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Reduction in the Incidence of Acute Myocardial Infarction Associated With a Citywide Smoking Ordinance

AQ: 1

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AQ: 2

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***Background*—**Secondhand smoke exposure increases the risk of acute myocardial infarction (AMI). One study (Helena, Mont) examined the issue and found a decrease in AMI associated with a smoke-free ordinance. We sought to determine the impact of a smoke-free ordinance on AMI admission rates in another geographically isolated community (Pueblo, Colo).

***Methods and Results*—**We assessed AMI hospitalizations in Pueblo during a 3-year period, 1.5 years before and 1.5 years after implementation of a smoke-free ordinance. We compared the AMI hospitalization rates among individuals residing within city limits, the area where the ordinance applied, versus those outside city limits. We also compared AMI rates during this time period with another geographically isolated but proximal community, El Paso County, Colo, that did not have an ordinance. A total of 855 patients were hospitalized with a diagnosis of primary AMI in Pueblo between January 1, 2002, and December 31, 2004. A reduction in AMI hospitalizations was observed in the period after the ordinance among Pueblo city limit residents (relative risk [RR]=0.73, 95% confidence interval [CI] 0.63 to 0.85). No significant changes in AMI rates were observed among residents outside city limits (RR=0.85, 95% CI 0.63 to 1.16) or in El Paso County during the same period (RR=0.97, 95% CI 0.89 to 1.06). The reduction in AMI rate within Pueblo differed significantly from changes in the external control group (El Paso County) even after adjustment for seasonal trends ($P<0.001$).

***Conclusions*—**A public ordinance reducing exposure to secondhand smoke was associated with a decrease in AMI hospitalizations in Pueblo, Colo, which supports previous data from a smaller study. **(*Circulation*. 2006;114:&NA;-.)**

AQ: 3

Key Words: myocardial infarction ■ smoking ■ prevention ■ population

Chronic exposure to secondhand smoke (SHS) is associated with an increase in the risk of acute myocardial infarction (AMI).[1–5] However, only 1 study has demonstrated the impact of a smoke-free ordinance on AMI rates.[4] Researchers in Helena, Mont, noted a 40% decline in hospital admissions for AMI during a 6-month smoking ordinance within Helena city limits. Enforcement of this smoking ordinance was suspended by a legal challenge that precluded longer-term analysis of its health impact. Given the small size of the Helena community (≈68 140), only 304 incident AMIs, including both primary and secondary diagnoses, occurred during a 5-year study period. Results from a single observational study based on a small number of events require confirmation. We therefore assessed the impact of a similar smoke-free ordinance on AMI hospitalizations in a larger community, Pueblo, Colo.[6] Pueblo, like Helena, is considered geographically isolated, which provides a unique opportunity to assess temporal changes in AMI associated with enactment of a smoke-free ordinance. In addition, the larger population in Pueblo allowed us to limit our analysis to primary AMI diagnoses, which are more likely to reflect acute coronary events in the community rather than incidental increases in cardiac biomarkers among severely ill hospitalized patients.

Methods

Setting

Pueblo is a blue-collar community located in southern Colorado and has a higher percentage of smokers than the statewide average (22.6% versus 18.6%).[7] The median age of Pueblo residents in 2003 was 36.5 years. All persons with recognized AMIs that occur in the city and surrounding county receive care at 1 of 2 hospitals, Parkview Medical Center or St. Mary-Corwin Medical Center. Pueblo County had an estimated population of ≈147 751 individuals on July 1, 2003.[6] The majority of its citizens reside within city limits (103 648, or 70.2%).

Colorado Springs and its surrounding county, El Paso County, served as an external control. El Paso County and Pueblo County are adjacent, but the 2 major cities are 45 miles apart (Figure 1); they F1

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AQ: 4

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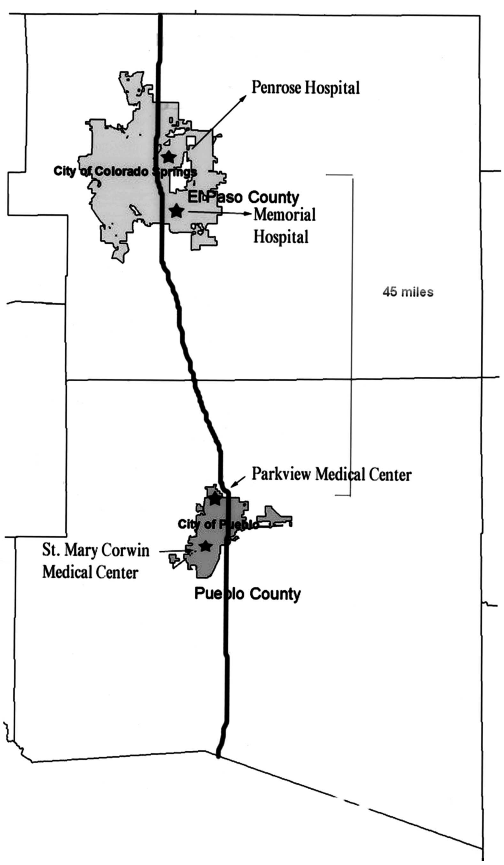

Figure 1. A map of the 2 Colorado counties compared for the study. The smoking ordinance was in Pueblo City, located within the surrounding county (shaded). Hospitalization data were obtained from Parkview and St Mary-Corwin Medical Centers (stars) in Pueblo and compared with Penrose and Memorial Hospitals (stars) located in Colorado Springs, El Paso County (shaded), which lacked a smoking ordinance and served as a concurrent external control.

constitute 2 proximate but geographically isolated communities. In contrast to Pueblo County, El Paso County has a large proportion of military and high-technology workers. El Paso County has an estimated population of 550 478, with the majority residing in Colorado Springs (370 448, or 67.3%) on July 1, 2003. The El Paso County smoking rate is estimated to be 17.7%, 4.9% lower than Pueblo.[7] The median age of El Paso County residents in 2003 was 33.6 years. Like Pueblo, El Paso County is served by 2 hospitals, Penrose and Memorial Hospitals.

Smoke-Free Ordinance

In 2003, a special election was designated, and Pueblo citizens voted to implement the Smoke-Free Air Act within city limits. The ordinance prohibited smoking inside the workplace and all buildings open to the public, including restaurants, bars, bowling alleys, and other business establishments. Pueblo law enforcement officials strongly supported the ordinance and imposed significant fines on violators and on facility owners who allowed smoking on their premises. Implementation and enforcement of the ordinance began on July 1, 2003, and has remained in force ever since.

Patients

The combined Institutional Review Board for Parkview Medical Center and St. Mary-Corwin Medical Center hospitals approved the study using administrative data without unique patient identifiers. Administrative data collected for the purpose of reporting to the Colorado Hospital Association[7] were obtained electronically and included admission date, primary diagnosis code, gender, age, zip code, and hospital name. No other patient-level data were available, including patient smoking status.

Like the Helena study, our principal analysis focused on AMIs in persons who reached the hospital, recognizing that some individuals die before hospitalization. All patients with a primary diagnosis of AMI (International Classification of Diseases, 9th revision, codes 410.xx) admitted to either institution between January 1, 2002, and December 31, 2004, were identified. To enhance diagnostic certainty, we excluded secondary AMI diagnoses. We also explored the potential impact of Pueblo's smoke-free ordinance on cardiac death rates by obtaining the number of fatal AMIs among residents within Pueblo city limits around the time the ordinance was passed (Health Statistics Section of the Colorado Department of Public Health and Environment, December 2005).

Residence within the city of Pueblo was ascertained with the patient's zip code. Because zip codes do not completely agree with city limit boundaries, we classified residential zip codes as being inside or outside the city limits on the basis of a majority of residential addresses. The zip codes 81001, 81003, 81004, 81005, and 81008 were classified as within the city limits, because the maximum percent of addresses outside of the city limits among these zip codes was only 3%. Similarly, the zip codes of 81006, 81007, 81019, 81022, 81023, 81025, and 81069 were classified as outside city limits. Only 1 of these zip codes spans the city limits (81006), with 90% of residential addresses outside of the city limits.

In an effort to evaluate only individuals impacted by the ordinance, we excluded all AMI patients transferred from outside facilities or residents with zip codes outside Pueblo County. We then obtained AMI hospitalization data in a neighboring county, El Paso County, during the identical period as a contemporaneous control group. Data from Colorado Springs and its surrounding county, El Paso County, were also obtained from the Colorado Hospital Association database.[7]

Analysis

We assessed AMI hospitalization rates among individuals residing in 3 locations: inside Pueblo city limits, outside Pueblo city limits, and in El Paso County. Covariates available for the patients hospitalized with AMI included gender and age. Gender was summarized by the number and percent of patients in each category by residential location. A χ^2 test was used to compare gender differences across location. Age was summarized within residential location with means and SDs, and an ANOVA model was used to test for equality of the mean ages at the 3 locations. Individual pairs of mean ages were then compared with the Tukey multiple comparison procedure. AQ: 5

The primary outcome variable in the present study was AMI hospitalizations. Both contingency table methods and Poisson regression models[8] were used to compare daily AMI hospitalizations before and after implementation of the smoke-free ordinance among Pueblo city-limit residents, county residents outside Pueblo city limits, and residents of El Paso County. Secondarily, AMI death rates among residents inside Pueblo city limits were computed for the year before (2002) and the year after (2004) the ordinance. Given that only yearly aggregate AMI death data were available, data from 2003 were excluded because ordinance enforcement did not begin until midyear.

Previous research has demonstrated a seasonal trend in AMI hospitalization rates, with the peak occurring in winter months.[9] In the present study, the data available before the ordinance was enforced spanned 1 year plus the preceding spring and winter season, whereas the data available after the ordinance included 1 year plus a summer and fall season. Differences due to seasonal trends in AMIs could confound the estimate of the preordinance to postordinance effect. We therefore accounted for seasonality in the analysis.

Because contingency table analyses are unadjusted for seasonality, monthly AMI hospitalizations were also analyzed with Poisson regression. A series of regression models were fit to the monthly data to best model the potential covariates of seasonality (1 and 2 harmonics fit over the 3-year time span). All regression models included fixed effects for time (preordinance or postordinance),

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TABLE 1. Demographic Characteristics of AMI Patients by Location

	Inside Pueblo City Limits (N=690)	Outside Pueblo City Limits (N=165)	El Paso County (N=1939)
Male, n (%)	408 (59.1)	110 (66.7)	1285 (66.3)
Female, n (%)	282 (40.9)*	55 (33.3)*	654 (33.7)*
Age, y, mean±SD	68.7±14.4†	66.5±12.6†	64.8±14.2†

*Gender variation by location, $P=0.003$.
†Age variation by location, $P=0.001$.

residence (inside Pueblo city limits, outside Pueblo city limits, or in El Paso County), and the interaction of time and residence. The models allowed for overdispersion/underdispersion and included the estimated population size from July 1, 2003, as an offset variable. The best-fitting model was selected on the basis of a penalized deviance statistic in which the penalty was twice the number of parameters. The best model contained time, location, time-by-location interaction, and 2 harmonics to account for seasonality. Contrasts of the preordinance to postordinance means were made within the Poisson regression model. After a final model was selected, an equivalent model without the main effects for time and location was fit to obtain more easily interpretable regression parameters.

Plots of monthly AMI counts divided by estimated population sizes standardized to 100 000 residents were created to illustrate the trend in AMI admissions over the 3-year study period. All tests were 2-sided and conducted at the 5% level of significance. Analyses were performed with SAS version 9.1 (SAS Institute, Cary, NC).

The authors had full access to the data and take full responsibility for their integrity. All authors have read and agree to the manuscript as written.

Results

We identified a total of 2794 patients at all 3 locations who were hospitalized with a principal diagnosis of AMI during the study period, 855 of whom were Pueblo County residents. Demographic characteristics of the AMI patients are shown
AQ: 6 in Table 1. The distribution of gender by location differed significantly ($P=0.003$). A higher proportion of AMI patients residing within Pueblo city limits were females (40.1% compared with 33.3% of those residing outside of Pueblo city limits and 33.7% of El Paso County residents). The mean age of AMI patients in El Paso County was almost 4 years younger than that of patients within Pueblo city limits ($P=0.001$).

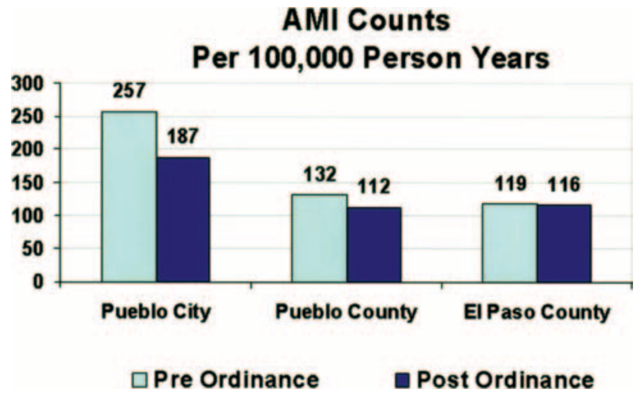

Figure 2. AMI rates per 100 000 person-years for each location (inside Pueblo city limits, outside Pueblo city limits, and El Paso County) 1.5 years before and after enforcement of the smoking ordinance within Pueblo city limits. No smoking ordinances were in effect outside the Pueblo city limits or in El Paso County.

Table 2 summarizes the total number of AMI hospitalizations preordinance and postordinance by location and AMI rates per 100 000 person-years. On the basis of the summary AMI data, a reduction in AMI hospitalizations was observed 1.5 years after the smoking ordinance was enacted compared with an equal length of time before the ordinance among residents within Pueblo city limits (relative risk [RR]=0.73, 95% confidence interval [CI] 0.63 to 0.85). No significant changes in AMI hospitalizations were observed among residents outside of Pueblo city limits (RR=0.85, 95% CI 0.63 to 1.16) or in El Paso County (RR=0.97, 95% CI 0.89 to 1.06) during the same time period. The decline in AMI hospitalizations per 100 000 person-years within Pueblo was 70. This contrasts with a decline in AMI counts per 100 000 person-years outside Pueblo city limits of 20 and a decline in El Paso County of only 3 per 100 000 person-years (Figure 2). T2 F2

TABLE 2. Observed and Expected AMI Counts/100 000 Person-Years by Time and Location

Location	Pre	Post	RR (95% CI) for AMI, Post to Pre	Seasonally Adjusted RR (95% CI) for AMI, Post to Pre
Inside Pueblo city limits	...	...	0.73 (0.63–0.85)	0.74 (0.64–0.86)
n	399	291	...	...
Rate per 100 000 person-years	257	187	...	...
Outside Pueblo city limits	...	...	0.85 (0.63–1.16)89	0.87 (0.64–1.17)
n	89	76	...	...
Rate per 100 000 person-years	132	112	...	...
El Paso County	...	...	0.97 (0.89–1.06)	0.99 (0.90–1.08)
n	984	955	...	...
Rate per 100 000 person-years	119	116	...	...

Pre indicates preordinance; Post, postordinance.

Test of linear contrasts between preordinance and postordinance changes adjusted for seasonality: Pueblo City vs El Paso County, $P<0.001$; Pueblo City vs outside Pueblo city limits, $P=0.353$; Outside Pueblo city limits vs El Paso County, $P=0.754$.

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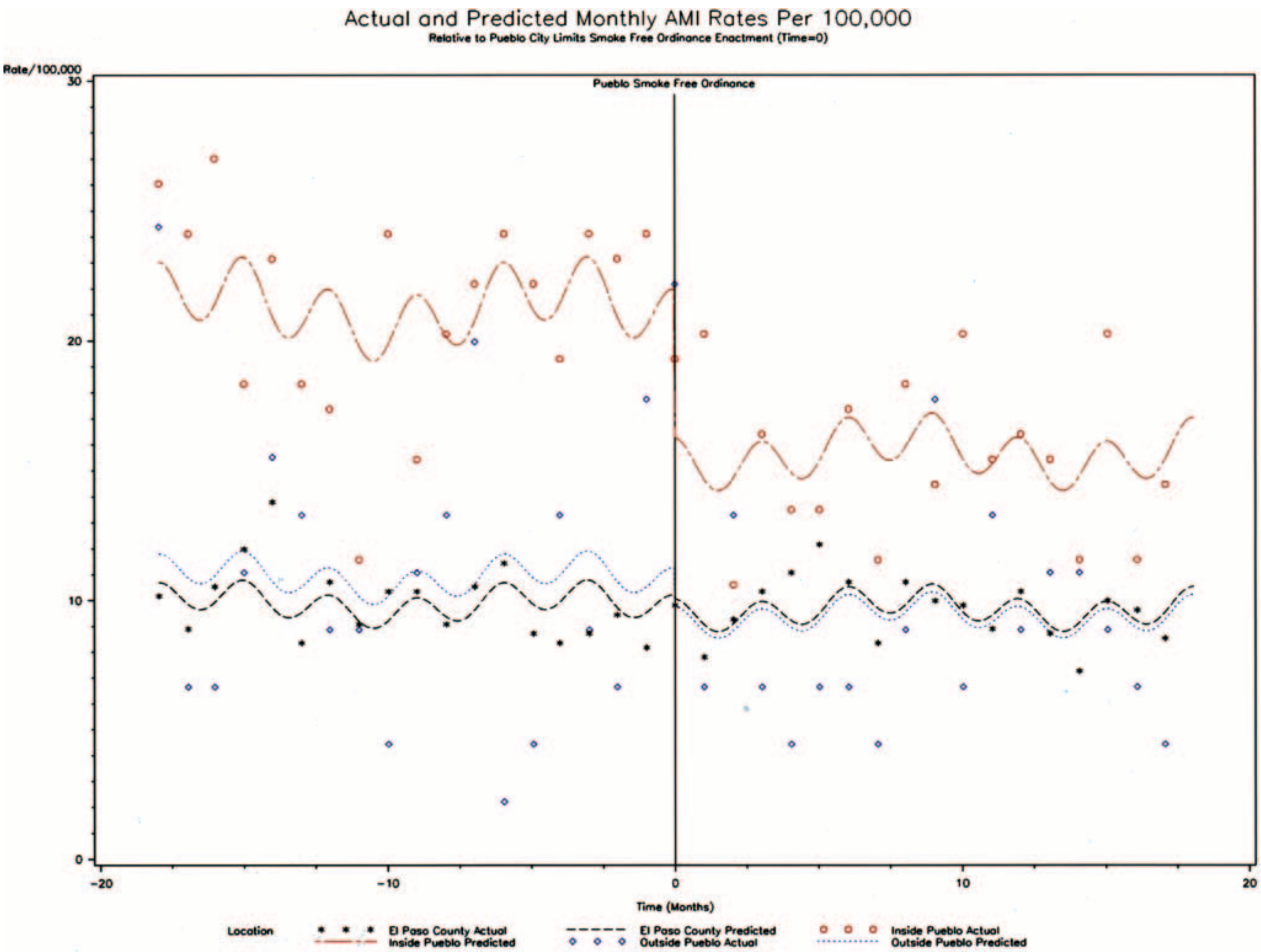

Figure 3. Predicted and actual monthly adjusted AMI rates per 100 000 persons by location (inside Pueblo city limits, outside Pueblo city limits, and in El Paso County) illustrate a significant decline in AMI rates within Pueblo city limits after the ordinance, whereas no significant changes were observed in the group residing outside the city limits or in the external control location (El Paso County) during the same time period. The ordinance was in effect in Pueblo city only. Symbols show the actual monthly AMI rates, whereas dashed lines show predicted rates with the Poisson regression model with effects for seasonality, location, time relative to ordinance enforcement, and the interaction of location and time. Tests of linear contrasts between preordinance and postordinance changes: Pueblo city vs El Paso County, $P<0.001$; Pueblo city vs outside Pueblo city limits, $P=0.353$; outside Pueblo city limits vs El Paso County, $P=0.754$.

To account for the possibility that the 27% reduction in AMI hospitalizations could be offset by an increase in out-of-hospital AMI deaths, we computed population-adjusted AMI death rates in 2002 versus 2004 (42/100 000 versus 54/100 000). Because the overlap in AMI death and AMI hospitalization cannot be determined from administrative data, the RR of AMI hospitalization within Pueblo city limits was reestimated assuming a worst-case scenario: that all fatal AMIs failed to reach the hospital, and no hospitalized AMI patients died. Even accounting for this increase in fatal AMIs, the attenuated RR remained statistically significant (RR=0.77, 95% CI 0.64 to 0.93).

F3 Figure 3 shows monthly population-adjusted AMI rates per 100 000 persons for each of the 3 locations (inside Pueblo city limits, outside Pueblo city limits, and El Paso County) and the predicted Poisson regression curves. A clear and rapid decline in AMI rates was seen within Pueblo city limits after enforcement of the ordinance, whereas no significant changes were observed in the group residing outside the city limits or in the external control location (El Paso County). Variability in monthly AMI rates was less in El Paso County, given its larger population size compared with the other communities.

Table 2 lists the postordinance to preordinance RR estimates based on the raw data and from the final Poisson regression model with adjustment for seasonality. The interaction between time and location was significant ($P=0.004$) even after adjustment for seasonality, which indicates that mean changes over time differed for the 3 locations. In the principal comparison, the reduction in AMI rate within Pueblo city limits differed substantially from the change in the external control, El Paso County ($P<0.001$). After adjustment for seasonality, the RR within Pueblo city limits was essentially unchanged from the unadjusted RR (RR=0.74, 95% CI 0.64 to 0.86).

Discussion

The association between active smoking and cardiovascular disease has been known for nearly a century,[10,11] whereas secondhand smoke exposure has been more extensively studied as a coronary heart disease risk factor for only 2 decades.[1,12,13] The present study extends this observational evidence base by demonstrating a temporal association between a public smoking ordinance and a reduction in AMI hospitalizations. We found a significant decrease in AMI hospitalizations after implementation of a smoke-free ordinance in Pueblo city (RR=0.73, 95% CI 0.63 to 0.85). Of note, this 27% (95% CI 37% to 15%) reduction is similar in magnitude to the decline (40%; 95% CI 64% to 1%) demonstrated in another western US city, Helena, Mont, which had a similar ordinance.[4] The results of the present study mirror those in the Helena study, with a reduction in AMI seen only among citizens residing within the city, and strengthen the possibility that a reduction in AMI hospitalizations is directly related to enforcement of the smoking ordinance. These data suggest that community adoption of a smoke-free environment has the potential to rapidly improve the cardiovascular health status of its citizens.

A recent analysis[2] and systematic review[14] found that never-smokers had an estimated 30% greater risk of ischemic heart disease if they lived with a smoker. This was almost half the risk of smoking 20 cigarettes daily, even though the exposure to tobacco smoke was only 1% of that of a smoker. This suggests a nonlinear dose-response relation between SHS exposure and risk of coronary heart disease. A recent 20-year prospective study[5] that used a biomarker of overall passive exposure to tobacco smoke (serum cotinine level) suggested the increased RR for developing coronary heart disease may be as high as 57%, approximating the risk among light (1 to 9 cigarettes/d) active smokers. The higher-magnitude risk estimate observed in that study compared with the data derived from questionnaires in the meta-analysis (57% versus 30%) may be due to the use of cotinine measurements, which more accurately reflect individuals exposed to SHS.

The Helena study was limited to a 6-month ordinance period, after which enforcement of the law was suspended. During the ordinance period, AMI rates decreased, only to rebound after the suspension of the ordinance. By contrast, the longer enforcement period in Pueblo resulted in a sustained reduction in AMI rates. Another major criticism of the Helena study is the small number of AMI cases analyzed and the use of secondary AMI diagnoses. The present study analyzed nearly 3 times as many AMI cases in Pueblo County and focused solely on primary International Classification of Diseases, 9th revision–coded diagnoses. We believe this provides a more precise estimate of the relative effect size of a public smoking ordinance. As in the Helena study, we used a contemporaneous control population, El Paso County, that lacked a smoking ordinance, which strengthens the study design.

Because this is a time series study, relevant potential confounding variables are those temporally related to ordinance enforcement and to AMI incidence. Three such confounders are readily identified: seasonality, decreases in air pollution, and community-wide changes in cardiovascular preventive care. The present study directly modeled and adjusted for seasonality and found that adjustment for seasonality did not alter the conclusions, although it is possible that adjustment over a 3-year time span was insufficient to eliminate all confounding by seasonality. Although air pollution levels, especially particulate levels, were not directly adjusted for, inclusion of the proximal community of El Paso County, where similar air pollution fluctuations exist, diminishes the possibility that pollution variability accounted for our findings. Furthermore, no major events such as industrial plant closures occurred over this 3-year time span that might have substantially decreased air pollution levels. Variation in cardiovascular preventive care is also unlikely to have confounded our results, because there were no major economic or health-care delivery changes during the observed period.

One might postulate that after the ordinance, some Pueblo citizens with AMI may not have been counted because they died before hospital arrival. Even after we accounted for the changes in AMI deaths in a conservative manner, however, the magnitude and significance of the association remained. Finally, a higher AMI rate was seen in Pueblo than in El Paso County, both before and after the smoking ordinance. The higher mean age and the greater proportion of smokers in Pueblo compared with El Paso County may explain some of this discrepancy.

Poisson regression models were used to determine whether the observed decrease in AMI rates was due to confounding based on seasonality. We found that even after adjustment, the reduction in AMI hospitalizations in the city of Pueblo differed significantly from the change in El Paso County, the external control population ($P<0.001$).

We lacked information regarding potentially important time variant risk factors at the patient level, such as changes in smoking status, but included 2 control groups with similar demographics followed up during an identical time period. We do not believe that patient-level smoking status changes would have substantively altered our findings; a smoking ordinance, however, has the potential both to impact the cardiovascular health of nonsmokers and to facilitate a reduction in cigarette consumption among smokers.[3]

Review of the time series plot (Figure 2) suggests the effects of the ordinance on AMI hospitalization rates occurred within months. Recent reviews suggest that SHS is capable of rapidly precipitating acute atherothrombotic events.[15,16] Accumulating in vivo experimental evidence also demonstrates that many critical responses of the cardiovascular system are exquisitely sensitive to the toxins in SHS.[2] Inflammatory markers including C-reactive protein, fibrinogen, and oxidized low-density lipoprotein cholesterol are increased with only minimal exposure to SHS and were surprisingly similar in magnitude to those seen among active smokers.[17] Ischemic risk due to brief exposure to SHS may also be mediated by a decreased high-density lipoprotein cholesterol, mitochondrial damage, and insulin resistance.[18,19] Platelet aggregation is central to intracoronary thrombosis,[20] and SHS significantly increases platelet aggregation and the propensity for AMI.[21,22] Further plaque destabilization may result from the nicotine present in SHS, which augments matrix metalloproteinase activity, an enzyme that degrades the fibrous cap in coronary plaques.[23] Only 30 minutes of SHS exposure significantly impairs coronary endothelial function[24] and increases aortic stiffness to an extent similar to that of active smokers.[25,26] Finally, passive SHS exposure reduces heart rate variability,[27] a marker of excess sympathetic nervous system activity and a predictor of sudden cardiac death. In summary, extensive in vivo data provide biological plausibility for the rapid reduction in AMI hospitalizations observed in the present study.

Smoking is the most potent modifiable coronary heart disease risk factor. It is estimated that making workplaces smoke-free in the United States could prevent ≈610 stroke and AMI deaths in the first year alone, many of which occur in nonsmokers.[3] This suggests that initiation of smoke-free workplace and public establishment laws such as the one in Pueblo, Colo, may provide substantial community health benefits. Fifteen years after California launched its tobacco control program and 10 years after passage of its statewide smoke-free workplace law, a field research survey found 90% of citizens approved of the law, and the majority of smokers who recently quit believed the law facilitated their abstinence.[28] This builds on studies demonstrating that workplace tobacco restrictions increase smoking cessation attempts, lower rates of relapse in those who attempt to quit, and significantly decrease the number of cigarettes smoked among current daily smokers.[29–32] Thus, a smoke-free ordinance could mediate a reduction in AMI risk both through limiting SHS exposure and by decreasing smoking rates among persons already dependent on tobacco.

In conclusion, Pueblo, Colo, witnessed a significant decline in hospital admissions for AMI after the institution of a comprehensive smoke-free ordinance in public buildings and workplaces. Although a causal relationship between SHS and AMI cannot be definitively proven with observational data, the decline in AMI hospitalizations in the present study overlaps the decline demonstrated in a similar, albeit smaller study in Helena, Mont. Taken together, we suggest that these data indicate a smoking ordinance may be a vehicle for reducing the burden of ischemic heart disease. It will take decades to realize the significant health benefits of increased smoking cessation AQ: 7 rates on a population level.[33] With regard to acute myocardial infarction, the public health benefits from a smoking ordinance may be realized much more rapidly.

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Disclosures

None. AQ: 8

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CLINICAL PERSPECTIVE

Major advances in both primary and secondary prevention of cardiovascular disease have occurred within the last decade. Effective risk-reduction strategies include guideline-based medications and therapeutic lifestyle changes, which are directed primarily toward the individual patient. At the population level, public health policy may also impact health, but it may often take decades to reduce the burden of chronic disease. We assessed the impact of a smoke-free ordinance on the incidence of acute myocardial infarction in a geographically isolated community. Over an 18-month period, we observed a rapid decline in acute myocardial infarction rate as a result of a public smoking ordinance in Pueblo, Colo, compared with a reference population, Colorado Springs, Colo, which lacked an ordinance. These data reinforce similar findings from Helena, Mont, and suggest that a smoke-free policy has the potential to significantly impact cardiovascular health.