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The impact of a smoking ban on hospital admissions for coronary heart disease

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Abstract

Objective. In March 2002, the city of Bowling Green, Ohio, implemented a clean indoor air ordinance banning smoking in workplaces and public places. This study evaluates the effect of this ordinance on hospital admissions for smoking-related diseases.

Methods. A quasi-experimental design with interrupted time-series was used including a matched control city (Kent, Ohio) with no clean indoor air ordinance. Data on hospital admissions during the period of January 1999 to June 2005 were analyzed using Autoregressive Integrated Moving Average (ARIMA) models.

Results. A reduction in admission rates for smoking-related diseases was achieved in Bowling Green compared to the control city. The largest reduction was for coronary heart disease, where rates were decreased significantly by 39% after 1 year and by 47% after 3 years following the implementation of the ordinance. ARIMA models revealed a statistically significant downward trend in monthly admission rates for coronary heart disease (Bowling Green, $\omega=-1.69$, $p=0.036$ vs. Kent, $\omega=-1.14$, $p=0.183$) and support the hypothesis that the ordinance had a significant impact on admission rates for coronary heart disease.

Conclusion. The findings of this study suggest that clean indoor air ordinances lead to a reduction in hospital admissions for coronary heart disease, thus reducing health care costs.
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Keywords: Secondhand smoke; Environmental tobacco smoke; Clean air ordinance; Indoor smoking ban; CHD; Hospital admission; ARIMA

Introduction

Secondhand smoke (SHS) is as a major threat to public health. Exposure to SHS is associated with a number of serious diseases and is a leading cause of death in the United States. An estimated 50,000 deaths per year in the U.S. are attributed to SHS (Centers for Disease Control (CDC), 2005a).

In terms of risk factors for coronary heart disease (CHD), the effect of exposure to SHS may be nearly as large as active smoking (Barnoya and Glantz, 2005). The U.S. Surgeon General concluded that even brief exposure to SHS has immediate adverse effects on the cardiovascular system and increases risks for heart disease (USDHHS, 2006). Exposure to SHS among non-smokers is associated with a 30% to 60% excess risk of coronary heart disease (USDHHS, 2004; He et al., 1999; Whincup et al., 2004).

The greater the number of smokers in a population, the greater the likelihood that more people will be exposed to SHS and the greater the intensity of the exposure. In 2004, Ohio had the fifth highest rate of smoking prevalence (25.9%) of all the states (Centers for Disease Control, 2005b). Smoking induced illnesses in Ohio contributed almost 5% of all hospital costs in 1999 (Miller et al., 1999). Due to the CHD risks associated with SHS, health care practitioners should advise all patients with known coronary heart disease

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and those at increased risk for CHD to avoid exposure to SHS (Pechacek and Babb, 2004).

Nearly half of the population of the United States is at risk of exposure to SHS (Williams et al., 2005). However, health risks from SHS are completely preventable (USDHHS, 2000). Exposure to SHS can be reduced by over 80% through the elimination of smoking in public places (CDC, 2004). In the past decade, exposure to SHS in the U.S. has decreased considerably, largely as a result indoor smoking bans.

Clean indoor air ordinances (CIA) that ban smoking in public places may lead to significant reductions in the prevalence of smoking and cigarette consumption (Fichtenberg and Glantz, 2002) and therefore may reduce the prevalence of exposure to SHS. Reducing exposure to SHS may lead to a reduction in smoking-related diseases. For this and other reasons, many jurisdictions are implementing laws banning smoking in public places.

Bowling Green Ohio implemented a CIA ordinance in March 2002. Smoking was prohibited in all public places within the city, except for bars and restaurants with bars, provided that the bar area was isolated within a separate smoking room. Smoking was allowed in bars and bowling alleys at the discretion of the owners. The purpose of this study was to evaluate whether this ordinance significantly impacted the rate of hospital admissions for coronary heart diseases.

Methods

To test the impact of the indoor smoking ban on CHD-related hospital admissions, we employed a quasi-experimental design with an intervention city (Bowling Green, Ohio) and a matched control city (Kent, Ohio). Using information from the Health Resources and Services Administration (HRSA), the authors selected the city of Kent to serve as the matched control city. The cities of Bowling Green and Kent were 150 miles apart yet very similar with regard to population size, age and gender distribution. The proportion of African Americans was higher in Kent (9%) than Bowling Green (3%).

Hospital discharge data were obtained for all hospitals within the State of Ohio and data for the residents of the two cities were extracted. The data covered a 6-year time period: 1999–2004 and the first half of 2005. Admission rates for adults (age ≥18 years) were analyzed based on the primary diagnosis for admission. The 2000 census population data were used as the denominator for rates throughout the study time period. The primary diagnosis was reported using the *International Classification of Diseases*, version 9 (ICD) (American Medical Association, 2002). CHD (ICD 410-414, 428) included angina, heart failure, atherosclerosis and acute myocardial infarction.

Data analysis

Age-standardized rates were calculated using the combined population of Bowling Green and Kent as the standard population. Differences in standardized admission rates between the two cities were examined using Mantel–Haenszel chi-square tests. Autoregressive Integrated Moving Average (ARIMA) intervention time series analysis (McCleary and Hay, 1982) was used to model the monthly distribution of hospital admissions.

Due to the novelty of the ban, initial resistance by its opponents and legal wrangling over its enforcement, we believed that several months of consistent enforcement would be needed before citizens would actually change their behavior. We postulated that at least 6 months would be needed to allow for the potential health effects from reduction in exposure to second hand smoke, reduction in smoking prevalence and smokers reducing the quantity of cigarettes smoked. Previous studies have demonstrated that ischemic heart disease risks typically decrease within several months after reducing or eliminating exposure to active or passive smoking (Barnoya and Glantz, 2005; Lightwood and Glantz, 1997; Pechacek and Babb, 2004). Therefore, we waited until October 2002 before assessing the impact of the ordinance.

A dummy variable (coded as 0 for all months before October 2002 and 1 for all months after that time) was used to test for the impact of the intervention. If the estimate of the intervention variable (ω) is negative and statistically significant, an intervention effect is assumed to exist. It was assumed for purposes of these analyses that such extraneous factors (e.g., dietary changes, exercise and other intervening variables) would influence both cities equally. Statistical analysis was conducted using SAS 9.1 (SAS Institute, 2004).

Results

Standardized admission rates for adults in Bowling Green and Kent from 1999 to first half of 2005 are presented in Table 1. Admission rates for CHD-related diseases showed a significant downward trend reduction in the intervention city starting in 2003. Admission rates for CHD in Bowling Green were statistically significantly reduced from 36 per 10,000 populations in 2002 to 22 per 10,000 populations in 2003 (39% decrease; 95% CI, 33% to 45%) and to 19 per 10,000 populations in the first half of 2005 (47% decrease; 95% CI, 41% to 55%). Admission rates for CHD in Kent were not significantly changed during the same period of time ($p=0.945$).

Admission rates varied during the 6-year study period. For the first 4 years (1999–2003), Kent had higher admission rates for non-smoking-related causes than Bowling Green for (Table 1). For non-smoking-related admissions, the rate decreased in 2003 for both cities. Thereafter, the rate increased in Bowling Green but the difference between the two cities was not statistically significant ($p=0.14$).

To gain further insight into the ban's effect on CHD, we investigated the monthly admission rates attributed to CHD from January 1999 to June 2005. Monthly admissions rates for CHD in Bowling Green are plotted in Fig. 1. A steady decline in the monthly rates series indicated a downward trend in the rates. After initially rising, the admission rates for CHD began a marked decline in November 2002, 7 months after the full implementation and enforcement of the smoking ban in Bowling Green. The estimate of ω (the parameter representing a change in the series level) was −1.69 and was statistically significant ($p=0.04$). The estimates of the autocorrelations up to

Table 1
Standardized Hospital Admission rates per 10,000 population (18 and over) for 1999–2005, Bowling Green and Kent, Ohio, United States

Year	Coronary heart diseases		Non-smoking-related diseases	
	Bowling Green	Kent	Bowling Green	Kent
1999	35	42	720	1107
2000	24	49	710	1158
2001	24	41	722	1112
2002 [a]	36	47	754	1087
2003	22	39	780	1112
2004	26	38	838	1140
2005 [b]	19	48	809	1120

[a] The ordinance went into force on March.
[b] Rates are based on the first 6 months admissions (doubled).

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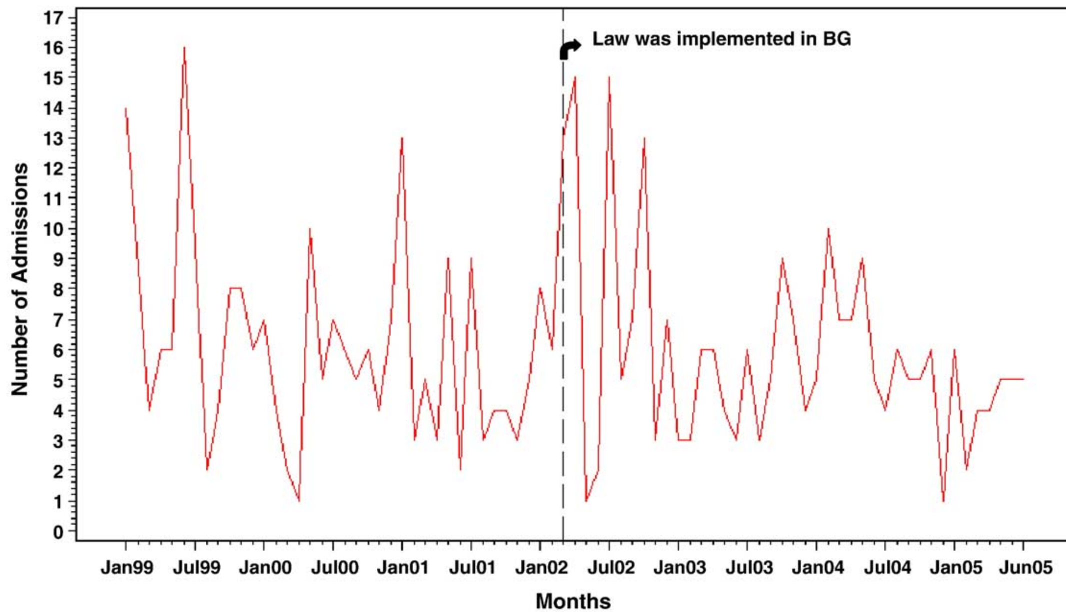

Fig. 1. Monthly distribution of hospital admissions for coronary heart disease in the city of Bowling Green, Ohio, United States.

lag 24 were not significant and the ARIMA model was sufficient to explain the first order autocorrelation in the series. This result indicates that the CIA ordinance significantly decreased admissions rates for CHD in the city of Bowling Green.

Fig. 2 presents monthly admissions rates for CHD in Kent. The monthly admissions appear to be constant except for a reduction a few months before and several months after implementation of the ordinance in Bowling Green. The estimate of ω was −1.14 and was not statistically significant ($p=0.18$). This analysis indicates that the rates in Kent did not show parallel significant changes following the implementation of the smoking ban in the city of Bowing Green.

The distribution of admissions for non-smoking-related causes was also examined for both cities. In the city of Bowling Green, the estimate of ω was 13.8 and was not statistically significant ($p=0.17$). The estimate of ω in Kent was −20.3 and was not statistically significant ($p=0.13$). These analyses indicate that admission rates for causes unrelated to smoking were not significantly changed in the cities during the study period.

Discussion

Our findings suggest that the implementation of a CIA ordinance in Bowling Green Ohio led to a reduction in hospital

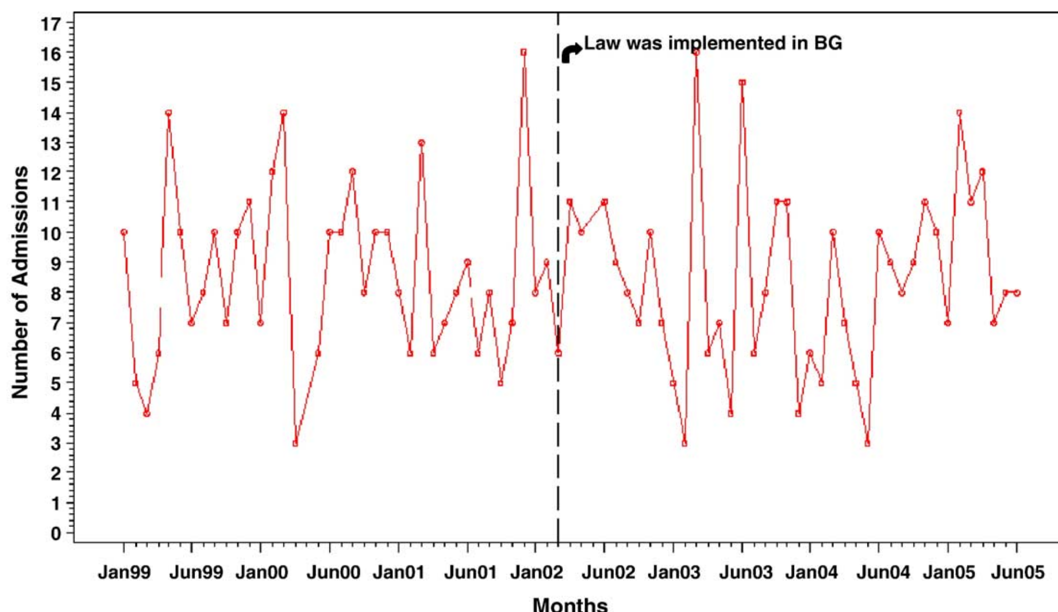

Fig. 2. Monthly distribution of hospital admissions for coronary heart disease in the city of Kent, Ohio, United States.

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admissions for CHD. We repeated the analysis for other admissions to assess whether the change in admission rate for smoking-related diseases could have resulted from systematic differences in admissions. Non-smoking-related admissions did not decrease during the study period.

Our results are corroborated by findings from three other research studies. Sargent et al. (2004) reported a 40% reduction in admissions for acute myocardial infarction at the local hospital following the implementation of the law in Helena, Montana. However, our findings were significant only 6 months after the CIA ordinance. A similar study in Pueblo, Colorado, examined CHD admissions for the primary hospitals a year and a half before Pueblo's CIA ordinance went into effect and a year and a half following enactment of the ordinance. CHD hospital admissions decreased by 27% after the CIA ordinance went into effect (Bartecchi et al., 2006). The third study in northern Italy examined the change in hospital admissions for acute myocardial infarctions (AMIs) for adults under 60 years of age before and after a national law banning smoking went into effect (Barone-Adesi et al., 2006). The Italian researchers found an 11% decrease in hospital admissions for AMIs. This lower rate of reduction in admissions was likely due to the truncated age range (<60 years) used by the Italian researchers but not used in the other studies nor in our study.

The reduction in CHD in Bowling Green Ohio is likely due to several factors: the reduction in exposure to SHS among non-smokers; a reduction in the number of cigarettes smoked by smokers; and an increase in smoking cessation (Farrelly et al., 1999; Gilpin and Pierce, 2002). More specifically, the 39% decrease in CHD-related admissions could plausibly be explained by assuming that people exposed to passive smoking have a relative risk of AMI of 1.3 (Law et al., 1997) and that most non-smokers were exposed to SHS in public places. Based on these assumptions, the reduction of AMI would be approximately 17%. The remaining 21% of the reduction in AMI may have been due to a decrease in smoking prevalence and a decrease in the amount of cigarettes smoked among smokers.

Gallus et al. (2006) reported that after a ban on indoor smoking went into effect, there was a 8.9% reduction in cigarette sales; a 5.5% decrease in the mean number of cigarettes smoked per day; and a 2.3% decrease in overall smoking prevalence. Longo et al. (2001) reported that indoor smoking bans were associated with an increase in smoking cessation and a decrease in the amount of time involved in quitting among adults. Implementation of smoke-free policies is also associated with increased cessation attempts and successful long-term cessation among affected smokers (Williams et al., 2005; Bauer et al., 2005; Moskowitz et al., 2000; Longo et al., 2001; Stephen et al., 2001). Smoking restrictions may also change social norms regarding the acceptability of smoking in a community (Levy and Friend, 2003). As a result, smokers may become more motivated to quit smoking or may not initiate smoking at all, thereby reducing the total number of smokers (Williams et al., 2005).

Our findings are biologically plausible considering the role of SHS in the pathogenesis of CHD (Barnoya and Glantz, 2005). SHS is a complex mixture of nearly 4000 chemicals, with over 60 known carcinogens and 6 developmental and reproductive toxicants (National Cancer Institute, 1999). Many of these compounds are likely to effect CHD risk. Experimental studies have demonstrated a marked increase in platelet aggregation and endothelial dysfunction in humans and animals at low levels of exposure to SHS (Glantz and Parmley, 2001; Law et al., 1997). Smoking is associated with adverse changes in serum lipids and fibrinogen (Cullen et al., 1998). Reduction of tobacco consumption from 21.5 g/day to 10.8 g/day has been associated with "healthier" levels of fibrinogen, white blood cells and high density/low density lipoprotein ratios (Eliasson et al., 2001).

Exposure to SHS and the associated risks of CHD depends, in large part, on the short-term thrombogenic effects of tobacco smoke constituents on the blood vessels and not on accumulated exposure (Smith and Fischer, 2001). Laboratory data suggest that 30 min of exposure to a typical dose of SHS induces changes in arterial endothelial function in exposed non-smokers of a magnitude similar to those measured in active smokers (Otsuko et al., 2001). Compared with unexposed non-smokers, non-smokers exposed to SHS had higher white blood cell counts, C reactive protein, homocysteine, fibrinogen and oxidized low density lipoprotein cholesterol concentrations. The values for these biomarkers of inflammation were similar to those observed in active smokers (Panagiotakos et al., 2004). Other mechanisms that increase the overall risk of acute myocardial infarction are reduced high density lipoprotein cholesterol and increased carboxyhemoglobin concentrations. These factors have been shown to have non-linear dose–response relations with exposure to tobacco smoke (Law and Wald, 2003). Exposure to SHS also interacts with other risk factors for cardiovascular disease (e.g., hypercholesterolemia, diabetes mellitus and hypertension) (Houston et al., 2006).

The results of the current study should be interpreted in light of the potential limitations. First, Kent was selected as the control city based on the assumption that its residents would have been impacted by the same intervening variables that impacted admission rates in Bowling Green. It was also assumed that the residents of Kent were not influenced by the smoking ban that was enacted in Bowling Green. Even though the cities are separated by 150 miles, it is possible that some influence (e.g., media) may have been present. Second, changes in CHD risk factors other than smoking may have influenced the reduction of admission rates for CHD. However, it is likely that risk factors for CHD such as diet and exercise would have affected the populations of the two cities equally. Lastly, we did not measure citizens' exposure to SHS nor did we measure the smoking habits of residents in both cities. The number of subjects with CHD that were actually exposed to active and passive smoke in the two cities may have been different. The number of subjects at risk for CHD may not have been comparable in the two cities. The high percentage of Black population in Kent may be associated with higher percentage of subjects at

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risk for CHD. There is a need for more research that is focused at the individual exposure level.

Conclusion

A CIA ordinance in Bowling Green Ohio was associated with a statistically significant reduction in hospital admission rates for CHD. These findings provide further support for the effectiveness of CIA ordinances in reducing hospital admission rates for CHD. The findings of the current study should encourage civic and public health leaders at the local and state levels to continue to promote clean indoor air ordinances as an effective method of protecting and promoting the health of the American public.

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