Reductions in Injury Crashes Associated With Red Light Camera Enforcement in Oxnard, California

Richard A. Retting, MS, and Sergey Y. Kyrychenko, MS

Objectives. This study estimated the impact of red light camera enforcement on motor vehicle crashes in one of the first US communities to employ such cameras—Oxnard, California.

Methods. Crash data were analyzed for Oxnard and for 3 comparison cities. Changes in crash frequencies were compared for Oxnard and control cities and for signalized and nonsignalized intersections by means of a generalized linear regression model.

Results. Overall, crashes at signalized intersections throughout Oxnard were reduced by 7% and injury crashes were reduced by 29%. Right-angle crashes, those most associated with red light violations, were reduced by 32%; right-angle crashes involving injuries were reduced by 68%.

Conclusions. Because red light cameras can be a permanent component of the transportation infrastructure, crash reductions attributed to camera enforcement should be sustainable. (*Am J Public Health.* 2002;92:1822–1825)

Each year in the United States more than 800 people die and an estimated 200 000 are injured in crashes that involve red light running.[1] Red light cameras can help reduce red light running by automatically photographing vehicles whose drivers run red lights. A red light camera system is connected to a traffic signal and to sensors that monitor traffic flow. The system continuously monitors the traffic signal, and the camera itself is triggered by any vehicle passing over the sensors beyond both a preset minimum speed and a specified time after the signal has turned red. The camera records the date, time of day, time elapsed from the beginning of the red signal, and the speed of the vehicle. Tickets typically are issued to owners of violating vehicles, based on review of the photographic evidence. To date, approximately 50 communities in the United States have implemented red light camera enforcement.

Red light camera enforcement is very effective in reducing red light violations. For example, in both Oxnard, California, and Fairfax, Virginia, violations due to red light running dropped by about 40% during the first year of camera enforcement.[2,3] In both cities, reductions in red light violations were nearly identical at intersections equipped and not equipped with red light cameras, suggesting that camera enforcement produces general changes in motorists' behavior rather than simply encouraging drivers to obey traffic signals at specific locations. Similar reductions in red light violations following implementation of camera enforcement were reported in Australia,[4] Singapore,[5] and the United Kingdom.[6]

Less is known, however, about the impact of red light camera enforcement on crashes, the outcome of primary interest. Such enforcement would be expected to reduce the frequency of right-angle collisions—the principal type of crash associated with red light running—at signalized intersections. Also, some additional rear-end crashes might result from nonuniform changes in driver behavior. For example, drivers, if they stop more often for red lights, may be struck from behind by drivers not intending to stop.

Rocchi and Hemsing[7] identified numerous anecdotal and unpublished reports on reductions in right-angle or "red light running related" crashes following implementation of red light camera enforcement; reported reductions ranged from 10% in New York City to 88% in Essex, United Kingdom. In Australia, where red light cameras have been in use for about 20 years, controlled studies in Melbourne, Sydney, and Victoria have generally reported reductions in right-angle crashes that range from 32% to 50%.[8–10] Moderate increases in rear-end crashes have been reported in Sydney and Victoria but not in Melbourne.

The purpose of this study was to estimate the impact of red light camera enforcement on intersection crashes in Oxnard, California, one of the first US communities to employ such cameras.

METHODS

Changes in the number of motor vehicle crashes were evaluated in Oxnard, which had as estimated population of 156,372 in 1999 and a land area of 24.4 square miles.[11,12]

A statewide red light camera law took effect in California in January 1996, permitting municipal governments to establish local red light camera enforcement programs. Under this California law, a vehicle driver who runs a red light, if sufficiently identified, is charged with a moving violation. Front photography is used to capture a likeness of the driver and the vehicle's front license plate (if present). In cases in which the sex and estimated age of the photographed driver match those of the registered vehicle owner, the owner is presumed to be the driver and is issued a ticket by mail (the registered owner is permitted to rebut this presumption in court). Under California law, citations issued through red light camera enforcement programs carry the same monetary penalties and license sanctions as those resulting from conventional police traffic stops—currently $271 and 1 driver's license demerit point.

A 30-day warning period, during which red light cameras photographed violators but no tickets were issued, preceded red light camera enforcement in Oxnard. As required by state law, signs advising motorists of photo enforcement of traffic signal laws were posted on major roadways at numerous locations, including entrances to the city. In addition, city officials attempted to publicize and generate awareness of the new program by issuing a

press release and providing information to local media. Also, postcards were mailed to Oxnard residents during the warning period to alert them to the new program.

Actual enforcement began on July 1, 1997. Of approximately 125 intersections in Oxnard with traffic signals, 11 intersections were equipped with red light cameras. At each camera location, only 1 of the typical 4 approaches to an intersection was monitored.

Controls

Three California cities that did not implement red light camera enforcement during the study period were used as controls to eliminate potentially confounding external factors that might affect the frequency of motor vehicle crashes, such as economic conditions, fuel prices, and weather. The cities of Bakersfield and San Bernardino were selected because they each have approximately the same number of annual crashes as Oxnard, and their locations (more than 100 miles from Oxnard) made it unlikely that camera enforcement in Oxnard affected driver behavior in these cities. The city of Santa Barbara, approximately 40 miles north of Oxnard, was also selected because of its earlier use as a control for Oxnard in evaluating changes in red light violations following implementation of camera enforcement.[2] Red light violation rates did not change in Santa Barbara during the evaluation of the Oxnard red light enforcement program.

Crash data for the 4 cities were obtained from the California Statewide Integrated Traffic Records System (SWITRS). Crashes were analyzed for 29 months preceding camera enforcement (January 1995–May 1997) and for 29 months of enforcement (August 1997–December 1999). The first month of enforcement (July 1997) was excluded from analysis to ensure that drivers were aware of the red light camera program, as was the month before the start of enforcement (June 1997), when a warning period announcing the enforcement was in effect.

Intersections of each city were divided into 2 groups, signalized and nonsignalized. Because of the relatively small numbers of crashes associated with the 11 camera enforcement sites in Oxnard and because prior research has documented a large spillover effect of camera enforcement to intersections in the same community not equipped with cameras,[2,3] crashes at the 11 camera-equipped intersections were not analyzed separately. As the "before" and "after" periods would include different months, the numbers of crashes for these periods would be somewhat affected by seasonal variations; however, these variations were not expected to bias estimates of the effect of red light cameras, because the statistical model used identical periods for all 4 cities and for nonsignalized as well as signalized intersections.

SWITRS does not contain a variable that indicates whether an intersection is signalized; therefore, it was necessary to identify manually all intersections with traffic signals in the 4 cities by means of lists of signalized intersections provided by the cities and the California Department of Transportation (CALTRANS). Any intersection not identified as having a traffic signal was considered nonsignalized. Information provided by the 4 cities and CALTRANS regarding installation of any new signals during the analysis period was used to eliminate those intersections from the study (a total of 82 new signals were installed during the analysis period—10 in Oxnard, 41 in Bakersfield, 18 in San Bernardino, and 13 in Santa Barbara).

Changes in crash rates after enforcement were compared for Oxnard and control cities, as well as for signalized and nonsignalized intersections. Injury crashes were limited to cases with a SWITRS variable for collision severity equal to "fatal," "severe injury," or "other visible injury," the latter 2 classifications being based on police-reported information.

Two types of multiple-vehicle crashes—right angle and rear end—were defined by means of SWITRS variables. Right-angle crashes (expected to be reduced at signalized intersections by red light camera enforcement) were defined by means of SWITRS codes as "broadside" collisions involving 2 motor vehicles that were traveling at right angles to each other before the crash (based on recorded compass directions). Because SWITRS does not contain a specific code to identify red light–running crashes, it was not possible to categorize crashes specifically as red light running events. The closest category, right-angle collisions, also could include some left-turn crashes—SWITRS does not have a separate category for left-turn crashes—as well as crashes in which drivers may have been exiting from a driveway located close to an intersection. Left-turn crashes, however, do not typically involve red light running.

Rear-end crashes, which might increase with red light camera enforcement due to changes in driver behavior with regard to stopping for red lights, were defined by means of SWITRS codes as "rear-end" collisions involving 2 motor vehicles traveling in the same direction.

Model

A generalized linear regression model was developed to evaluate changes in total crashes, injury crashes, and specific crash types. The model used the natural logarithm of crash counts as the response variable. Independent variables were city, intersection type (signalized and nonsignalized), and period (before and after enforcement). Two-factor interactions of City × Period and City × Intersection Type also were included, because crash trends were different in different cities. Analysis of variance was used to test for statistical significance.

RESULTS

Table 1 summarizes changes in the numbers of crashes from the baseline period through the enforcement period, for signalized and nonsignalized intersections. For the 3 control cities, the frequency of crashes changed in a roughly similar manner at both signalized and nonsignalized intersections. In Bakersfield and Santa Barbara, the number of crashes declined at both types of intersections; in San Bernardino, it increased. Table 1 also summarizes the effect of red light camera enforcement as evaluated by the model. We estimated that red light camera enforcement would reduce the number of crashes at signalized intersections in Oxnard by 7% (95% confidence interval [CI] = 1.3, 12.5).

Table 2 summarizes changes in the number of injury crashes for signalized and nonsignalized intersections in all 4 cities. As was found for total crashes, the number of injury crashes in control cities changed in a roughly similar manner at signalized and nonsignalized intersections from the baseline period through the enforcement period. Results of the statistical model used to evaluate changes in injury crashes also are summarized in Table 2. We

TABLE 1—Total Crashes Before and After Enforcement and Its Estimated Effects

City and type of Intersection	Before	After	Change (%)
Bakersfield			
Nonsignalized	760	753	-0.9
Signalized	771	739	-4.2
San Bernardino			
Nonsignalized	1220	1283	5.2
Signalized	1324	1400	5.7
Santa Barbara			
Nonsignalized	712	622	-12.6
Signalized	488	438	-10.2
Oxnard			
Nonsignalized	994	1011	1.7
Signalized	1322	1250	-5.4

Estimated Effects

Effect	Degrees of Freedom	Mean Square	F value	*P* value	Estimate	Change (%)
Camera	1	0.0013308	11.33	0.0281	-0.07296	-7.0
Error	4	0.00011741	...	...	...	...

TABLE 2—Injury Crashes Before and After Enforcement and Its Estimated Effects

City and type of Intersection	Before	After	Change (%)
Bakersfield			
Nonsignalized	245	241	-1.6
Signalized	243	233	-4.1
San Bernardino			
Nonsignalized	204	225	10.3
Signalized	239	246	2.9
Santa Barbara			
Nonsignalized	113	115	1.8
Signalized	89	84	-5.6
Oxnard			
Nonsignalized	173	194	12.1
Signalized	299	239	-20.1

Estimated Effects

Effect	Degrees of Freedom	Mean Square	F value	*P* value	Estimate	Change (%)
Camera	1	0.02865345	35.62	0.004	-0.33855	28.7
Error	4	0.00080437	...	...	...	...

estimated that red light camera enforcement would reduce the number of injury crashes at signalized intersections in Oxnard by 29% (95% CI=16.6, 39.1).

Table 3 summarizes the effects of red light camera enforcement at intersections on 2 primary types of multiple-vehicle crashes—right angle and rear end. Overall, right-angle crashes accounted for approximately 36% of all crashes at signalized intersections and 42% of all crashes at nonsignalized intersections; rear-end crashes accounted for approximately 9% of all crashes at both signalized and nonsignalized intersections. Based on trends in right-angle crashes in the 3 comparison cities and relative to changes in the frequency of these types of crashes at nonsignalized intersections in Oxnard, the model estimated a significant 32% (95% CI=3.2, 53.0) reduction in right-angle crashes at all signalized intersections in Oxnard due to the camera enforcement (with 95% confidence limits of 3.2 and 53.0) and a significant 68% (95% CI=56.7, 76.5) reduction in right-angle injury crashes at all signalized intersections (with 95% confidence limits of 56.7 and 76.5). Based on trends in rear-end crashes in the 3 comparison cities and relative to changes in the frequency of these types of crashes at nonsignalized intersections in Oxnard, we estimated a nonsignificant 3% increase in rear-end crashes at signalized intersections.

DISCUSSION

Despite the large numbers of communities using red light camera enforcement and a long history of international use, relatively little is known, even in Australia, about the effect of camera enforcement on motor vehicle crashes. This study provides evidence that red light cameras in the United States can reduce the risk of motor vehicle crashes, especially injury crashes, at intersections with traffic signals. During the time frame of this study, no other comprehensive traffic safety programs were implemented in Oxnard that could account for these crash reductions.

Crash reductions at signalized intersections were found on a citywide basis, even though cameras were installed at only 11 of 125 signalized intersections in Oxnard. Intersections typically have 4 approach legs; red light cameras monitored only 1 approach leg at each of the 11 enforcement sites in Oxnard, so only about 2% of all approaches to signalized intersections were camera enforced.

The finding that crash reductions were observed at traffic signals on a citywide basis is consistent with prior behavioral research findings that red light camera enforcement can

TABLE 3—Estimated Effects on Right-Angle, Right-Angle Injury, and Rear-End Crashes

Effect	Degrees of Freedom	Mean Square	F value	*P* value	Estimate	Change (%)
Right-angle crashes						
Camera	1	0.03871492	9.17	0.0388	–0.39352	–32.5
Error	4	0.00422139				
Right-angle injury crashes						
Camera	1	0.32634352	107.72	0.0005	–1.14253	–68.1
Error	4	0.00302947				
Rear-end crashes						
Camera	1	0.00022718	0.00418	0.9515[a]	0.030145	3.1
Error	4	0.05430999				

[a]Nonsignificant.

provide general deterrence against red light violations, with effects not limited to the specific intersections with cameras. This result is important because the goal of highly conspicuous traffic enforcement is to produce generalized changes in driver behavior with respect to traffic safety laws, not simply to penalize identified violators. And because red light cameras can be a permanent component of the transportation infrastructure, crash reductions attributed to camera enforcement should be sustainable.

Injury crashes may decline to a greater degree than less severe crashes because of the nature of red light running crashes, which are characterized by more severe side impacts and relatively high impact speeds. Crash reductions estimated in this study may be conservative, because the SWITRS data did not contain sufficient detail to identify crashes that were specifically red light running events. Although the findings of an overall 29% reduction in injury crashes at signalized intersections and a 32% reduction in right-angle crashes are very positive, it is possible that crashes specifically related to red light running declined to an even greater extent.

Exposure data were not available to examine the possibility that traffic volumes in Oxnard shifted from signalized to nonsignalized intersections during the course of the study; however, such a shift in driving patterns on a citywide basis is highly improbable. In addition, prior research provides evidence that no such shift of exposure occurred. At 12 Oxnard signalized intersections studied by Retting et al.[2] before red light camera enforcement and several months after enforcement began, there was no significant change between the baseline and enforcement periods in the number of vehicles per hour.

Changes in motor vehicle crashes associated with red light camera enforcement may differ in other communities because of factors that could influence program effectiveness, including number of cameras, penalty structure, and extent to which camera enforcement is publicized. Camera enforcement publicity will be important because driver awareness of traffic enforcement is the principal mechanism against red light violations.

Although red light cameras are effective in reducing red light violations and associated crashes, such enforcement should be viewed as a supplement to, and not a substitute for, good engineering design practices that can reduce red light running and enhance intersection safety. These practices include adequately timed yellow signal change intervals, use of all-red clearance intervals, conspicuous traffic signal housings, adequate signal brightness, coordinated signal timing, and use of advance warning signs on high-speed roads or at locations with limited sight distances. ■

About the Authors

Richard A. Retting and Sergey Y. Kyrychenko are with the Insurance Institute for Highway Safety, Arlington, Va.

Requests for reprints should be sent to Richard A. Retting, MS, Insurance Institute for Highway Safety, 1005 North Glebe Rd, Arlington, VA 22201-4751 (e-mail: rretting@iihs.org).

This article was accepted December 21, 2001.

Contributors

R. Retting managed the project and participated in the study design and analyses. S. Kyrychenko developed the regression model and performed the statistical analyses.

Acknowledgments

This work was supported by the Insurance Institute for Highway Safety.

The authors acknowledge contributions to this research made by the cities of Bakersfield, Oxnard, San Bernardino, and Santa Barbara and by the California Department of Transportation. The authors also acknowledge technical contributions by Charles M. Farmer of the Insurance Institute for Highway Safety.

Human Participant Protection

No protocol approval was needed for this study.

References

1. Retting RA, Ulmer RG, Williams AF. Prevalence and characteristics of red light running crashes in the United States. *Accid Anal Prev.* 1999;31:687–694.

2. Retting RA, Williams AF, Farmer CM, Feldman AF. Evaluation of red light camera enforcement in Oxnard, California. *Accid Anal Prev.* 1999;31:169–174.

3. Retting RA, Williams AF, Farmer CM, Feldman AF. Evaluation of red light camera enforcement in Fairfax, Virginia. *ITE Journal.* 1999;69:30–34.

4. Zaal D. Traffic law enforcement: a review of the literature. Victoria, Australia: Monash University Accident Research Centre; 1994. Report no. 53.

5. Chin HC. Effect of automatic red-light cameras on red-light running. *Traffic Engineering and Control.* 1989;30:175–179.

6. County Surveyors' Society. Traffic signal cameras. Derbyshire, England: Special Activity Group on Accident Reduction; 1990. Report no. 1/12.

7. Rocchi S, Hemsing S. A review of the road safety benefits of red light cameras. In: *Enhancing Transportation Safety in the 21st Century, ITE International Conference* [conference report on CD-ROM]. Washington, DC: Institute of Transportation Engineers; 1999.

8. Hillier W, Ronczka J, Schnerring F. An evaluation of red light cameras in Sydney. New South Wales, Australia: Roads and Traffic Authority; 1993.

9. Ogden KW. *Safer Roads: A Guide to Road Safety Engineering.* Hampshire, England: Avebury Technical; 1996.

10. South D, Harrison W, Portans I, King M. Evaluation of the red light camera program and the owner onus legislation. Victoria, Australia: Victoria Road Traffic Authority; 1988.

11. US Census Bureau. Table 3. *Land area, population, and density for places in California: 1990.* Washington, DC; May 1996. Available at: http://www.census.gov/population/censusdata/places/06ca.txt. Accessed April 13, 2001.

12. US Census Bureau. *1990 to 1996 cities and places population estimates, California.* Washington, DC; October 2001. Available at: http://www.census.gov/population/estimates/metro-city/scful/SC99F_CA.txt. Accessed April 13, 2001.