The Impact of Public Smoking Ban on the Incidence of Myocardial Infarction Hospitalizations

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Smoking is a well-established risk factor for cardiovascular disease (CVD) and acute myocardial infarction (AMI). Exposure to tobacco smoke is associated with an estimated 35,000 cardiovascular deaths per year in nonsmokers. In addition, the risk of CVD decreases with the cessation of exposure to smoking. Association of smoking with CVD has been well known for years; however, association of secondhand smoke with CVD has been a topic of great interest, especially for the past 2 decades. Multiple studies and articles have evaluated the impact of smoking ban on the incidence of AMI-related hospitalizations. In this article, we discuss the effect of smoking ban on the economy and on human health in general, as well as its potential effects on the prevalence of smoking.
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Introduction

Smoking is a well-established risk factor for cardiovascular disease (CVD) and acute myocardial infarction (AMI).[1,2] There is sufficient evidence to indicate increased risk of cardiovascular events from both active and passive smoking.[3] Exposure to tobacco smoke is associated with an estimated 35,000 cardiovascular deaths per year in nonsmokers.[4] In addition, the risk of CVD decreases with the cessation of exposure to tobacco smoke.[5]

The recognition of adverse health consequences from secondhand smoke (SHS) dates to the report of Surgeon General Jesse Steinfeld in 1972.[6] In 2003, the World Health Organization ratified its first international public health treaty, the Framework Convention on Tobacco Control (FCTC). FCTC sets legislative framework for tobacco control and has been adopted by 164 countries. The 2006 Surgeon General's Report[7] and the 2005 California Environmental Protection Agency (EPA) Report[8] further accelerated the movement of smoke-free environments by providing strong scientific evidence for the foundation of policies protecting nonsmokers from SHS.

Nonsmokers have been shown to have an approximate 30% increased risk of ischemic heart disease if they live in close proximity to smokers.

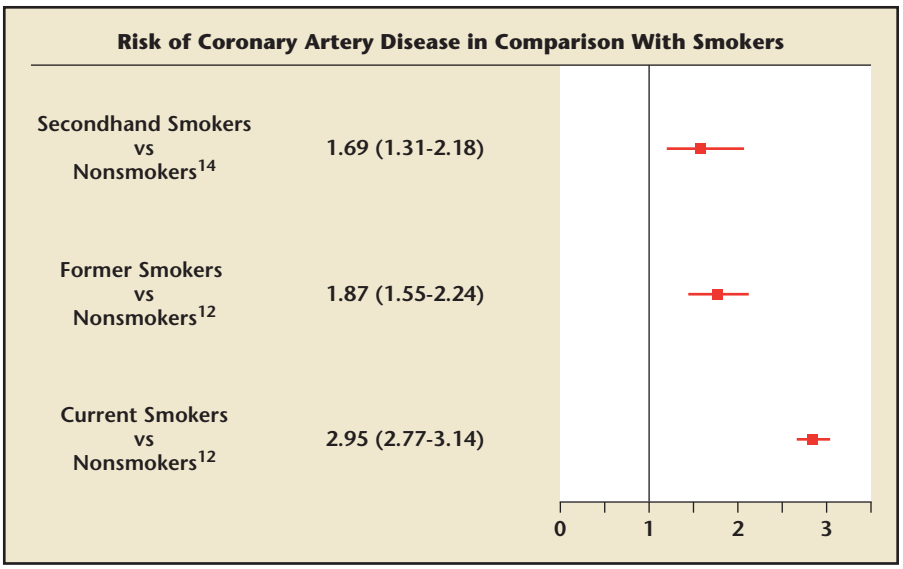
Effects of Smoking on the Cardiovascular System

Association of smoking with CVD has been well known for years; however, association of SHS with CVD has been a topic of great interest, especially in the past 2 decades. Nonsmokers have been shown to have an approximate 30% increased risk of ischemic heart disease if they live in close proximity to smokers. This is nearly half the risk of smoking 20 cigarettes per day, although the exposure to tobacco smoke amounts to just 1% of that of a smoker. These findings suggest a nonlinear relationship between SHS and heart disease.[3,9] A meta-analysis of 16 studies published in the US Surgeon General's 2006 report demonstrated a pooled relative risk (RR) of 1.27 (95% confidence interval [CI], 1.19-1.36) for coronary artery disease (CAD) associated with SHS exposure among nonsmokers as compared with no exposure to SHS among nonsmokers.[10] Another study of 23,521 men and 19,201 women smoking 1 to 4 cigarettes daily demonstrated a pooled RR of 2.74 (95% CI, 2.07-3.61) and 2.94 (95% CI, 1.75-4.95) for cardiac death as compared with nonsmoker men and women, respectively.[11]

In a substudy of the INTERHEART study (A Global Case-Control Study of Risk Factors for Acute Myocardial Infarction), Teo and colleagues[12] assessed the adverse effects of exposure to tobacco in active smokers and former smokers, and exposure to SHS. Including 27,089 participants from 52 countries, they found a higher risk of nonfatal AMI with active smoking with an odds ratio (OR) of 2.95 (95% CI, 2.77-3.14) compared with nonsmokers. The OR for nonfatal AMI for former smokers did drop to 1.87 (95% CI, 1.55-2.24) within 3 years of quitting, with the risk further dropping to OR 1.22 (95% CI, 1.09-1.37) as compared with nonsmokers in ≥ 20 years. They also assessed the progressive decline in the OR with decrease in duration of SHS exposure (OR 1.62 decreasing to 1.24 with exposure from > 21 hours to 1-7 hours/week, respectively).

Huhtasaari and coworkers,[13] evaluated the risk of AMI in snuff users, cigarette smokers, and in nonsmokers. They found an-age adjusted OR of 1.87 (95% CI, 1.40-2.48) in current smokers as compared with nonsmokers. He and colleagues[14] demonstrated a high risk of CAD in those exposed to SHS with adjusted OR of 1.69 (95% CI, 1.31-2.18) as compared with those not exposed to SHS. In another study, He and associates[15] studied the differential effects of exposure to SHS on Chinese women at home and work with respect to developing CAD. They found an OR of 1.24 (95% CI, 0.56-2.72) for those exposed to SHS at home versus 1.85 (95% CI, 0.86-4.0) to those exposed to SHS at work. Figure 1 demonstrates comparative risk of MI/CAD with varying types of exposure to smoking compared with nonsmokers. The degree of exposure to SHS and the comparative risk of MI/CAD are as displayed in Figure 2.

Figure 1. *Odds ratio of myocardial infarction and coronary artery disease in smokers and nonsmokers. Data from Teo KK et al.[12] and He Y et al.[14]*



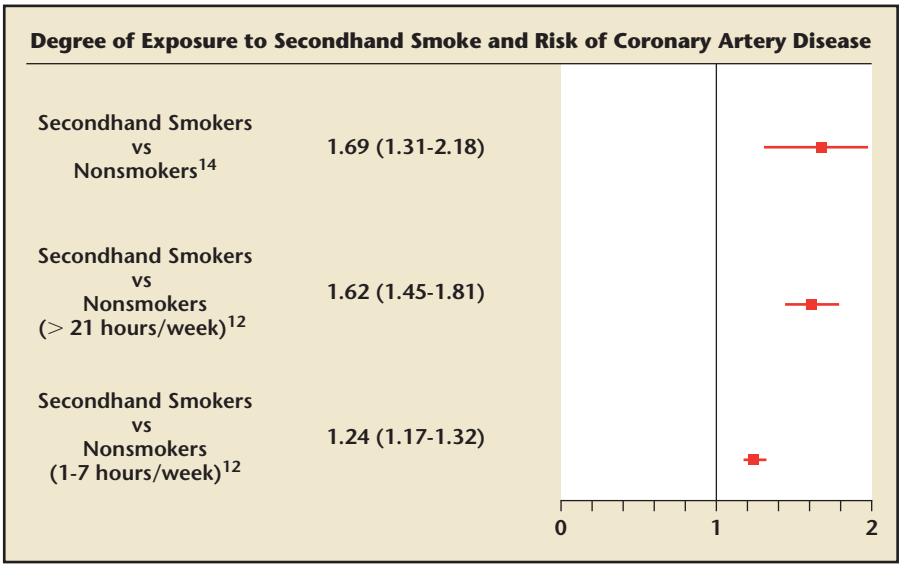


Figure 2. *Degree of exposure to secondhand smoke and odds ratio for myocardial infarction and coronary artery disease. Data from Teo KK et al.[12] and He Y et al.[14]*

The risk of CVD due to SHS is largely determined by short-term thrombogenic effects of tobacco smoke on the blood vessels.[16] Even 30 minutes of exposure to a certain dose of SHS can lead to changes in endothelial function similar to those seen in active smokers.[17] There is also an increase in the biomarkers of inflammation such as C-reactive protein, fibrinogen, and oxidized low-density lipoprotein cholesterol, even with minimal exposure to SHS, to the same extent as noted in active smokers.[18] SHS has been shown to increase platelet aggregation, and nicotine destabilizes the coronary plaque by activating matrix metalloproteinase activity. This is particularly important with the recent decline in the rate of daily smoking along with the associated increase in the rate of light and intermittent smoking, which is often under-identified.[19]

Interventions to Reduce Smoking

Population-wide interventions are crucial to containing the pandemic of smoking-related diseases. Increase in the retail price of cigarettes has been shown to reduce smoking prevalence.[20] Media campaigns have also been found useful for motivating behavioral changes. Televised tobacco control campaign activity was noted to be more effective in reducing adult smoking prevalence than state-level tobacco programs.[21] However, behavioral changes are more closely related to recent media exposure and decline over time after the campaign ends, as was seen in many studies, including the Minnesota youth tobacco-use prevention program.[22]

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Comprehensive Smoking Ban

Another method to reduce cardiovascular impact of smoking is by comprehensive smoking ban (CSB) legislation. Several countries, states, and cities around the world have prohibited smoking to some degree in public places, whereas others have issued CSB legislations.

As of January 5, 2010, there are 840 municipalities in 38 states and the District of Columbia with statewide partial or complete CSB legislation either already in effect or soon to be in the future (Table 1); 25 of the 38 states have statewide CSB legislation in all enclosed public places, including Arizona, California, Colorado, Connecticut, Delaware, Hawaii, Illinois, Iowa, Maine, Maryland, Massachusetts, Michigan (effective May 1, 2010), Minnesota, Montana, Nebraska, New Jersey, New Mexico, New York, Ohio, Oregon, Rhode Island, Utah, Vermont, Washington, and Wisconsin (effective July 5, 2010). Seven of these 38 states exempt bars from CSB legislation: Arkansas, Florida, Louisiana, Nevada, Pennsylvania, North Dakota, and Tennessee. Six of these 38 states have CSB legislation in certain places that do not fit into any specific category: Georgia, Idaho, New Hampshire, North Carolina, South Dakota, and Virginia. Among the non-state territories, the District of Columbia and Puerto Rico have CSB legislation in all enclosed public places; Guam has partial CSB legislation, and there is no CBS legislation in American Samoa, the Northern Mariana Islands,

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Table 1
List of Smoking Bans by State

State	Smoking Ban	Date of Smoking Ban	State	Smoking Ban	Date of Smoking Ban
Alabama	No	N/A	Montana	Yes	10/1/05
Alaska	No	N/A	Nebraska	Yes	6/1/09
Arizona	Yes	5/1/07	Nevada	Partial	12/8/06
Arkansas	Partial	7/21/06	New Hampshire	Partial	9/17/07
California	Yes	1994	New Jersey	Yes	4/15/06
Colorado	Yes	7/1/06	New Mexico	Yes	6/15/07
Connecticut	Yes	4/1/04	New York	Yes	7/2003
Delaware	Yes	11/2002	North Carolina	Partial	1/2/10
Florida	Partial	7/1/03	North Dakota	Partial	8/1/05
Georgia	Partial	7/1/05	Ohio	Yes	12/7/06
Hawaii	Yes	11/6/06	Oklahoma	No	N/A
Idaho	Partial	7/2004	Oregon	Yes	1/1/09
Illinois	Yes	1/1/08	Pennsylvania	Partial	9/11/08
Indiana	No	N/A	Rhode Island	Yes	3/1/05
Iowa	Yes	7/1/08	South Carolina	No	N/A
Kansas	No	N/A	South Dakota	Partial	2002
Kentucky	No	N/A	Tennessee	Partial	7/1/07
Louisiana	Partial	1/1/07	Texas	No	N/A
Maine	Yes	1/1/04	Utah	Yes	1/1/09
Maryland	Yes	2/1/08	Vermont	Yes	9/1/05
Massachusetts	Yes	7/1/04	Virginia	Partial	12/1/09
Michigan	Yes	5/1/10	Washington	Yes	12/8/05
Minnesota	Yes	10/1/07	West Virginia	No	N/A
Mississippi	No	N/A	Wisconsin	Yes	7/5/10
Missouri	No	N/A	Wyoming	No	N/A

N/A, not applicable.

and the US Virgin Islands.[23] Graphical representation of these areas is detailed in Figure 3.

Multiple studies and articles evaluated the impact of CSB legislation on the incidence of AMI-related hospitalizations in various places all over the world, including the United States (Table 2). Some of the studies looked into the effects of CSB legislation in the same area before and after its implementation, whereas others compared the impact of CSB legislation in 2 different geographic areas.

A recently published study conducted by the Department of Public Health at the University of Bath (Bath, England) reflected a sharp 10% decrease in the rate of heart attack following the smoking ban in England in 2007. Similar and even more impressive results were quoted in a different study, with an approximate 14% decrease in the rate of heart attack in Scotland, a 15% decrease in France, and an 11% decrease in Italy and Ireland.[24]

Sargent and colleagues[25] studied the impact of smoking ban in public and workplaces on the incidence of hospital admissions for AMI in Helena, MT. They noted a reduction in the number of average admissions for AMI from 40 to 24 patients for the same months in the prior year and after the CSB legislation was implemented. Interestingly, the incidence increased by approximately 46% in the surrounding areas with no CSB legislation for the same time period.

Bartecchi and associates[26] conducted a similar study in Pueblo, CO. They included a larger number of patients in their study and noted a similar trend of significant decrease in AMI hospitalizations before and after the implementation of CSB legislation with an RR of 0.73 (95% CI, 0.63-0.85; $P < .001$) for the first 18 months after the ban was imposed. A further decline of 19% was noted over an additional 18-month period for the city of Pueblo, with an overall 41% reduction over a period of 3 years. This was in contrast to no change noted in the incidence of AMI in the surrounding communities.

Juster and coworkers[27] conducted another study with a much larger study population in the state of New York. They noted the admission rates for AMI and stroke from 1995 to 2004. Admissions for AMI decreased by 3813 for the year 2004 following passage of CSB legislation. The study did demonstrate a significant decrease in the direct health care costs; however, no reduction was noted in the number of admissions for stroke for the same time period. The smoking prevalence was also noted to decrease from 21.5% to 18.5% from the year 2002 to 2004 following CSB implementation; in addition, salivary cotinine was noted to decrease by 47% in the general population.

Another study was conducted in Monroe County, Indiana, where

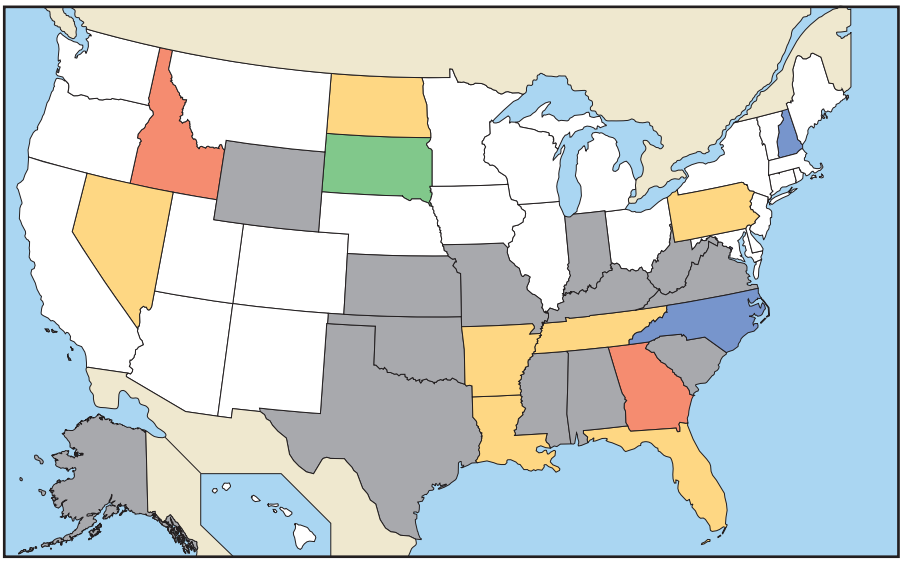

Figure 3A. *Map of the United States showing the states with current and scheduled future state-wide smoking bans as of December 18, 2009. http://creativecommons.org/license/by-sa/3.0/.*

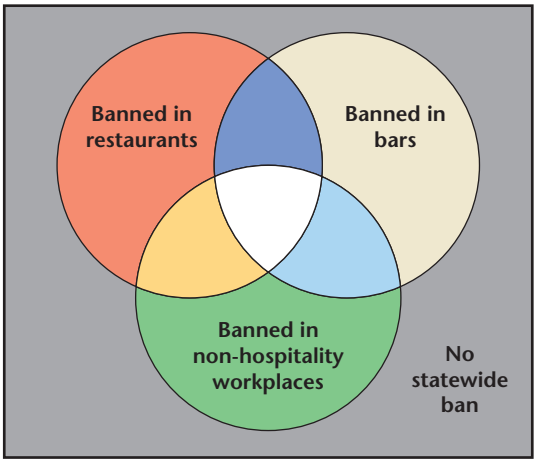

Figure 3B. *Color key for the interpretation of the map in Figure 3A.*

there has been a smoking ban in restaurants, retail outlets, and workplaces since 2003, with the inclusion of bars in 2005. People with prior history of any cardiac intervention and those with positive cardiac risk factors were excluded from the study. The incidence of AMI was noted to drop significantly from 14 cases per 100,000 person-years to 7 cases per 100,000 person-years. This was in contrast to a drop of 20% (a case drop from 15-12 per 100,000 person-years) in neighboring Delaware County, which had no such smoking ban. An interesting finding of the study was that the hospital admission rate for nonsmokers dropped by 70%, constituting the majority of the decline in hospital admissions.[28]

Studies looking for similar trends were also performed outside of the United States. Barone-Adesi and colleagues[29] performed a study in Piedmont, Italy. A significant reduction was noted in the number of admissions for AMI among persons age $<$ 60 years (RR 0.89, 95% CI, 0.81-0.98). No decline in the number of hospital admissions for AMI was noted among persons age $\geq$ 60 years. The cumulative RR for all ages for the period before CSB compared with the period after the implementation of CSB was 1.01 (95% CI, 0.97-1.06). It was estimated from the study that the observed decrease in active smoking following the smoking ban could have accounted for a 0.7% (0.6% among men, 0.9% among women) reduction in hospital admissions for AMI during the study period. The implementation of a CSB in early 2005 was associated with a decline in exposure to active and passive smoking, as was seen with a 90% to 95% decrease in the nicotine vapor phase concentration in randomly selected pubs and night clubs before and after the smoking ban. There was also a decrease of 8.9% in legal cigarette sales in the year 2005.

Cesaroni and coworkers[30] conducted a study after the implementation of a CSB in all indoor places in January 2005 in Rome, Italy. They noted an 11.2% reduction in acute coronary events in patients aged 35 to 64 years and a reduction of 7.9% in patients aged 65 to 74 years. The reduction was noted to be greater in men and in people with low socioeconomic background; no reduction in acute coronary events was noted in the elderly population (persons aged $\geq$ 75 years). There was a decline in cigarette sales by approximately 5.5% between 2004 and 2005, as well as a reduction in the prevalence of smoking among men (from 34.9% to 30.5%) and women (from 20.6% to 20.4%). Data were also collected on particulate matter with an aerodynamic diameter $<$ 10 µm (PM_{10}) from monitors in residential areas and run by the EPA. The average concentration of PM_{10} was demonstrated to decrease from 46 µg/m^3 in the year 2000 to 39 µg/m^3 in the year 2005. The number of days PM_{10} rose above 50 µg/m^3 also decreased from 144 days in the year 2000 to 73 days in the year 2005.

A study conducted in Scotland by Pell and associates[31] demonstrated a 17% reduction (from 3235 to 2684) in the number of hospital admissions for acute coronary events after the implementation of CSB legislation as compared with a 4% reduction in

Table 2
Studies Evaluating Smoking Ban Effect on AMI Incidence

Study	Location	Population	Year of CSB	AMI Before CSB (N)	AMI After CSB (N)	Approximate % Change in AMI	Relative Risk (95% CI)
Sargent RP et al.[25]	Helena, MT	68,140	2002	40	24	−40	0.60 (0.21-0.99)
Bartecchi C et al.[26]	Pueblo, CO	147,751	2003	399	291	−27	0.73 (0.64-0.82)
Juster HR et al.[27]	New York, NY	19,306,183	2003	483/100,000 person-years	445/100,000 person-years	−8	0.92 (0.81-1.05)
Barone-Adesi F et al.[29]	Piedmont, Italy	4,300,000	2005	< 60 y = 922	832	−10	0.89 (0.81-0.98)
				> 60 y = 2659	2823	+1	1.05 (1.00-1.11)
Cesaroni G et al.[30]	Rome, Italy	2,700,000	2005	35-64 y = 2.006/1000	1.80/1000	−11	0.89 (0.85-0.93)
				65-74 y = 7.508/1000	6.95/1000	−8	0.92 (0.88-0.97)
				75-84 y = 12.368/1000	12.59/1000	+1	1.017 (0.98-1.07)
Pell JP et al.[31]	Scotland, UK	5,100,00	2006	3235	2684	−17	0.83 (0.82-0.86)
Lemstra M et al.[32]	Saskatoon, Canada	231,688	2004	176.1/100,000 population	152.4/100,000 population	−13	0.87 (0.84-0.90)

AMI, acute myocardial infarction; CI, confidence interval; CSB, comprehensive smoking ban.

England, with no such legislation. This was a prospective study using both direct and indirect measure of exposure to smoking. Nonsmokers reporting exposure to SHS decreased from 43% to 22% and serum nicotine levels decreased by 18%. Again, it was noted that the nonsmokers comprised 67% of the total decrease in hospital admissions for acute coronary events in contrast to the percentage contribution by active smokers.

Lemstra and colleagues[32] conducted a study in Saskatoon, Canada, following a public smoking ban on July 1, 2004. They noted a reduction in the incidence rate of AMI from 176.1 cases per 100,000 population to 152.4 cases per 100,000 population. The prevalence of smoking was noted to decrease from 24% for the year 2003 to 18% for the year 2005. According to a telephone poll of 1255 Saskatoon residents, 79% of these residents favored the ban.

Analysis of results from all the studies reviewing the impact of CSB legislation on the incidence of AMI reflected a favorable outcome. In a meta-analysis by Lightwood and Glantz,[33] it was demonstrated that not only was there a 15% decrease in hospital admissions for AMI during the first year of follow-up after CSB legislation was implemented, but this effect is linear and could approach approximately 36% in a 3-year period. Meyers and coauthors,[34] in another meta-analysis of 11 studies, demonstrated a 17% overall reduction in the risk of AMI following CSB implementation, predominantly among nonsmokers and younger individuals. The decline in the incidence of AMI following CSB is mediated by various factors including, but not limited to, decline

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in the prevalence of smoking, decrease in the tobacco sales, high compliance to the ban, and improved air quality with decreased environmental exposure to tobacco smoke in the corresponding areas.

Validity of some of these studies has been seriously questioned by contradicting data. Data released by the National Health Services (in England) on hospital admissions for AMI showed only a 2% decrease in the admission rate for 2007-2008 as compared with a decrease of 2.8% for 2006-2007 and 3.8% for 2005-2006.[35] Likewise, data reported for Scotland were in contrast to an official report stating a drop of 8% in the rate of heart attacks (as opposed to approximately 17%) following smoking ban and was quoted as being among "The Worst Junk Stats of 2007" in the *London Times*.[36]

Effects of Smoking Ban on the Economy

One of the concerns with CSB legislation is how it will affect the economic health of bars and restaurants. The Smoke-Free Workplace Act, passed on January 1995 in the State of California, prohibited smoking in all indoor public and private workplaces, including restaurants. It was opposed by owners of alcohol-serving restaurants based on their fear of losing business. However, following the passage of this legislation, revenue for such restaurants dropped by only 4% transiently before rapidly returning to the baseline.[37] Another study, released by the city of New York, quoted in the March 29, 2004 issue of *The New York Times*, claims prosperity for bars and restaurants following passage of CSB legislation. However, critics claimed the study to be flawed because separate statistics for bars (believed to suffer more from the ban) and restaurants were not provided.[38] The El Paso, TX, smoking ban is the strongest smoke-free indoor air ordinance in Texas. The Texas Department of Health and the Centers for Disease Control and Prevention analyzed the sales tax and mixed-beverage tax data from 12 years before to 1 year after the smoking ban. No significant changes were seen in revenues for bars or restaurants following the ban.[39] These data can be used to implement and enforce smoke-free environment legislation in other places. According to a study conducted by Juster and colleagues[27] in New York City, CSB legislation has also been shown to have a positive effect on the economy, evidenced by a total cost savings of $56 million in 2004.

Other Effects of Smoking Ban and Exposure to SHS

Indoor smoking ban has been shown to increase smoking cessation and decrease time in quitting smoking. Smoking restrictions can also change social norms and acceptance of smoking in the community. Clean indoor air (CIA) ordinances that ban smoking in public places significantly reduce smoking prevalence and thereby decrease exposure to SHS. Implementation of CIA in Bowling Green, OH, in 2002 showed reduced hospital admissions for CVD and thus reduced health care costs.[40]

Exposure to smoke has also been a major concern in patients with chronic obstructive pulmonary disease (COPD); approximately 25% to 45% of patients with COPD are nonsmokers. A study by Kałucka[41] found a statistically significant impact of smoke inhalation for more than 20 years and the development of COPD. Another study looked into the effects of passive exposure to tobacco smoke in childhood. This study found a higher disease severity in those exposed to maternal smoking versus those without passive smoking exposure. Ebbert and coworkers[42] also reported a significant dose-dependent relationship between the exposure to SHS and the development of respiratory tract illness in flight attendants who never smoked but were exposed to SHS during the period when smoking was permitted on airplanes.

SHS has also been implicated in the development and progression of peripheral vascular disease (PVD) and cerebral vascular accidents (CVA). In a Chinese study, SHS was found to be associated with the development of PVD and CVA with an OR of 1.87 and 1.56, respectively.[14] In a study by Iribarren and associates,[43] high level SHS at home after adjusting for confounding variables was independently found to be associated with a higher risk of first CVA among nonsmokers. Additionally, SHS was not only implicated as an important factor in the development of CVA but also in CVA-related mortality.[44]

SHS has also been implicated in the development and progression of peripheral vascular disease (PVD) and cerebral vascular accidents (CVA).

Conclusions

CSB legislation is a simple and effective intervention to improve public health. Smoking ban is associated with a decrease in hospital admissions for AMI. In addition, there is sufficient evidence to support the idea that the initial benefits seen with this legislation will not only be maintained, but will likely increase with time. Future studies should focus on the impact of CSB legislation on rates of hospitalization for other disease states and their economic impact. ■

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Main Points

- Smoking is a well-established risk factor for cardiovascular disease (CVD) and acute myocardial infarction (AMI). Evidence supports increased risk of cardiovascular events from both active and passive smoking.
- The risk of CVD due to secondhand smoke (SHS) is largely determined by short-term thrombogenic effects of tobacco smoke on the blood vessels. Even 30 minutes of exposure to SHS can lead to changes in endothelial function similar to those seen in active smokers.
- Population-wide interventions such as increased cigarette tax, media campaigns, and comprehensive smoking ban (CSB) legislation are crucial in curtailing smoking-related diseases.
- CSB legislation is a simple and effective intervention to improve public health. Smoking ban is associated with a decrease in hospital admissions for AMI and reduced health care costs to the community.

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