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REDUCED ADMISSIONS FOR ACUTE MYOCARDIAL INFARCTION ASSOCIATED WITH A PUBLIC SMOKING BAN: MATCHED CONTROLLED STUDY

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ABSTRACT

There has been no research linking implementation of a public smoking ban and reduced incidence of acute myocardial infarction (AMI) among nonsmoking patients. An ex post facto matched control group study was conducted to determine whether there was a change in hospital admissions for AMI among nonsmoking patients after a public smoking ban was implemented in Monroe County compared with Delaware County, Indiana without such a ban. Poisson analysis was conducted for 44 months of hospital admissions. A significant drop occurred in the number of admissions among nonsmoking patients in Monroe County after the ban whereas a non-significant decrease in the number of admissions occurred in Delaware County. The changes in the number of smoking-patient admissions before and after the ban were not significant.

INTRODUCTION

Epidemiological studies have shown that environmental tobacco smoke (ETS), which includes both exhaled mainstream smoke and sidestream smoke from burning cigarettes, increases the risk of a myocardial infarction (Barnoya & Glantz, 2005; Centers for Disease Control and Prevention, 2002; Glantz & Parmley, 1991; He et al., 1999; Law, Morris, & Wald, 1997; National Cancer Institute, 1999; Whincup et al., 2004). The ETS is shown to cause acute changes in platelet and vascular endothelial function (Glantz & Parmley, 1995, 2001) and

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is associated with endothelial dysfunction of the coronary circulation in healthy nonsmoking young adults (Celermajer et al., 1996; Otsuka et al., 2001). Recognizing the adverse health effects of ETS, a total of 519 U.S. municipalities have put a 100% smoke-free provision in place either in workplaces, restaurants, or bars as of October 6, 2006 (American Nonsmokers' Rights Foundation, 2006). Monroe County, Indiana, enacted a public smoking ban that has been in effect for all restaurants, retail stores, and workplaces since August 1, 2003. Beginning January 1, 2005, previously exempt bars and clubs have been included in the existing smoking ban.

Despite experimental evidence of detrimental health effects of ETS and an increasing number of U.S. municipalities joining a public smoking ban, only two studies (Bartecchi et al., 2006; Sargent, Shepard, & Glantz, 2004) were conducted so far to affirm the association between the public smoking ban and reduction in heart disease morbidity and no study about such an association among nonsmokers. Sargent et al. (2004) observed a significant decrease in hospital admissions of heart attack victims among residents in Helena, Montana during the first six months following passage of an ordinance banning smoking in public places. Similar findings were observed in Pueblo, Colorado (Bartecchi et al., 2006). However, several limitations of the two studies necessitated replication of a similar yet more rigorous study.

First, the control area (outside Helena or Pueblo) was not chosen based on similarities of factors that might affect the outcome measure. The authors divided all heart patients of a hospital into either intervention area (within city limits) or control area (outside city limits) using zip codes. Although the Pueblo study added a county to the control area, it was adjacent to the intervention area. Geographical proximity between intervention and control areas in the two previous studies might have confounded the findings of the study as people could commute to other areas with or without the smoking ban. Also, the authors did not report whether or not there were any systematic differences in demographic characteristics between intervention and control area that might affect the outcome measure.

Second, the authors did not account for the effect of smoking status of heart patients in their studies. Examination of heart patients admitted to the hospital for acute myocardial infarction by their smoking status would provide more meaningful information about the effect of a public smoking ban. A significant drop in hospital admissions for acute myocardial infarction among nonsmoking patients rather than smoking patients would indicate the effectiveness of the public smoking ban much better.

Third, the two previous studies did not exclude all the patients who had prior cardiac history or percutaneous interventions, or the patients with hypertension or high cholesterol who were at a higher risk of developing heart disease than those who did not have those co-morbid conditions. The authors in the Helena study excluded only the patients who had no recent procedure that could have precipitated acute myocardial infarction, without defining "recent procedure."

The authors in the Pueblo study did not mention how they treated these patients. Because those who have prior cardiac history, hypertension, or high cholesterol are more likely to be admitted to a hospital for acute myocardial infarction than those who do not, not necessarily triggered or aggravated by ETS exposure, inclusion of these patients might have confounded the findings of the study.

Lastly, the outcome variable (hospital admissions for acute myocardial infarction) was based on a short period of a smoking ban—six months for the Helena study and 1.5 years for the Pueblo study. In particular the six months of a smoking ban in Helena was very short to reliably infer the major findings of the study to other areas. This limitation was due to the fact that Helena's smoke-free ordinance was suspended by a court order six months after the enforcement.

Hence, this study was conducted to rigorously determine whether there was a change in hospital admissions for acute myocardial infarction while a local ordinance banning smoking in public places was in effect, avoiding the limitations identified in the above.

METHODS

An ex post facto matched control group design was used. During the study period, Bloomington Hospital served almost all heart patients in Monroe County. The nearest hospital that dealt with heart patients was nearly 60 miles (96 km) away. A public smoking ban has been in effect for all restaurants, retail stores, and workplaces in Monroe County since August 1, 2003 (expanded to bars since January 1, 2005). Meticulous efforts were made to find a county without such a ban that closely matched Monroe County on the variables that might affect the outcome measure.

Selection of Control County

A control county was selected from Indiana counties that: 1) are geographically distant (at least 50 miles away) from Monroe County; 2) have no ordinance in place that bans smoking in public places; 3) have similar demographic profiles to those of Monroe County primarily in terms of population size and racial/ethnic proportions; 4) have similar median household income to that of Monroe County; and 5) have a similar heart disease mortality rate to that of Monroe County among annual deaths.

Out of a total of 92 counties (including Monroe County with a population of 120,563 and 90.1% being whites) in the State of Indiana, five counties were identified to meet the first three criteria: Tippecanoe (a population of 148,955 and 88.9% being whites); Madison (133,358, 89.9%); Delaware (118,769, 90.9%); La Porte (110,106, 86.3%); and Vigo (105,848, 90.7%) (U.S. Census Bureau, 2006a). In terms of median household income, Delaware ($34,659) and Vigo ($33,184) counties were similar to that of Monroe County ($33,311), whereas Tippecanoe ($38,652), Madison ($38,925), and La Porte ($41,430) counties were

16%-24% higher than that of Monroe County (U.S. Census Bureau, 2006a). In terms of heart disease mortality rate among annual deaths, Delaware (35.4%) and Tippecanoe (32.8%) counties were similar to that of Monroe County (33.2%), whereas Vigo (42.3%), La Porte (40.2%), and Madison (37.8%) counties were 14%-27% higher than that of Monroe County (StatsIndiana, 2006).

Thus, Delaware County was selected as the control county. Besides, Monroe County and Delaware County have similar urban population rates (76.7% vs. 76.6%), mean household income ($46,072 vs. $47,415) (U.S. Census Bureau, 2006a), and cancer mortality rates among annual deaths (23.8% vs. 24.2%) (StatsIndiana, 2006). Also, each of the two counties has a college town as the largest city (57.5% of Monroe County residents live in Bloomington whereas 56.8% of Delaware County residents live in Muncie) (U.S. Census Bureau, 2006a). During the study period, Bloomington Hospital and Ball Memorial Hospital were the only hospitals that served heart patients in Monroe County and Delaware County, respectively.

Data Collection Procedure

After obtaining the institutional review board (IRB) approval for the protocol of the study from Bloomington Hospital, Ball Memorial Hospital, and Indiana University, the investigators contacted both hospitals to enter into contracts for data collection. Due to the Health Insurance Portability and Accountability Act (HIPAA) regulations, no investigators except authorized hospital employees were allowed to get access to the patient charts. Both hospitals were asked to extrapolate the following data for all the patients with a primary or secondary diagnosis of acute myocardial infarction (ICD-9-CM (International Classification of Diseases 9th Revision Clinical Modification) codes 410.xx) admitted to each of the hospitals for the period of August 1, 2001 to May 31, 2005 except for the two months from June 1, 2003 to July 31, 2003: admission date, smoking status, co-morbidity such as hypertension and high cholesterol, past cardiac history such as angioplasty, diagnosis status, and lab values such as troponin I concentrations or creatine phosphokinase. The period from June 1, 2003 to July 31, 2003 was excluded because the same two 22-month periods (August 2001 to May 2003 vs. August 2003 to May 2005) were to be compared to control for any possible seasonal variation in the outcome measure. Both hospitals extracted patient records that contained the ICD-9-CM diagnosis codes of 410.0x through 410.9x. The first three digits (410) indicate acute myocardial infarction defined as "a sudden insufficiency of blood supply to an area of the heart muscle; usually due to a coronary artery occlusion" (Hart & Hopkins, 2005). The fourth digit indicates a specific affected location in the heart muscle. The code 1 is assigned to the fifth digit in case of an initial episode of care and code 2 is assigned in case of a subsequent episode of care. During these 44 months, there were 35,482 admissions for all causes (including acute myocardial infarction) from Monroe County and 41,640 from Delaware County.

Bloomington Hospital used a combination of paper and electronic medical records. The patient population was identified by running a query against ICD-9-CM diagnosis codes abstracted in the Hospital's clinical data database. To confirm the accuracy of the data, each source record, whether in paper or electronic form, was manually reviewed by a Bloomington Hospital employee. Ball Memorial Hospital used electronic medical records—STAR system—which was a database that included all patient medical records. The system was queried using the patient inclusion criteria the investigators provided. Then, a Ball Memorial Hospital employee reviewed each patient's individual medical record using Patient Information Management system to ensure there were no duplicates and that all information was correct. Currently both hospitals use the same STAR system. Because both hospitals used the same ICD-9-CM diagnosis codes in running a query, comparability of the two datasets is ensured. The investigators did not change any portion of the data sets provided by each of the hospitals.

Selection of Patients

Selection criteria of patients included: 1) a primary or secondary diagnosis of acute myocardial infarction (ICD-9-CM codes 410.xx); 2) no past cardiac procedure that could have precipitated acute myocardial infarction; 3) no co-morbidity such as hypertension and high cholesterol that could have precipitated acute myocardial infarction; 4) chemical evidence such as increased troponin I concentrations or creatine phosphokinase activity; and 5) onset of symptoms in the study area. For the secondary diagnosis of acute myocardial infarction, the chemical evidence had to be present at the time of admission or within the first 24 hours of admission.

Main Outcome Measures

The main outcome measure was the number of nonsmoking heart patients admitted for acute myocardial infarction who did not have any past cardiac history before the admission and did not have hypertension and high cholesterol co-morbidity for the two 22-month periods (August 2001 to May 2003 vs. August 2003 to May 2005). The same months were selected to control for any possible seasonal variation in the outcome measure. A complementary measure was the number of smoking heart patients admitted for acute myocardial infarction who did not have any past cardiac history before the admission and did not have hypertension and high cholesterol co-morbidity for the two 22-month periods.

Statistical Methods

The Poisson distribution is a discrete probability distribution and is used to model the number of events occurring within a given time interval if: 1) the occurrences of the event are independent; 2) theoretically, an infinite number of

occurrences of the event can be possible in the interval; 3) the probability of the single occurrence of the event in a given interval is proportional to the length of the interval; and 4) in any infinitesimally small portion of the interval, the probability of more than one occurrence of the event is negligible (Daniel, 2005, p. 104). As the outcome measure of this study was the number of hospital admissions due to acute myocardial infarction ("event") within a 22-month period and that no evidence of violations of the assumptions mentioned above was noted, the Poisson distribution was adopted as a test distribution. The null hypothesis that the number of hospital admissions due to acute myocardial infarction was equal between the two 22-month periods within and across the counties was tested by examining 95% confidence intervals using Poisson analysis as the outcome measure was count data in equal time periods (Fleiss, Levin, & Paik, 2003, p. 344).

RESULTS

As is shown in Table 1, in Monroe County there was a significant drop (–12 admissions from 17 to 5; 95% confidence interval [CI] = –21.19 to –2.81) in the number of nonsmoking patient admissions for acute myocardial infarction from Period 1 (August 2001 to May 2003) to Period 2 (August 2003 to May 2005) during which the smoke-free law was in effect. In Delaware County, there was a non-significant drop (–2 admissions from 18 to 16; 95% CI = –13.43 to 9.43) in the number of nonsmoking patient admissions between Period 1 and Period 2.

Although there was no significant difference in nonsmoking patient admissions between Monroe County and Delaware County for Period 1 during which none of the counties implemented a public smoking ban (17 vs. 18), there was a significant difference in nonsmoking patient admissions between the two counties for Period 2 during which Monroe County enforced a public smoking ban ordinance (5 vs. 16). Interestingly, no admissions for acute myocardial infarction among non-smoking people have been observed in Monroe County since January 1, 2005 when the existing smoking ban was expanded to previously exempt bars and clubs.

Table 1. Nonsmoking Patient Admissions Without Past Cardiac History, Hypertension, and High Cholesterol[a]

Area	Period		Difference (95% CI)
	Aug. 2001 to May 2003	Aug. 2003 to May 2005	
Monroe County	17	5	–12 (–21.19 to –2.81)
Delaware County	18	16	–2 (–13.43 to 9.43)
Difference (95% CI)	1 (–10.60 to 12.60)	11 (2.02 to 19.98)	

[a]All comparisons were conducted assuming Poisson distribution.

Table 2. Smoking Patient Admissions Without Past Cardiac History, Hypertension, and High Cholesterol[a]

Area	Period		Difference (95% CI)
	Aug. 2001 to May 2003	Aug. 2003 to May 2005	
Monroe County	8	7	–1 (–8.59 to 6.59)
Delaware County	8	6	–2 (–9.33 to 5.33)
Difference (95% CI)	0	1 (–6.07 to 8.07)	

[a]All comparisons were conducted assuming Poisson distribution.

As is shown in Table 2, in both counties, there was a non-significant drop in the number of smoking patient admissions for acute myocardial infarction from Period 1 to Period 2.

DISCUSSION

This study was the first attempt to examine the effect of a public smoking ban on the number of hospital admissions for acute myocardial infarction among nonsmoking patients using an ex post facto design that allows exploration of a possible causal relationship among variables that cannot be manipulated by the investigator (McMillan & Schumacher, 2001). During the implementation of an ordinance banning smoking in public places in Monroe County, a significant drop was observed in admissions for acute myocardial infarction among nonsmoking patients while such a drop was not observed in the control area. This indicates that a public smoking ban may help decrease the number of heart attacks, supporting previous findings (Bartecchi et al., 2006; Sargent, Shepard & Glantz, 2004).

It is notable that there was no significant change in the number of admissions for acute myocardial infarction among smoking patients between the two time periods in Monroe County as well as in Delaware County. Also, no admissions for acute myocardial infarction among nonsmoking patients have been observed in Monroe County since January 1, 2005 when the existing smoking ban was expanded to previously exempt bars and clubs, although the study examined admissions only until May 31, 2005. This indicates that health benefits of reduced incidences of myocardial infarction due to implementation of a public smoking ban might occur more through reduced exposure to ETS among nonsmokers than through reduced consumption of tobacco or quitting among smokers. Further research is desirable to confirm this finding especially as this study was the first attempt to reveal the association among nonsmoking victims.

According to the U.S. Census Bureau's estimate (U.S. Census Bureau, 2006b, 2006c), there has been a small change in the population sizes between 2000 and

2004. The total population increased by 0.4% in Monroe County from 120,563 to 121,013 and decreased by 0.8% in Delaware County from 118,769 to 117,774. There is no reason to believe that these slight changes in the population sizes might have affected the findings of this study. If there had been any effect of the small change in the population size, it would have biased the results toward the null (no decrease in the number of admissions in Monroe County during Period 2). A significant reduction was detected in the number of nonsmoking patient admissions in Monroe County despite an increase in its population size, whereas such a significant reduction was not observed in Delaware County where the population size decreased.

There are several important aspects of this study. First, the control county was very similar to the intervention county on many important aspects: similar population size, racial/ethnic proportions, number of households, characteristics and size of the largest city (a college town) within each county, urban population rates, and both median and mean household income levels. The two counties were also similar to each other in heart disease mortality rates and cancer mortality rates among annual deaths. Second, both areas were relatively isolated areas with a single hospital in each area that served all admissions for acute myocardial infarction. Third, the confounding factors such as geographical proximity between intervention and control areas and failure to account for patients' smoking status, past cardiac history, and co-morbidity that affect the likelihood of developing heart disease were controlled. Lastly, although it was required by the HIPAA, the investigators did not access the patient charts. All the data were extrapolated by hospital employees. Therefore, there was no room for subjective judgment for inclusion of cases into the data set. All of these design controls are imperative to be able to attribute observed changes in admissions for acute myocardial infarction to the implementation of a public smoking ban.

Although the current study examined admissions for 22 months of a public smoking ban, the total number of analyzed admissions was small. This can be a limitation of this study. Further research that evaluates the effect of a longer implementation of such a ban is desirable to confirm the findings of this study. Another limitation of this study is that the results of this study might have been affected by some unobserved confounding variables although no evident history bias was noticed during the study time period. The only conspicuous event that might be related to this study was observed in Delaware County. There were a lot of discussions and debate in Delaware County in 2005 about adopting a public smoking ban ordinance, which led Delaware County to enact the ordinance on February 21, 2006, effective from July 15, 2006. The investigators do not believe the debate had a significant effect on the results of this study because the majority of the debate occurred after May 2005 although sporadic local media's coverage of public smoking bans enforced by other municipalities might have affected some residents' behavior. If there had been any effect of the debate, it would have biased the results toward the finding of a decrease in the number of admissions in

Delaware County during Period 2 because of the public's increased awareness of ETS exposure, which further strengthens the finding of this study.

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