 17% overall reduction in acute coronary syndrome hospitalizations, including a 14% reduction among smokers, a 19% reduction among former smokers, and a 21% reduction among those who never smoked. Taken together, these studies demonstrate that smoking ordinances provide health benefits irrespective of smoking status. In this context, our study provides confirmatory evidence that smoke-free legislation is a defensible policy approach to cardiovascular disease prevention in the overall population, beyond individual health-promotion strategies such as smoking cessation and risk factor modification.

The mechanisms for differential effects of environmental tobacco exposure policies among smokers and nonsmokers is not well understood, but could be explained by differences in baseline risk of the populations studied as well as the potential temporal reductions in smoking prevalence. A higher community smoking prevalence also may translate into greater secondhand smoke exposure and a larger magnitude risk reduction. In addition, age is one of the strongest predictors of cardiovascular disease. Furthermore, smoking is a mediator of ordinance effect size is supported by the Scotland study, which suggested a larger overall magnitude (20%) reduction in hospitalizations among men older than 55 and women older than 65 years of age. In the current study, mean age...
was 67.9 years, with a commensurate 27% reduction in acute myocardial infarction hospitalizations. Furthermore, the greater stringency of the Greeley smoking ordinance relative to other studies may have created an increased incentive to stop smoking because patrons were prohibited from smoking even in outdoor public seating areas.

Finally, we evaluated ordinance impact as a function of acute coronary syndrome category on presentation and did not identify a significant difference. Both total coronary occlusion (ST elevation) events and simple plaque rupture events with relatively preserved coronary flow (non-ST elevation) were reduced to a similar extent. Although secondhand smoke is a potent stimulator of platelet aggregation, this is likely applicable across the spectrum of acute coronary syndrome presentation. Moreover, prior research suggests that components of secondhand smoke lead to plaque degradation through matrix metalloproteinase activation, which may be equally pertinent in patients presenting with and without ST-segment elevation. Regardless, the potential cardioprotective mechanisms of smoke-free legislation are numerous and well documented. Even exposure at minimal levels (1-7 hours per week) increases myocardial infarction risk (odds ratio 1.24; 95% CI, 1.17-1.32) as compared with no exposure.

A number of limitations should be considered when interpreting our study. Like all previous studies, observational data are insufficient to establish a causal relationship between secondhand smoke and the incidence of acute myocardial infarction. Because the decrease in incidence rates was not statistically different between Greeley and the surrounding area, the possibility that the reduction reflects secular trends cannot be excluded. In any time series analysis, unmeasured potential confounding factors must be considered and may include population changes in modifiable risk factors, including obesity, smoking prevalence, and levels of physical activity. In Colorado, a tobacco quitline became available in 2000 before our study period, and a state-wide clean indoor air act commenced in July 2006 after our study period, and thus, neither would have temporally confounded our results. As in any uncontrolled study, additional unrecognized confounding variables may exist. Because our analysis was limited to acute myocardial infarction hospitalizations, unrecognized or fatal events were not evaluated, which could be differentially impacted by the smoking ordinance.

Another substantial limitation is the use of residential zip codes, potentially leading to misclassification of exposure. Unlike our previous study in Pueblo, Colorado, smokers could avoid the Greeley city ordinance simply by frequenting restaurants and bars just blocks away. This misclassification of exposure would be expected to bias results toward the null. The current study, therefore, did not include a true control population to compare with Greeley. However, the surrounding area provided confirmation of an expected, numerically smaller reduction in acute myocardial infarction hospitalization incidence.

Mortality rates from acute myocardial infarction have decreased over time in the general population, which also could result in temporal confounding. However, a recent report from the Framingham Heart Study found stable long-term acute myocardial infarction hospitalization rates, suggesting that temporal changes are unlikely solely to explain the reduction in nonfatal events observed in our study. Another consideration is progressive aging of the population, which could influence hospitalization rates for ischemic heart disease. Although detailed age-specific population estimates by zip code were not available, census estimates show that age groups of the population did not change during the study period. Furthermore, aging of the population would be expected to exert its effect in the opposite direction, increasing acute myocardial infarction hospitalization rates over time, yielding an upwardly biased estimate of ordinance impact.

In conclusion, a smoking ordinance in Greeley, Colorado was associated with a significant decrease in acute myocardial infarction hospitalizations of a magnitude identical to ordinance enactment in Pueblo, Colorado. No differential impact on type of myocardial infarction was noted. In contrast to prior studies, the reduction in acute coronary events was magnified among smokers. Like all prior studies, the current analysis demonstrates only an association between an ordinance and acute myocardial infarction incidence rates. A causal relationship cannot be proven, given the possibility of unmeasured confounding and secular trends. Furthermore, the pre-/postreduction in acute myocardial infarction rates, although numerically greater in Greeley, was not significantly different compared with the surrounding region. Nonetheless, from a public health perspective, this study suggests that the benefits of reducing secondhand smoke exposure may be realized by all individuals, irrespective of smoking status.

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References


