

Reduced incidence of acute myocardial infarction in the first year after implementation of a public smoking ban in Graubünden, Switzerland

Lukas D. Trachsel^a, Max U. Kubn^{a,b}, Walter H. Reinhart^a, Thomas Schulzki^{a,c}, Piero O. Bonetti^{a,d}

^a Department of Internal Medicine, Kantonsspital Graubünden, Chur, Switzerland

^b Division of Pneumology, Kantonsspital Graubünden, Chur, Switzerland

^c Blood Transfusion Service SRC, Kantonsspital Graubünden, Chur, Switzerland

^d Division of Cardiology, Kantonsspital Graubünden, Chur, Switzerland

Summary

Objective: On March 1st, 2008 a smoking ban in public buildings became effective in the Canton of Graubünden, Switzerland. The aim of our study was to investigate, whether implementation of this new regulation was followed by a decrease in the incidence of acute myocardial infarction (AMI).

Patients and methods: The Kantonsspital Graubünden serves as a tertiary care hospital, possessing the only cardiac catheterization laboratory in the Canton of Graubünden. Based on an excellent functioning network including all hospitals in the Canton of Graubünden, virtually all patients experiencing an AMI in the Canton of Graubünden are transferred to our hospital for either acute or early coronary angiography. Data of all patients with AMI undergoing coronary angiography at our hospital between March 1st, 2008 and February 28th, 2009 were collected prospectively. The data were then compared with those of the two corresponding 12-month periods preceding implementation of the public smoking ban.

Results: In the two years before adoption of

smoke-free legislation, the number of patients with AMI was 229 and 242, respectively ($p = \text{ns}$). In the 12 months after implementation of the public smoking ban, the number of AMI patients dropped to 183 ($p < 0.05$ vs. each of the previous 12-month periods), representing an overall 22% reduction in the AMI incidence within the first year after enactment of the new regulation. This reduction was driven by a significant decrease in the AMI incidence in men, nonsmokers, and individuals with established coronary artery disease, including those with prior AMI or prior percutaneous coronary intervention.

Conclusions: Similar to other countries in Europe and various regions of the USA and Canada, implementation of a public smoking ban was followed by a significant early decline in the incidence of AMI in the Canton of Graubünden, Switzerland.

Key words: smoking ban; secondhand smoke; myocardial infarction

Introduction

Smoking represents one of the largest modifiable risk factors for coronary artery disease (CAD). In addition, current evidence suggests that exposure of nonsmokers to secondhand smoke is also associated with a significant increase in the risk of CAD [1–3]. Recently, implementation of regulations banning smoking in public buildings was shown to lead to a significant and rapid decline in the total number of hospital admissions for acute coronary syndromes in several countries, including Italy, Scotland and some regions of the USA and Canada [4–15]. However, despite the present evidence supporting the beneficial effect of regu-

lations banning smoking in public places, enactment of such legislation is still heavily disputed.

The Canton of Graubünden adopted smoke-free legislation by popular vote on November 25th, 2007, and therefore became one of the first regions in Switzerland to do so. Accordingly, on March 1st, 2008 a smoking ban in public buildings, including cafés, bars, and restaurants, became effective in the Canton of Graubünden. The aim of the present study was to assess whether implementation of this new regulation was followed by an early change in the incidence of acute myocardial infarction (AMI).

There is no conflict of interest for any of the authors. The present study was funded by the Department of Internal Medicine, Kantonsspital Graubünden, Chur, Switzerland.

Patients and methods

Setting

The Canton of Graubunden is the largest Canton of Switzerland covering an area of 7106 km². In contrast, with a resident population of 188 000 Graubunden represents the Canton with the lowest population density in Switzerland. However, because of its unique landscape Graubunden is the largest holiday destination of the country, offering a multitude of recreational activities in all seasons. Hence, a total of ≈6 million visitor overnight stays are recorded in Graubunden every year. Based on the large number of visitors, the population of the Canton of Graubunden may almost double during the holiday season.

The Kantonsspital Graubunden serves as a tertiary care hospital possessing the only cardiac catheterization laboratory in the Canton of Graubunden. The Kantonsspital Graubunden provides a 24-hour emergency service for primary percutaneous coronary intervention (PCI) in patients with AMI. Based on an excellent functioning network including all hospitals in the Canton of Graubunden and excellent transportation capacities, either by ambulance or by helicopter, all patients experiencing an AMI in the Canton of Graubunden are transferred to our hospital for either acute or early coronary angiography. Although primary PCI represents the therapy of choice in patients with ST-elevation myocardial infarction (STEMI) in our Canton, a few STEMI patients are treated with intravenous thrombolysis in more distant secondary care hospitals, particularly when weather conditions preclude rapid patient transfer by helicopter. However, patients also undergoing successful thrombolytic therapy are subsequently transferred to the Kantonsspital Graubunden for secondary coronary angiography before hospital discharge. Thus, in general, all patients suffering from an AMI in the Canton of Graubunden undergo coronary angiography at the Kantonsspital Graubunden.

Study population

Data of all patients suffering from an AMI in the Canton of Graubunden and undergoing coronary angiography at the Kantonsspital Graubunden, within the first year after implementation of the public smoking ban (between March 1st, 2008 and February 28th, 2009), were collected prospectively. The data were then compared with those of all patients who suffered from an AMI in the Canton of Graubunden and underwent coronary angiography at our hospital during the two corresponding 12-month time periods preceding implementation of the public smoking ban (between March 1st, 2006 and February 28th, 2007, and between March 1st, 2007 and February 29th, 2008, respectively), whereby these patients were identified by their diagnoses at hospital discharge (ICD-10 codes) and by analyzing various local databases (coronary angiography database, intensive care unit database). Patients who suffered from an AMI outside the Canton of Graubunden but were treated at the Kantonsspital Graubunden were excluded from our analysis. According to the universal definition of myocardial infarction, AMI was defined as a detectable level of cardiac troponin in a clinical setting consistent with myocardial ischemia [16]. Based on changes of the ST segment, patients were further classified as having STEMI or non-ST-elevation myocardial infarction (NSTEMI) [16, 17]. Patients in whom further examination revealed a non-coronary etiology of symptoms, laboratory findings and/or electrocardiographic changes (e.g. pericarditis) were not included in the present analysis.

Statistical analysis

In order to compare the numbers of AMI cases between the three 12-month time periods, 2×2 tables were set up to check for equal distribution. One-way analysis of variance (ANOVA) for continuous data and χ^2 test for categorical data were used to compare differences regarding patient characteristics between the populations before

Table 1

Characteristics of the study population in the two years before (3/2006-2/2007 and 3/2007-2/2008) and the year after (3/2008-2/2009) implementation of the public smoking ban.

		3/2006-2/2007 Before smoking ban (n = 229)	3/2007-2/2008 Before smoking ban (n = 242)	3/2008-2/2009 After smoking ban (n = 183)	P-value
Age (years)		66 ± 12	66 ± 11	65 ± 11	0.60
Age groups	<45 years	10 (4)	8 (3)	8 (4)	0.78
	45-65 years	98 (43)	95 (39)	80 (44)	
	>65 years	121 (53)	139 (58)	95 (52)	
Men		171 (75)	182 (75)	134 (73)	0.89
Women		58 (25)	60 (25)	49 (27)	
Residents		168 (73)	177 (73)	133 (73)	0.99
Non-residents		61 (27)	65 (27)	50 (27)	
Smoking status	Nonsmokers	151 (66)	160 (66)	109 (60)	0.30
	Smokers	78 (34)	82 (34)	74 (40)	
Other cardiac risk factors	Arterial hypertension	128 (56)	127 (52)	103 (56)	0.67
	Hyperlipidemia	169 (74)	183 (76)	128 (70)	0.42
	Diabetes mellitus	28 (12)	34 (14)	25 (14)	0.83
Documented CAD		65 (28)	66 (27)	33 (18)	0.03
Prior AMI		44 (19)	48 (20)	20 (11)	0.03
Prior PCI		45 (20)	48 (20)	25 (14)	0.19
Prior CABG		14 (6)	16 (7)	15 (8)	0.69

Data are presented as mean ± SD or numbers (%) of patients.

CAD: coronary artery disease; AMI: acute myocardial infarction; PCI: percutaneous coronary intervention; CABG: coronary artery bypass graft.

and after implementation of the public smoking ban. A *p*-value of <0.05 was considered statistically significant.

Statistical analyses were performed using STATISTICA software, version 8.0 (StatSoft Inc., Tulsa, OK, USA).

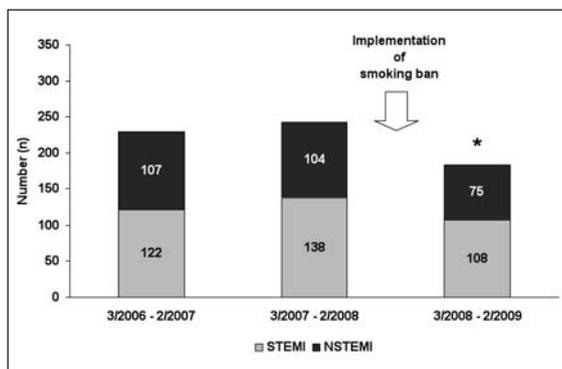
Results

In the two 12-month periods before implementation of the public smoking ban, a similar number of patients with AMI underwent coronary angiography at the Kantonsspital Graubunden (229 vs. 242; *p* = not significant). In the 12 months after adoption of smoke free legislation, the

number of AMI patients dropped significantly to a total of 183 (fig. 1). Thus, when taking the average of the two years preceding implementation of the smoking ban, an overall 22% reduction in the incidence of AMI was observed in the first year after the public smoking ban became effective. This reduction was due to a similar decrease in the number of patients with both STEMI and NSTEMI (fig. 1).

Figure 1

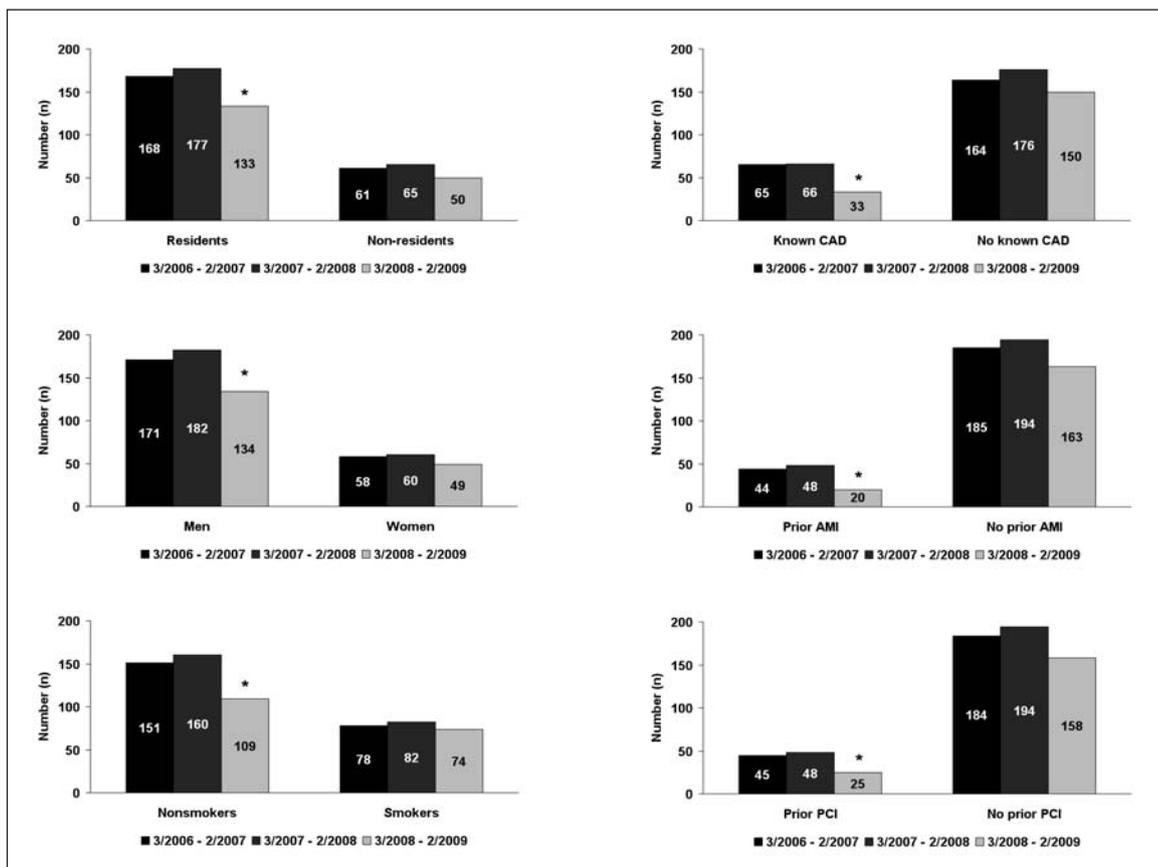
Numbers of patients with ST-elevation myocardial infarction (STEMI) and non-ST-elevation myocardial infarction (NSTEMI) in Graubunden in the two years before (3/2006-2/2007 and 3/2007-2/2008) and the year after (3/2008-2/2009) implementation of a public smoking ban. The reduction of the overall myocardial infarction incidence observed after adoption of smoke-free legislation was caused by a similar decrease in the incidence of STEMI and NSTEMI.
* *p* <0.05 vs. each of the two previous 12-month periods.



Baseline characteristics of the study population are shown in table 1. Compared with the two preceding years, the number of residents and non-residents with AMI decreased by 25% and 21%, respectively, following implementation of the public smoking ban. Thus, the pre- and the post-ban proportions of patients with AMI were identical in both the resident and the non-resident population. However, a statistically significant reduction in AMI incidence after introduction of the smoking ban was observed only in the resident population, which accounted for almost three quarters of all AMI patients in the three studied time periods (fig. 2). In the first twelve months after adoption of smoke-free legislation, AMI rate in men dropped significantly by 24% when compared with the two previous years. In contrast, the number of female AMI patients, who made up one

Figure 2

Numbers of patients with acute myocardial infarction (AMI) in various populations in the two years before (3/2006-2/2007 and 3/2007-2/2008) and the year after (3/2008-2/2009) implementation of a public smoking ban. * *p* <0.05 vs. each of the two previous 12-month periods. CAD: coronary artery disease; AMI: acute myocardial infarction; PCI: percutaneous coronary intervention.



quarter of all AMI cases, showed a non-significant 17% decrease in the same time period (fig. 2). Also, in the first year after the public smoking ban became effective, the incidence of AMI in non-smokers was significantly lower (30% reduction) than in the two years before, whereas smokers

showed similar AMI rates before and after implementation of the ban (fig. 2). Finally, following adoption of smoke-free legislation, AMI rates fell significantly by 50% in patients with established CAD, including those with prior AMI (57% reduction) or prior PCI (46% reduction) (fig. 2).

Discussion

In contrast to the well known association between smoking and the risk of fatal and non-fatal CAD, the fact that exposure to secondhand smoke increases the risk of CAD in nonsmokers by up to 30% is less well appreciated [2]. For the first time in Switzerland, the present study demonstrates a significant decrease in the incidence of AMI, within the first year, after reducing the general population's exposure to secondhand smoke by implementation of a smoking ban in public buildings.

Our results, showing a 22% reduction in the incidence of AMI after adoption of smoke-free legislation, are in line with those reported in several other countries, where smoke-free policies have been introduced earlier [4–15]. A recently published meta-analysis, which included all of the currently published, peer-reviewed original articles on the impact of public smoking bans on the incidence of acute coronary syndromes, concluded that such bans are associated with a 17% overall reduction in the risk of AMI [18]. Moreover, the authors noted that the beneficial effect of smoking bans on AMI incidence grows with time, resulting in an additional decrease in the AMI incidence of 26% with each year of post-ban observation. Consistent with these findings, another recent meta-analysis on the same topic concluded that implementation of smoke-free legislation may lead to a ~15% drop in AMI incidence during the first year and a continuing exponential decline, reaching ~36% after three years [19].

~Graubuenden is a well known holiday destination, recording a total of ~6 million visitor overnight stays every year. Therefore, it is not surprising that non-residents made up more than one quarter of all AMI cases in our study. Notably, when compared with the resident population, non-residents showed only a slightly lower proportional decrease in the incidence of AMI after implementation of the public smoking ban (-21% vs. -25%). However, given the relatively small number of non-residents, this reduction did not reach statistical significance. Hence, the overall decrease in the incidence of AMI observed after adoption of smoke-free legislation was mainly driven by a reduction of the number of resident AMI patients. Nevertheless, the equal percentage of non-residents in the pre- and the post-ban period suggests that not only residents but also non-residents benefited from the public smoking ban. Based on this observation, it may be speculated

that not only a long-term but even a short-term reduction of secondhand smoke exposure may result in a beneficial effect on coronary health.

The reduction in the rate of AMI observed after the introduction of smoke-free legislation in the present study was largely caused by a decrease in the incidence of AMI in men, who accounted for three quarters of all AMI cases. Similar results were reported by investigators in Rome, Italy and in the Italian 4 regions study [5, 6]. In contrast, in another Italian study of the Piedmont region and in a Scottish study women experienced a larger decrease in AMI rates than men following implementation of a public smoking ban [4, 7]. For now, the reasons for these contradictory results remain unclear. It has been suggested that a greater benefit in men might be attributed to their higher prevalence of smoking, allowing for a larger percentage to quit [18]. On the other hand, data from Scotland showing a greater post-ban reduction in serum cotinine levels in nonsmoking women compared with men suggest a more pronounced reduction in secondhand smoke exposure in women than in men [7]. In addition, the relative risk associated with smoking seems to be greater in women [18].

In the present study, the reduction in the rate of AMI observed after introduction of the smoking ban in public buildings was essentially restricted to nonsmokers. This observation is consistent with findings in Scotland, where nonsmokers accounted for a total of 67% of the decrease in the number of admissions with acute coronary syndromes observed after implementation of a smoking ban [7]. Similarly, investigators in Monroe County, Indiana, USA reported a 70% decline in AMI incidence in nonsmokers compared with no change among smokers after adoption of smoke-free legislation [12]. Together with these data, our results suggest that smoke-free policies achieve their primary aim of protecting nonsmokers from secondhand smoke.

To our knowledge, the present study is the first to demonstrate that individuals with established CAD might particularly benefit from public smoking bans. Indeed, among patients with known CAD we observed a 50% drop in AMI incidence during the first year of the ban. Notably, this decrease was most pronounced in patients with a history of a previous myocardial infarction. Thus, given that the prevalence of vulnerable atherosclerotic plaques is higher in patients with prior myo-

cardial infarction [20], it can be speculated that secondhand smoke exposure may be particularly hazardous for this population by triggering further destabilization and rupture of preexisting vulnerable plaques.

The mechanisms by which secondhand smoke may increase the risk of acute coronary syndromes are thought to include platelet activation, induction of endothelial dysfunction, increase in arterial stiffness, enhanced oxidative stress, reduced antioxidant defense, induction of inflammation, decreased parasympathetic output, and an increase in insulin resistance [2, 21, 22]. Notably, most of these detrimental effects are observed at very low exposure doses and occur within minutes or hours after exposure to secondhand smoke. This might explain why the beneficial effects of smoking bans seem to be rapid, with declines in AMI rates within 3 months in certain regions [6]. However, although implementation of public smoking bans is associated with a significant decrease in overall secondhand smoke exposure [7], it should be noted that such regulations can also affect the magnitude and prevalence of active smoking. Indeed, it has been demonstrated that introduction of smoking laws is followed by a decrease in cigarette consumption in those who continue to smoke but also by an increase in the proportion of people who quit smoking, resulting in a reduction of smoking prevalence [23].

Given the aforementioned deleterious effects of secondhand smoke on vascular health, it appears plausible that the significant decrease in the incidence of AMI observed after realization of a public smoking ban in the Canton of Graubünden represents the consequence of the population's reduction in secondhand smoke exposure. However, the proof of causality between smoke-free legislation and reduced AMI rate represents one of the major limitations of studies on this topic, including the current study. It has been argued, that the decrease in the incidence of AMI observed after implementation of public smoking bans could just mirror a temporal trend [24]. In the case of AMI, variation of the size of the population at risk, random variability of the number of AMI patients over a specific period of time, and promotion of other preventive measures such as the use of lipid-lowering therapy are factors that may affect incidence over time. In this regard, it should be noted that the size of the resident population in the Canton of Graubünden was similar in all three analyzed 12-month time periods, as was the number of non-residents as assessed by the number of visitor overnight stays. In order to minimize a potential confounding effect of random temporal case variability on our results, we assessed the numbers of AMI patients in the two consecutive years preceding the ban. Remarkably, the number of patients with AMI was virtually identical in the two pre-ban years. Thus, the lack of considerable variability in the numbers of patients experiencing an AMI in the two years before

the ban and the magnitude of the decrease in the AMI frequency after the ban argue against a "natural" temporal trend towards a lower rate of AMI in the present study. In contrast, an increase in the use of lipid-lowering drugs during the study period might represent an issue. Indeed, since 2006, sales figures of lipid-lowering drugs increased gradually by about 9% every year in the Canton of Graubünden. However, the temporal course of AMI incidence showing a stable (or even slightly increasing) number of AMI patients in the two pre-ban 12-month periods followed by an abrupt 22% drop within the first year after adoption of smoke-free legislation, contrasts with the linear increase in the use of lipid-lowering drugs in Graubünden during the entire study period. Thus, although wider use of lipid-lowering drugs might have contributed to some decline in the frequency of AMI in our study, the obvious temporal coincidence between implementation of the public smoking ban and the drop in the AMI rate on the one hand and the lack of a temporal relationship between increased lipid-lowering drug consumption and AMI incidence on the other, argue against a major impact of lipid-lowering therapy on the results of the present study. Further support for a substantial beneficial effect of public smoking bans, stems from five studies which used comparison sites without smoking laws [7-9, 12, 13]. Although in some of these studies, non-ban areas showed some decrease in AMI incidence, too, these reductions were always much smaller than those observed in sites with smoking bans. Finally, the consistency in the findings of several studies performed worldwide on this topic and the results of two recently published meta-analyses represent strong arguments for a substantial preventive effect of public smoking bans on the risk of AMI [4-15, 18, 19].

In summary, although a recent study demonstrated that the prognosis of patients with AMI has improved significantly within the last years in Switzerland [25], primary prevention of AMI should be our primary goal. In the present study, for the first time in Switzerland, but similar to other countries, we were able to observe a significant decrease in the incidence of AMI within the first 12 months after implementation of a public smoking ban. Collection of further data from patients with AMI in the future will help to determine, whether this decrease indeed represents a true consequence of the population's reduction in secondhand smoke exposure or merely a temporal trend in the incidence of AMI. In the former case, implementation of a public smoking ban could be regarded as an effective means to reduce the risk of AMI in the general population.

Correspondence:

Piero O. Bonetti, MD, Division of Cardiology,
Kantonsspital Graubünden, Loëstrasse 170,
CH-7000 Chur, Switzerland
E-Mail: piero.bonetti@ksgr.ch

References

- Teo KK, Ounpuu S, Hawken S, Pandey MR, Valentin V, Hunt D, et al. on behalf of the INTERHEART Study Investigators. Tobacco use and risk of myocardial infarction in 52 countries in the INTERHEART study: a case-control study. *Lancet*. 2006;368(9536):647–58.
- Barnoya J, Glantz SA. Cardiovascular effects of secondhand smoke: nearly as large as smoking. *Circulation*. 2005;111(20):2684–98.
- He J, Vupputuri S, Allen K, Prerost MR, Hughes J, Whelton PK. Passive smoking and the risk of coronary heart disease - a meta-analysis of epidemiologic studies. *N Engl J Med*. 1999;340(12):920–6.
- Barone-Adesi F, Vizzini L, Merletti F, Richiardi L. Short-term effects of Italian smoking regulation on rates of hospital admission for acute myocardial infarction. *Eur Heart J*. 2006;27(20):2468–72.
- Cesaroni G, Forastiere F, Agabiti N, Valente P, Zuccaro P, Perucci CA. Effect of the Italian smoking ban on population rates of acute coronary events. *Circulation*. 2008;117(9):1183–8.
- Vasselli S, Papini P, Gaelone D, Spizzichino L, De Campora E, Gnani R, et al. Reduction incidence of myocardial infarction associated with a national legislative ban on smoking. *Minerva Cardioangiol*. 2008;56(2):197–203.
- Pell JP, Haw S, Cobbe S, Newby DE, Pell AC, Fischbacher C, et al. Smoke-free legislation and hospitalizations for acute coronary syndrome. *N Engl J Med*. 2008;359(5):482–91.
- 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(7446):977–80.
- Bartecchi C, Alsever RN, Nevin-Woods C, Thomas WM, Estacio RO, Bartelson BB, et al. Reduction in the incidence of acute myocardial infarction associated with a citywide smoking ordinance. *Circulation*. 2006;114(14):1490–6.
- Centers for Disease Control and Prevention. Reduced hospitalizations for acute myocardial infarction after implementation of a smoke-free ordinance. City of Pueblo, Colorado, 2002–2006. *MMWR Morb Mortal Wkly Rep*. 2009;57(51):1373–7.
- Juster HR, Loomis BR, Hinman TM, Farrelly MC, Hyland A, Bauer UE, et al. Declines in hospital admissions for acute myocardial infarction in New York State after implementation of a comprehensive smoking ban. *Am J Public Health*. 2007;97(11):2035–9.
- Seo DC, Torabi MR. Reduced admissions for acute myocardial infarction associated with a public smoking ban: matched controlled study. *J Drug Educ*. 2007;37(3):217–26.
- Khuder SA, Milz S, Jordan T, Price J, Silvestri K, Butler P. The impact of a smoking ban on hospital admissions for coronary artery disease. *Prev Med*. 2007;45(1):3–8.
- Lemstra M, Neudorf C, Opondo J. Implications of a public smoking ban. *Can J Public Health*. 2008;99(1):62–5.
- Meyers DG, Neuberger JS. Cardiovascular effect of bans on smoking in public places. *Am J Cardiol*. 2008;102(10):1421–4.
- Thygesen K, Alpert JS, White HD on behalf of the joint ESC/ACC/AHA/WHF Task Force for the Redefinition of Myocardial Infarction. Universal definition of myocardial infarction. *Eur Heart J*. 2007;28:2525–38 and *Circulation*. 2007;116(22):2634–53.
- The Joint European Society of Cardiology/American College of Cardiology Committee. Myocardial infarction redefined – A consensus document of The Joint European Society of Cardiology/American College of Cardiology Committee for the Redefinition of Myocardial Infarction. *Eur Heart J*. 2000;21(18):1502–13 and *J Am Coll Cardiol*. 2000;36(3):959–69.
- Meyers DG, Neuberger JS, He J. Cardiovascular effect of bans on smoking in public places. *J Am Coll Cardiol*. 2009;54(14):1249–55.
- Lightwood JM, Glantz SA. Declines in acute myocardial infarction after smoke-free laws and individual risk attributable to secondhand smoke. *Circulation*. 2009;120(14):1373–9.
- Naghavi M, Libby P, Falk E, Casscells SW, Litovsky S, Rumberger J, et al. From vulnerable plaque to vulnerable patient: a call for new definitions and risk assessment strategies: Part I. *Circulation*. 2003;108(14):1664–72.
- Pechacek TF, Babb S. How acute and reversible are the cardiovascular risks of secondhand smoke? *BMJ*. 2004;328(7446):980–3.
- Otsuka R, Watanabe H, Hirata K, Tokai K, Muro T, Yoshiyama M, et al. Acute effects of passive smoking on the coronary circulation in healthy young adults. *JAMA*. 2001;286(4):436–41.
- Fichtenberg CM, Glantz SA. Effect of smoke-free workplaces on smoking behaviour: systematic review. *BMJ*. 2002;325(7357):188.
- Gasparrini A, Gorini G, Barchielli A. On the relationship between smoking bans and incidence of acute myocardial infarction. *Eur J Epidemiol*. 2009: in press (published online: 01 August 2009).
- Stolt Steiger V, Goy JJ, Stauffer JC, Radovanovic D, Duvoisin N, Urban P, et al. Significant decrease in in-hospital mortality and major adverse cardiac events in Swiss STEMI patients between 2000 and December 2007. *Swiss Med Wkly*. 2009;139(31–32):453–7.