Declines in Hospital Admissions for Acute Myocardial Infarction in New York State After Implementation of a Comprehensive Smoking Ban

Harlan R. Juster, PhD, Brett R. Loomis, MS, Theresa M. Hinman, MPH, Matthew C. Farrelly, PhD, Andrew Hyland, PhD, Ursula E. Bauer, PhD, MPH, and Guthrie S. Birkhead, MD, MPH

Objectives. Reductions in exposure to environmental tobacco smoke have been shown to attenuate the risk of cardiovascular disease. We examined whether the 2003 implementation of a comprehensive smoking ban in New York State was associated with reduced hospital admissions for acute myocardial infarction and stroke, beyond the effect of moderate, local and statewide smoking restrictions, and independent of secular trends.

Methods. We analyzed trends in county-level, age-adjusted, monthly hospital admission rates for acute myocardial infarction and stroke from 1995 to 2004 to identify any association between admission rates and implementation of the smoking ban. We used regression models to adjust for the effects of pre-existing smoking restrictions, seasonal trends in admissions, differences across counties, and secular trends.

Results. In 2004, there were 3813 fewer hospital admissions for acute myocardial infarction than would have been expected in the absence of the comprehensive smoking ban. Direct health care cost savings of $56 million were realized in 2004. There was no reduction in the number of admissions for stroke.

Conclusions. Hospital admission rates for acute myocardial infarction were reduced by 8% as a result of a comprehensive smoking ban in New York State after we controlled for other relevant factors. Comprehensive smoking bans constitute a simple, effective intervention to substantially improve the public's health. (*Am J Public Health.* 2007;97:2035–2039. doi:10.2105/AJPH.2006.099994)

Exposure to environmental tobacco smoke is a preventable public health hazard associated with an estimated 35 000 deaths a year from coronary heart disease in nonsmokers.[1–6] Active smoking is a well-established cause of acute myocardial infarction (AMI), and exposure to environmental tobacco smoke is estimated to increase the risk of AMI in nonsmokers by about 30% compared with no exposure.[7] Even at low doses, environmental tobacco smoke increases cardiovascular disease risk.[8,9] It may also increase the risk of stroke in both men and women; however, the link is equivocal compared with that for AMI.[4,5,10–13] Mechanisms by which environmental tobacco smoke may induce cardiovascular events include increased platelet adhesion and subsequent thrombosis,[14] changes in vascular endothelial functioning,[15] and impaired arterial dilatation capacity,[15] which have implications for reducing vascular flow and development of atherosclerosis.[2]

The accumulating evidence of the health risks posed by environmental tobacco smoke has led municipalities (e.g., Boston, Mass, New York, NY), states (e.g., Massachusetts, Rhode Island, New York), and nations (e.g., Ireland, Norway, Scotland) to enact strong smoking bans and restrictions to reduce nonsmokers' exposure to environmental tobacco smoke. Two recent studies examined the effect of a comprehensive smoking ban on population-level cardiovascular events in local communities. Hospital admissions for AMI at a single hospital serving residents of Helena, Mont, decreased by about 40% after smoking restrictions in work and public places were implemented.[16] When the ban was lifted, the rate of admissions returned to pre-restriction levels. A nearby comparison community that had no smoking restrictions showed slight increases in hospitalizations during the same period.

A similar study in Pueblo, Colo, examined the total number of hospital admissions for AMI that occurred 18 months before and after a smoking ban was implemented in most workplaces, including bars and restaurants.[17] There were 27% fewer AMI admissions to the 2 hospitals serving Pueblo in the 18 months after the smoking ban went into effect; there was no reduction in a comparison community. Both the Helena and Pueblo studies identified significant reductions in hospitalizations for AMI, which were associated with the implementation of comprehensive smoking bans in communities where no previous law existed. However, these studies were geographically limited and the total number of cardiovascular events was relatively small.

New York State enacted limited statewide smoking restrictions in 1989. The restrictions limited or prohibited smoking in many public places including schools, hospitals, public buildings, and retail stores.[18] Employers were required to develop smoking policies and provide smoke-free work areas upon employee request. Larger restaurants were required to establish nonsmoking sections. Countywide smoking restrictions began in 1995 when Suffolk County and the 5 New York City counties implemented laws that restricted smoking in restaurants. By 2002, 75% of New Yorkers were subject to local smoking restrictions that were stronger than the state law.[19] Many of these local laws completely banned smoking in workplaces and some expanded restrictions on smoking in restaurants. None limited smoking in bars. On July 24, 2003, New York implemented a statewide comprehensive smoking ban that prohibited smoking in all workplaces including restaurants and bars. After implementation of the statewide law, population exposure to environmental tobacco smoke declined nearly 50%. Cotinine levels in the saliva from a representative sample of New York State adults,

declined from 0.078 ng/mL to 0.041 ng/mL.[20] Nassau County and New York City implemented similar comprehensive bans in March 2003.

We compared hospital admissions for AMI and stroke before and after the 2003 statewide comprehensive smoking ban went into effect. Prior to the comprehensive ban, between 1995 and 2003, moderate statewide and local smoking restrictions were enacted. After controlling for seasonal trends, changes in clinical care, geographic differences in hospitalization rates, and other secular trends, we hypothesized that implementation of the 2003 comprehensive statewide smoking ban is associated with reduced hospital admissions for AMI and stroke over and above the effect on admissions of more-moderate smoking restrictions.

METHODS

We obtained data about hospital admissions for AMI and stroke from a comprehensive administrative database maintained by the New York State Department of Health. All nonfederal public and private hospitals certified for inpatient care are required to submit patient data, including diagnoses, within 180 days of the end of the facility's fiscal year. We derived admission rates from the principal primary diagnosis that necessitated the admission. To increase accuracy, the principal admitting diagnosis is established at discharge and is based on the results of medical tests and other findings learned during the admission. AMI and stroke as secondary diagnoses were not used to establish admission rates.

Our analysis included 10 years of data because that time frame encompassed all of the local policies enacted in New York State. We did not include data before the 1989 statewide restriction because that law preceded electronic reporting and there were concerns about comprehensiveness and reliability.

We used *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*)[21] diagnostic codes 410.00–410.99 to identify admissions associated with a discharge diagnosis of AMI, and diagnostic codes 430.00–438.99 to identify admissions associated with stroke. The number of monthly hospital admissions associated with AMI and stroke from January 1995 to December 2004 and for persons aged 35 years and older, was extracted for each of New York State's 62 counties. We combined the number of hospital admissions with county population data[22] to calculate the monthly rate of hospital admissions for each condition. Rates were age-adjusted to the New York population, using year 2000 US Census data.

Information about New York county smoking restrictions was provided by the Americans for Nonsmokers' Rights Foundation Local Tobacco Control Ordinance Database (http://www.no-smoke.org). The database describes all municipal smoking bans, including dates of enactment and implementation and the specific restrictions and prohibitions of each. We defined comprehensive laws as those that prohibit smoking in all worksites, including restaurants, bars, and other hospitality venues with few or no exemptions. This includes the comprehensive statewide ban enacted on July 24, 2003, as well as the comprehensive laws enacted by Nassau County and New York City in March 2003. Moderate laws were defined as those that restrict smoking in most worksites but provide little or no protection in hospitality venues and include the remainder of the county laws. We considered restrictions that applied only to municipal buildings too limited in scope to include in the analysis. We rounded implementation dates for all laws to the nearest month.

We applied multiple linear regression using standard methods for interrupted time-series analysis to monthly age-adjusted county rates of hospital admission for AMI and stroke.[23,24] Monthly age-adjusted rates from each of 62 counties over 120 months resulted in an effective sample size of 7440 observations. We used a linear time-trend variable (month) to quantify changes in treatment, population risk factors, and other secular trends. Two dichotomous variables accounted for the main effect of comprehensive and moderate laws on hospital admissions, measuring the instantaneous change in rates at the time of smoking ban implementation. Interactions between laws and time accounted for continued rate changes following implementation of the law. Fixed county-level differences in rates of cardiovascular disease risk factors and other conditions (e.g., obesity) were explained by county indicator variables. We used the interaction of county indicator variables with time to control for county-specific secular change. We used indicator variables for month of the year to measure seasonal variation in AMI admissions.

Two estimates were made of admissions averted as a result of the statewide 2003 comprehensive smoking ban. The first estimate measured the effect of the 2003 comprehensive ban over the 1989 state law, plus the patchwork of local laws in place at the time of enactment. This estimated how much additional benefit the comprehensive state law provided over all the laws that existed at the time of its enactment. The second estimate measured the effect of the statewide comprehensive law over the early state law only, as if no local laws existed.

Estimated regression coefficients were used to predict the number of hospital admissions averted as a result of the implementation of comprehensive smoking bans. For the first prediction, we estimated monthly rates by removing the comprehensive law main effect and the comprehensive law by time interaction (i.e., setting these coefficients to zero). For the second estimate, we also removed local laws. The difference between the regression-based predictions with and without the influence of the comprehensive smoking restrictions represented the associated decrease in admissions rate. To calculate the number of admissions averted, we added the difference in fitted values to the actual monthly admission rates and then converted the difference into admission numbers, taking into account both the rate and the population aged 35 years and older in the state.

RESULTS

Table 1 displays the number of AMI and stroke admissions, the annual age-adjusted admission rates per 100 000, and the number of facilities that reported each year from 1995 to 2004. The age-adjusted rates reflect a statewide average of more than 46 000 annual admissions for AMI and more than 58 000 annual stroke admissions during the 10 years of the study. A mean of 252 hospitals reported discharge information each year.

TABLE 1—Numbers and Rates of Hospital Admissions for Acute Myocardial Infarction (AMI) and Stroke: New York State, 1995–2004

Year	No. of Hospitals Reporting	No. of Admissions		Rate[a]	
		AMI	Stroke	AMI	Stroke
1995	261	44 683	58 056	493.3	641.0
1996	260	45 449	60 410	496.2	659.5
1997	255	44 961	59 323	485.3	640.3
1998	255	44 651	59 133	475.6	629.9
1999	253	45 589	58 638	479.1	616.3
2000	252	48 010	59 701	490.0	609.4
2001	251	48 015	58 732	483.0	590.9
2002	248	47 943	58 118	476.4	577.5
2003	246	47 683	56 573	469.9	557.5
2004	243	45 412	56 149	445.4	550.7

[a]Age-adjusted rate per 100 000 adjusted to 2000 US Census (aged 35 years and older).

The reduction in the number of hospitals over time was because of a net increase in the number of hospitals closing during this period.

Results of the regression analysis are reported in Table 2. The main effects for the comprehensive smoking ban and moderate smoking restrictions measured the change in the intercept of the trend line in hospital admissions. That is, they measured whether the trend line shifted up or down, without regard to any change in the slope of the line, at the time the law was enacted. Neither main effect was significant; there was no sudden reduction in the hospitalization rate associated with the implementation of these laws.

The interactions between the law indicators and time measured change in the slope of the trend line after enactment of the law. Both interaction effects were significant and negative, which indicates that enactment of moderate laws at the county level and the statewide comprehensive smoking ban were associated with an accelerated decline in monthly AMI hospitalizations in New York State. The unstandardized parameter estimate for the moderate smoking restrictions × time interaction term was –0.15 ($P<.01$), implying that enactment of a moderate smoking restriction in a county would reduce the monthly trend rate in AMI hospital admissions in that county by 0.15 per 100 000 persons per month, on average. The comprehensive smoking ban × time interaction was also significant ($P<.001$) and showed that the statewide comprehensive smoking ban was associated with a reduction in the rate of hospital admissions by an average of 0.32 per 100 000 persons per month in all counties, more than twice the reduction of the moderate smoking restrictions.

Figure 1 shows the observed number of AMI hospitalizations from January 2002 through December 2004 and the estimated number of admissions had there been no comprehensive state law enacted. From August 2003 to December 2004, the model predicts 4033 fewer AMI admissions in New York associated with the comprehensive state smoking ban over the 1989 state law and the patchwork of local laws. The reduction in 2004 alone was 3813 AMI admissions statewide, a little more than an 8% decline. The comprehensive state law was associated with a 19% decline in admissions, had there been no local laws intervening between the 1989 state law and the 2003 comprehensive law.

Estimates of cost savings accrued from the averted AMI hospital admissions were calculated on the basis of the average in-hospital cost per AMI hospitalization of $14 772.[25] After estimating the economic effect of the comprehensive law over and above prior state and local moderate laws, the resulting cost savings was $56 million in 2004 (1998 dollars).

There were no significant negative associations between the stroke admission rate and moderate or comprehensive restrictions on smoking.

DISCUSSION

Rates of hospital admissions for AMI were reduced by 8% after a comprehensive ban on smoking in work sites, including hospitality venues (e.g., bars and restaurants), in New York State. This is equivalent to a reduction of approximately 3800 AMI hospital admissions in 2004 and an estimated cost savings of $56 million. Our results show that enactment of clean indoor air laws was associated with an accelerated decline of hospital admissions and that a comprehensive statewide law had the largest effect.

TABLE 2—Interrupted Time-Series Results Predicting Monthly Hospital Admission Rates per 100 000 Population for Acute Myocardial Infarction (AMI) and Stroke as a Function of Smoking Restrictions and Secular Trends: New York State, 1995–2004

Smoking Restriction	AMI		Stroke	
	b (95% CI)	*t*	b (95% CI)	*t*
Comprehensive smoking ban	–0.80 (–2.7, 1.1)	–0.81	–1.14 (–2.6, .30)	–1.55
Comprehensive smoking ban × time interaction	–0.32*** (–.47, –.16)	–4.10	0.06 (–.06, .18)	0.94
Moderate smoking restrictions	–1.1 (–2.3, .13)	–1.75	1.3* (.26, 2.26)	2.46
Moderate smoking restrictions × time interaction	–0.15** (–.25, –.06)	–3.10	0.05 (–.03, .14)	1.30
Overall F-test (138 7301)	98.92***		65.09***	

Note. Regression models also include indicator variables for month of admission (11 variables), county (61 variables), and a time-by-county interaction (61 variables).
*$P<.05$; **$P<.01$;***$P<.001$

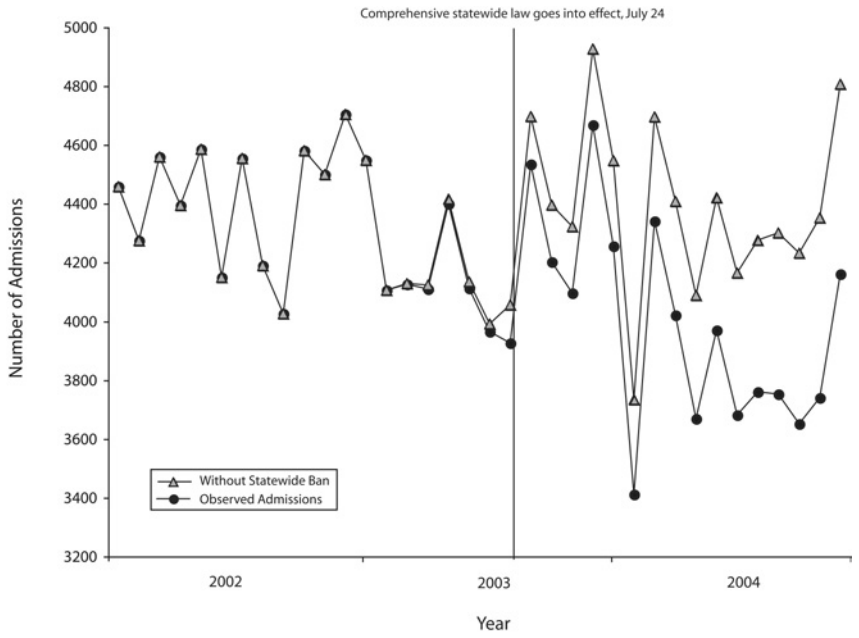

FIGURE 1—Observed number of hospital admissions for acute myocardial infarction and predicted number of hospital admissions in the absence of a comprehensive smoking ban, by month: New York State, 2002–2004.

The reduction in AMI hospital admissions we found is substantially smaller than that found in 2 previous studies conducted in Helena, Mont, (40% reduction) and Pueblo, Colo, (27% reduction). In a commentary on the Helena study, Pechacek and Babb[26] estimated that comprehensive smoking bans would likely reduce AMI admissions by a more conservative 10% to 15%.

The smaller effect size that we found is probably because of the incremental enactment of smoking bans and restrictions in New York over time and the generally modest level of environmental tobacco smoke exposure among New York residents before the implementation of the comprehensive statewide law. The first statewide restriction was passed in 1989, whereas local moderate and comprehensive laws were enacted in New York counties beginning in 1995. The 2003 statewide smoking ban superseded existing laws that offered moderate protection and coverage to a large percentage of New York's population. We measured the increased increment in protection that would be provided if a statewide comprehensive law replaced existing, more moderate local and statewide restrictions. Because of the incremental nature of the laws and specific characteristics of the database that focus on rates rather than individual patient-level data, we believe that our results represent low estimates of the relation between environmental tobacco smoke and AMI. Our results are thus consistent with the estimate of Pechacek and Babb[26] and suggest that comprehensive statewide smoking bans offer greater health protection than do more-modest smoking restrictions. Additional studies are needed to better understand the association between smoking restrictions and hospital admissions for stroke.

A weakness of this study was the inability to assess the effect of changing smoking prevalence on hospital admissions given the causal relation between active smoking and AMI. Although smoking prevalence was not available for each county and month, we repeated the analysis with quarterly statewide smoking prevalence estimates as an additional variable in the model. There was no association between hospital admissions and smoking prevalence. Smoking prevalence was relatively stable during the study period (1995 to 2004), although a downward trend began in 2000.

A lack of individual patient-level information is another weakness of this study and may have contributed to the fact that only small effects were found. Specific details about patient smoking status, exposure to environmental tobacco smoke, or other risk factors (e.g., obesity) for AMI were unknown but were summarized in the regression models to a limited extent by the time and county variables (because population rates, and not individual events, were modeled).

Our conclusions are strengthened by 2 studies that showed New York's comprehensive statewide smoking ban actually reduced opportunities for exposure to environmental tobacco smoke. Although there is limited information about the effect of moderate smoking restrictions,[27] a 2004 study of compliance with the statewide smoking ban by New York's hospitality venues showed that 93% of restaurants, bars, and bowling facilities were in compliance with the law in the year after implementation.[28] One month before the law, just 31% of these venues were smoke-free. A 2005 study of nonsmoking hospitality workers in New York showed significant reductions in saliva cotinine levels and symptoms associated with cigarette smoke exposure after the comprehensive law went into effect.[29]

Clinical implications of this and related studies are most relevant for patients who have existing cardiac conditions. Although environmental tobacco smoke exposure should be avoided by all, physicians should be particularly mindful of their cardiac patients who, if they smoke, should be advised to quit, and if they do not smoke, should be advised to avoid any exposure to environmental tobacco smoke.

Our study results support and extend previous studies to show that comprehensive smoking bans are associated with reductions in the rate of hospitalizations for AMI. Comprehensive smoking bans constitute a simple, effective intervention to substantially improve the public health. ■

About the Authors

Harlan R. Juster, Theresa M. Hinman, and Ursula E. Bauer are with the New York State Department of Health,

Albany. Brett R. Loomis and Matthew C. Farrelly are with RTI International, Research Triangle Park, NC. Andrew Hyland is with Roswell Park Cancer Institute, Buffalo, NY. Guthrie S. Birkhead is with the New York State Department of Health, Albany, and the University at Albany, School of Public Health, Rensselaer, NY.

Request for reprints should be sent to Harlan R. Juster, PhD, New York State Department of Health, Bureau of Chronic Disease Epidemiology and Surveillance, Empire State Plaza, Corning Tower, Room 565, Albany, NY 12237–0679 (e-mail: hrj01@health.state.ny.us).

This article was accepted January 22, 2007.

Contributors

H.R. Juster originated and supervised the study in its entirety. B.R. Loomis and M.C. Farrelly substantially directed the analysis and interpretation. T.M. Hinman directed data analysis and large dataset manipulation. A. Hyland, U.E. Bauer, and G.S. Birkhead participated in review of the procedures, analysis, and interpretation. All authors participated in writing, editing, and revising the article.

Acknowledgments.

This study was supported in part by the Centers for Disease Control and Prevention and the New York State Department of Health (cooperative agreement U58/CCU222783).

We thank Colleen McLaughlin for helpful discussions about the study design, Bonnie Eisenberg and Michael Zdeb for technical assistance with the Statewide Planning and Research Cooperative System database, Colleen Baker for technical assistance with the Behavioral Risk Factor Surveillance System, and James Tesoriero for helpful comments on statistical methodology.

Human Participant Protection

No protocol approval was needed for this study.

References

1. Centers for Disease Control and Prevention. Annual smoking-attributable mortality, years of potential life lost and productivity costs—United States, 1997–2001. *MMWR Morb Mortal Wkly Rep.* 2005; 54:625–628.

2. *The Health Consequences of Involuntary Exposure to Tobacco Smoke: A Report of the Surgeon General.* Atlanta, Ga: National Center for Chronic Disease Prevention and Health Promotion; 2006.

3. He J, Vupputuri S, Allen K, Prerost M, Hughes J, Whelton P. Passive smoking and the risk of coronary heart disease—a meta-analysis of epidemiologic studies. *New Engl J Med.* 1999;340:920–926.

4. Pitsavos C, Panagiotakos D, Chrysohoou C, et al. Association between exposure to environmental tobacco smoke and the development of acute coronary syndromes: the CARDIO2000 case-control study. *Tob Control.* 2002;11:220–225.

5. Whincup P, Gilg J, Emberson J, et al. Passive smoking and risk of coronary heart disease and stroke: prospective study with cotinine measurement. *BMJ.* 2004;329:200–205.

6. *The Health Consequences of Smoking: Cardiovascular Disease: A Report of the Surgeon General.* Washington, DC: US Government Printing Office; 1983. DHHS publication 84–50204.

7. *Health Effects of Exposure to Environmental Tobacco Smoke: the Report on the California Environmental Protection Agency.* Bethesda, Md: National Cancer Institute; 1999. NIH publication 99–4645.

8. Glantz SA, Parmley WW. Even a little secondhand smoke is dangerous. *JAMA.* 2001;286: 462–463.

9. Law MR, Morris JK, Wald NJ. Environmental tobacco smoke exposure and ischaemic heart disease: an evaluation of the evidence. *BMJ.* 1997;315:973–980.

10. Bonita R, Duncan J, Truelsen T, Jackson RT, Beaglehole R. Passive smoking as well as active smoking increases the risk of acute stroke. *Tobacco Control.* 1999;8:156–160.

11. Zhang X, Shu XO, Yang G, et al. Association of passive smoking by husbands with prevalence of stroke among Chinese women nonsmokers. *Am J Epidemiol.* 2005;161:213–218.

12. You R, Thrift A, McNeil J, Davis S, Donnan G. Ischemic stroke risk and passive exposure to spouses' cigarette smoking. Melbourne Stroke Risk Factor Study (MERFS) Group. *Am J Public Health.* 1999;89: 572–575.

13. Qureshi AI, Fareed M, Suri K, Kirmani JF, Divani AA. Cigarette smoking among spouses: another risk factor for stroke in women. *Stroke.* 2005;36(9):e74.

14. Glantz SA, Parmley WW. Passive smoking and heart disease: mechanisms and risk. *JAMA.* 1995;273: 1047–1053.

15. Otsuka R, Watanabe H, Hirata K, et al. Acute effects of passive smoking on the coronary circulation in healthy young adults. *JAMA.* 2001;286:436–441.

16. Sargent RP, Shepard RM, Glantz SA. Reduced incidence of admissions for myocardial infarction associated with public smoking ban: before and after study. *BMJ.* 2004;328:977–980.

17. Bartecchi B, Alsever N, Nevin-Woods C, et al. A city-wide ordinance reduces the incidence of acute myocardial infarction. Paper presented at: Scientific Sessions of the American Heart Association; November 14, 2005; Dallas, Tex.

18. Dearlove J, Glantz SA. Tobacco industry political influence and tobacco policy making in New York, 1983–1999. Available at: http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1012&context=ctcre. Accessed February 9, 2006.

19. Bauer UE. *Tobacco Use Prevention and Control Program Annual Report, 2002.* Albany: New York State Department of Health; 2002.

20. Centers for Disease Control and Prevention. Reduced secondhand smoke exposure after implementation of a comprehensive statewide smoking ban—New York, June 26, 2003–June 30, 2004. *MMWR Morb Mortal Wkly Rep.* 2007;56(28):705–708.

21. *International Classification of Diseases, Ninth Revision, Clinical Modification.* Hyattsville, Md: National Center for Health Statistics; 1980. DHHS publication PHS 80-1260.

22. US Census Bureau. *Estimates and Projections Area Methodology: County Population Estimates by Age, Sex, Race, and Hispanic Origin for July 1, 2004.* Available at: http://www.census.gov/popest/counties. Accessed October 9, 2005.

23. Heckman J, Hotz V. Choosing among alternative nonexperimental methods for estimating the impact of social programs: the case of Manpower Training. *J Am Statistical Assoc.* 1989;84:862–874.

24. Neter J, Kutner M, Nachtsheim C, Wasserman W. *Applied Linear Statistical Models.* 4th ed. New York, NY: WCB/McGraw Hill; 1996.

25. Krumholz HM, Chen J, Murillo JE, Radford MJ, Cohen DJ. Clinical correlates of in-hospital costs for acute myocardial infarction in patients 65 years of age and older. *Am Heart J.* 1998;135:523–531.

26. Pechacek TF, Babb S. Commentary: How acute and reversible are the cardiovascular risks of secondhand smoke? *BMJ.* 2004;328:980–983.

27. Hyland A, Cummings KM, Wilson MP. Compliance with the New York City Smoke-free Air Act. *J Public Health Manage Pract.* 1999;5:43–52.

28. RTI International. *First Annual Independent Evaluation of New York's Tobacco Control Program: Final Report.* Research Triangle Park, NC: RTI International; 2004.

29. Centers for Disease Control and Prevention. Indoor air quality in hospitality venues before and after implementation of a Clean Indoor Air Law—Western New York, 2003. *MMWR Morb Mortal Wkly Rep.* 2004;53(44):1038–1041.