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Authors
Doucet, Jay J
Godat, Laura N
Kobayashi, Leslie
et al.

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Enhancing trauma registries by integrating traffic records and geospatial analysis to improve bicyclist safety

AQ1 Jay J. Doucet, MD, Laura N. Godat, MD, Leslie Kobayashi, MD, Allison E. Berndtson, MD, Amy E. Liepert, MD,
AQ2 M.A.J. Eric Raschke, DO, USA, MC, John W. Denny, Jessica Weaver, MD, PhD,
Alan Smith, PhD, *and* Todd Costantini, MD*, San Diego, California*

BACKGROUND: Trauma registries are used to identify modifiable injury risk factors for trauma prevention efforts. However, these may miss factors useful for prevention of bicycle-automobile collisions, such as vehicle speeds, driver intoxication, street conditions, and neighborhood characteristics. We hypothesize that (GIS) analysis of trauma registry data matched with a traffic accident database could identify risk factors for bicycle-automobile injuries and better inform injury prevention efforts.

METHODS: The trauma registry of a US Level I trauma center was used retrospectively to identify bicycle-motor vehicle collision admissions from January 1, 2010, to December 31, 2018. Data collected included demographics, vitals, injury severity scores, toxicology, helmet use, and mortality.Matching with the Statewide Integrated Traffic Records System was done to provide collision, victim and GIS information. The GIS mapping of collisions was done with census tract data including poverty level scoring. Incident hot spot analysis to identify statistically significant incident clusters was done using the Getis Ord Gi* statistic.

RESULTS: Of 25,535 registry admissions, 531 (2.1%) were bicyclists struck by automobiles, 425 (80.0%) were matched to Statewide Integrated Traffic Records System. Younger age (odds ratio [OR], 1.026; 95% confidence interval [CI], 1.013–1.040, $p < 0.001$), higher census tract poverty level percentage (OR, 0.976; 95% CI, 0.959–0.993, $p = 0.007$), and high school or less education (OR, 0.60; 95 CI, 0.381–0.968; $p = 0.036$) were predictive of not wearing a helmet. Higher census tract poverty level percentage (OR, 1.019; 95% CI, 1.004–1.034; $p = 0.012$) but not educational level was predictive of toxicology positive—bicyclists in automobile collisions. Geographic information systems analysis identified hot spots in the catchment area for toxicology-positive bicyclists and lack of helmet use.

CONCLUSION: Combining trauma registry data and matched traffic accident records data with GIS analysis identifies additional risk factors for bicyclist injury. Trauma centers should champion efforts to prospectively link public traffic accident data to their trauma registries. (*J Trauma Acute Care Surg.* 2021;00: 00–00. Copyright © 2021 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Prognostic and Epidemiological, Level III
KEY WORDS: Spatial data analysis; GIS; trauma registry; bicycle; helmet.

In 2018 in the United States, over 650 bicyclists died, and there were almost 158,000 bicycle-automobile collision–related injuries.[1] Current bicycle injury prevention measures that have been proven include bicycle helmet programs and bicycle helmet laws.[2] Promising prevention measures include active lighting, increased rider visibility, and roadway modifications.[3] Trauma registries can be used to identify modifiable injury risk factors for trauma prevention efforts, including bicyclist collisions with automobiles. However, these may miss factors useful for prevention of bicycle-automobile collisions, such as vehicle speeds, driver intoxication, and patient group characteristics, such as financial stress, educational level, and languages spoken. Geographic information systems (GIS) use software that can relate seemingly unrelated data to provide better understanding of spatial patterns and relationships. The GIS studies in the trauma literature include optimizing trauma center location,[4,5] identifying underserviced areas for quality trauma care,[6,7] hotspot and cluster analysis for traffic collisions,[8] and helicopter basing and efficacy.[9] Trauma registries typically already contain some geospatial data, such as home and injury location addresses. Traffic records databases contain details about bicyclist automobile collisions not typically found in trauma registries, such as vehicle speeds, driver intoxication, street and lighting conditions, and driver or cyclist fault.[10] These records also include accurate exact collision locations, allowing GIS mapping. The GIS analysis also allows the use of census tract demographic data for both the collision location and patient's home for analysis.[11]

We hypothesize that GIS analysis of trauma registry data matched with a traffic records database could identify additional risk factors for bicycle-automobile injury helmet use or intoxication.

We also hypothesize that the addition of GIS analysis to the trauma registry will better inform injury prevention efforts.

METHODS

The trauma registry of the UC San Diego Level I trauma center was used retrospectively to identify bicycle-motor vehicle

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From the Division of Trauma, Surgical Critical Care, Burns and Acute Care Surgery, Department of Surgery (J.J.D., L.N.G., L.K., A.E.B., A.E.L., M.A.J.E.R., J.W., A.S., T.C.), University of California San Diego Health, San Diego, California; and Lloyd L. Gregory School of Pharmacy (J.W.D.), Palm Beach Atlantic University, West Palm Beach, Florida.
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Address for reprints: Jay J. Doucet, MD, Division of Trauma, Surgical Critical Care, Burns and Acute Care Surgery, University of California San Diego Health, 200 W Arbor Drive, #8896, San Diego, CA 92103; email: jdoucet@ucsd.edu.

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TABLE 1.

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	Helmeted Bicyclist	Unhelmeted Bicyclist	p
n	126	299	
Age (SD)	46.3 ± 17.3	37.5 ± 17.4	<0.001
Female sex	17/126 (13.4%)	53/299 (17.7%)	0.32
Non-White race	84/126 (66.7%)	144/299 (48.1%)	<0.001
Uninsured	15/126 (11.9%)	50/299 (16.85)	0.21
Homeless	1/126 (0.08%)	45/299 (15.1%)	<0.001
ISS mean (S.D.)	9.8 ± 10.2	10.2 ± 9.3	0.76
Median head-neck AIS score	2, IQR 0–2	2, IQR 0–2	0.198
Median LOS, d	1.20 (IQR, 0.86–3.1)	1.22 (IQR, 0.86–2.4)	0.86
In-hospital mortality	2/126 (1.6%)	9/299 (3.0%)	0.52
Discharge other than home	31/126 (24.6%)	47/299 (15.7%)	0.031
Intoxicated cyclist	12/111 (10.8%)	78/275 (28.3%)	<0.001
Intoxicated motorist	2/126 (1.6%)	12/299 (4.0%)	0.20
Home census tract poverty score mean	14.5% ±12.2	20.1% ± 14.5	<0.001
Median home census tract education level	Level 5 (bachelor's), IQR 4–5	Level 4 (some college), IQR, 3–5	<0.001

collision admissions from January 1, 2010, to December 31, 2018. Data collected included demographics, home and injury location addresses, injury severity scores, blood alcohol, toxicology, helmet use, hospital length of stay (LOS) and mortality.

Matching of the registry cases with the California Statewide Integrated Traffic Records System (SWITRS) was done to provide collision, bicyclist, driver, and geospatial information for bicycle-automobile collisions within the County of San Diego for the same period. Statewide Integrated Traffic Records System is administered by the California Highway Patrol, and includes all traffic collisions in California with a law enforcement report. Matching was deterministic and was done by bicyclist age, bicyclist sex, zip code, date and time ±1 hour between the SWITRS collision time and the trauma registry admission time transfers from outside the County of San Diego were excluded. Outcomes of interest included toxicology—available as "Alcohol Involved" in SWITRS collision data and "Party Sobriety" under SWITRS party data or from blood alcohol and urine toxicology in the trauma registry. Helmet use was found as reported in SWITRS or the trauma registry. Missing variables in either database were managed by excluding such cases from analysis using that variable.

Geocoding, mapping, and geospatial analysis of matched case SWITRS collision locations was done using ArcGIS Pro 2.6 (esri, Redlands, CA). Registry home addresses of cases were also geocoded and used with US Census Bureau census tract data to provide the below poverty level percentage for home census tracts. The educational attainment level for cases was done by selecting the predominant education level (< grade 9, grades 9–12, high school, some college, bachelor's degree, graduate degree) within the patient's home address census tract from the US Census Bureau's American Community Survey 2014 to 2018 5-year estimates, Table B15002. The language spoken at home was selected by home address census tract in the U.S. Census Bureau's American Community Survey 2014 to 2018 5-year estimates, Table B16007. Locations of bike lanes in San Diego County for analysis of their associations with collisions were obtained from SanGIS for Bike Paths (class I), which are

TABLE 2.

	Toxicology Negative Bicyclist	Toxicology Positive Bicyclist	p
n	231	194	
Age ± SD, y	41.1 ± 20.0	38.9 ± 14.9	0.213
Female sex	37/231 (16.0%)	33/194 (17.0%)	0.783
Non-White race	120 (51.9%)	108 (55.7%)	0.443
Uninsured	33/231 (14.3%)	32/194 (16.5%)	0.529
Homeless	7/231 (3.0%)	39/194 (20.1%)	<0.001
Helmeted	92/231 (39.8%)	24/194 (17.5%)	<0.001
ISS mean ± SD	9.2 ± 10.0	10.7 ± 10.0	0.120
Median head-neck AIS score	2, IQR 2–2	2, IQR 2–3	0.405
Median LOS, d	1.28, IQR 1.0–2.2	1.78 IQR 0.9–4.1	0.037
In-hospital mortality	5/231 (2.2%)	6/194 (3.1%)	0.548
Discharge other than home	189/231 (8.9%)	158/194 (81.4%)	0.921
Drugs screen positive	0/231 (0%)	90/194 (46.4%)	<0.001
Home census tract poverty score mean	16.8 ± 13.7	20.3 ± 14.3	0.009
Median home census tract education	Level 4 (some college), IQR, 3–5	Level 4 (some college), IQR, 3–5	0.580

TABLE 3A. Logistic Regression—Helmet Worn

				95% CI	
	B	*p*	OR	Lower	Upper
Age, y	0.026	<0.001	1.026	1.013	1.040
Non-White	0.290	0.241	1.337	0.823	2.172
Intoxicated bicyclist	−1.672	<0.001	5.32	2.72	10.38
Census Tract Poverty Level %	−0.024	0.007	0.976	0.959	0.993
High school or less education	−0.633	0.036	0.608	0.381	0.968
Constant	−2.425	<0.001	0.088		

TABLE 3B. Logistic Regression—Toxicology Positive

				95% CI	
	B	*p*	OR	Lower	Upper
Age	−0.009	0.134	0.991	0.979	1.003
Non-White	0.441	0.046	1.555	1.008	2.400
Census Tract Poverty Level %	0.019	0.012	1.019	1.004	1.034
High school or less education	−0.363	0.084	1.434	0.952	2.170
Constant	−0.187	0.634	0.829		

physically separated from traffic; bike lanes (class II), which are defined by pavement striping and signage on streets; and Bike Routes (class III), which are shared use with motor vehicle traffic in the same travel lane and designated by signs only. Locations of alcoholic beverage control licenses in San Diego County for analysis of association with intoxicated bicyclist collisions was obtained from the California Department of Alcoholic Beverage Control via SanGIS and esri.

The spatial clustering of bicycle-automobile collisions and hotspots were assessed using spatial autocorrelation via the Getis-Ord Gi* statistic in ArcGIS Pro.[10] Analyses of descriptive and tabular data were performed with IBM SPSS Statistics 27. χ^2 Analysis was done for categorical data, means were compared via ANOVA and distributions of educational level, LOS, and head-neck Abbreviated Injury Scale (AIS) were compared with the Mann-Whitney *U* test. Two-sided *p* values less than 0.05 were considered significant. Binary logistic regression was used for the outcome variables of helmet use and toxicology, selecting factors with a *p* value less than 0.01 in the univariate analysis. The SWITRS data were used under the terms of the data use agreement provided by the California Highway Patrol. The study was exempted from further review by the UC San Diego Human Research Protections Program.

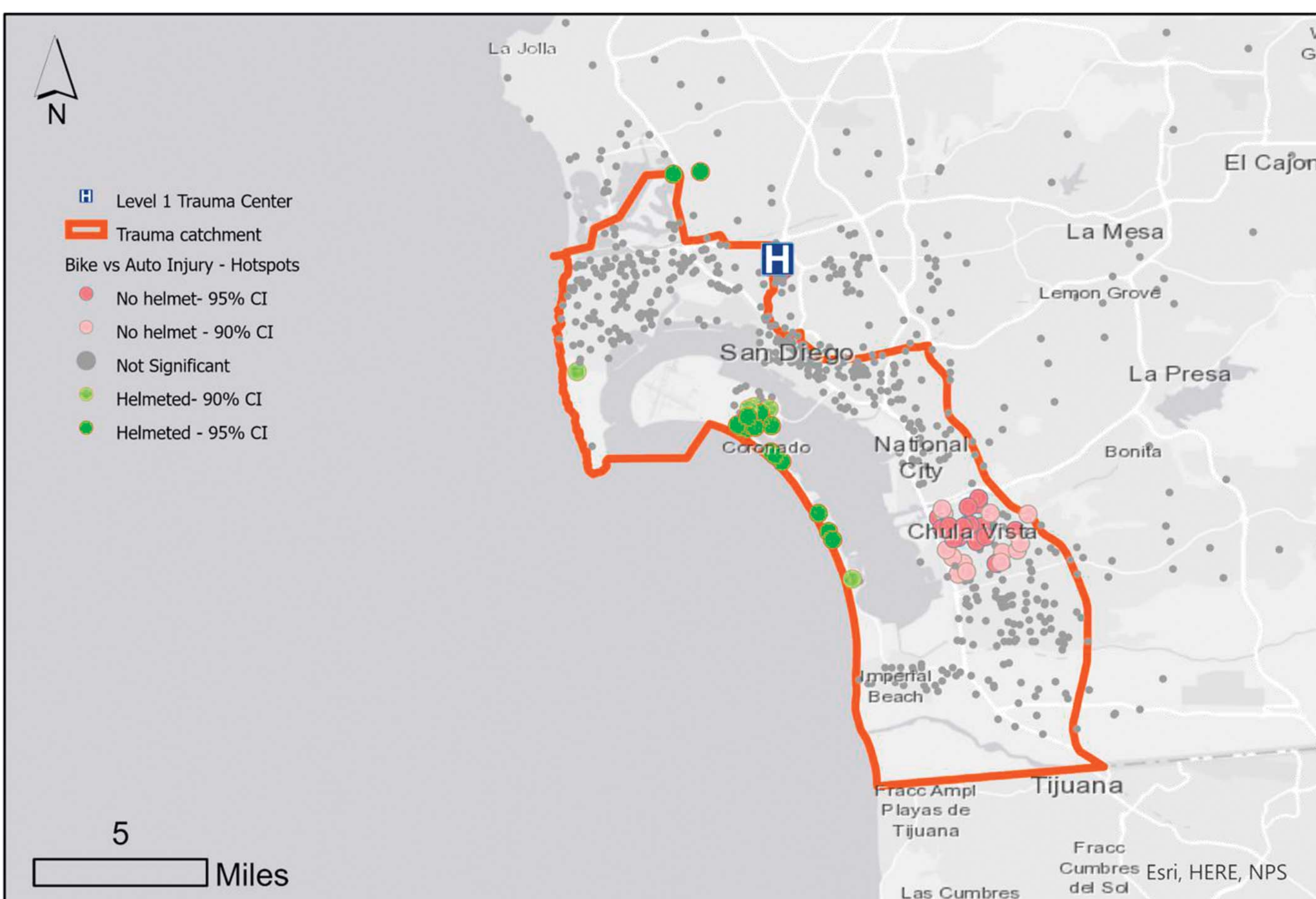

Figure 1. Bicycle versus automobile helmet use hotspot analysis.

RESULTS

Out of 25,535 UC San Diego trauma registry admissions from January 1, 2010, to December 31, 2018, 531 (2.1%) were bicyclists struck by automobiles, and 425 (80.0%) of these admissions were successfully matched to SWITRS. There were 11 (2.5%) bicyclist deaths after admission, all these were matched between SWITRS and the trauma registry. Statewide Integrated Traffic Records System also identified five automobile-bicyclist collision scene deaths in the catchment that were not in the trauma registry that were excluded from further study.

T1 Table 1 shows the descriptive data for bicyclists grouped by helmet use. One hundred twenty-six (29.0%) of 435 bicyclists had evidence of helmet use in SWITRS or the trauma registry. On average, unhelmeted bicyclists were almost a decade younger than those wearing a helmet. Non-White bicyclists were significantly more likely to be wearing a helmet. Homeless persons were significantly less likely to be wearing a helmet. Unhelmeted bicyclists were almost three times likely to have a positive alcohol or drug screening test. The shaded portion of Table 1 contains data obtained from census tract data, showing that unhelmeted bicyclists lived in census tracts with higher home poverty rates than helmeted bicyclists (14.5% ± 12.2 vs. 20.1% ± 14.5, $p < 0.001$). Unhelmeted bicyclists were also more likely to live in a census tract with a lower predominant level of educational attainment (Level 4 (some college), interquartile range [IQR], 3–5 versus Level 5 (bachelor's degree); IQR, 4–5, $p < 0.001$). Helmeted bicyclists were more likely to be discharged to a long-term or rehabilitation facility. There were no significant differences between groups in uninsured status, hospital LOS, Injury Severity Score (ISS), head-neck AIS, or mortality.

Table 2 shows the descriptive data for bicyclists grouped by positive toxicology. One hundred ninety-four (44.6%) of 425 bicyclists had positive toxicology. Alcohol only was found in 71 bicyclists, 73 had drugs detected by urinalysis without alcohol detected, and 50 had both drugs and alcohol detected. Drug screening urinalysis was not done in 18 (4.2%) bicyclists. There was no significant difference in age, sex, race, uninsured status, ISS, head-neck AIS, or mortality between toxicology positive and toxicology negative bicyclists. Homeless persons were significantly more likely to be toxicology positive. The shaded portion of Table 2 contains data obtained from census tract data, showing that toxicology-positive bicyclists had higher home census tract poverty rates. The predominant level of educational attainment did not have a significant association with bicyclist positive toxicology. T2

Table 3A shows the binary logistic regression for predictors of helmet use, these were increased age (odds ratio [OR], 1.026; 95% confidence interval [CI], 1.013–1.040; $p < 0.001$), T3

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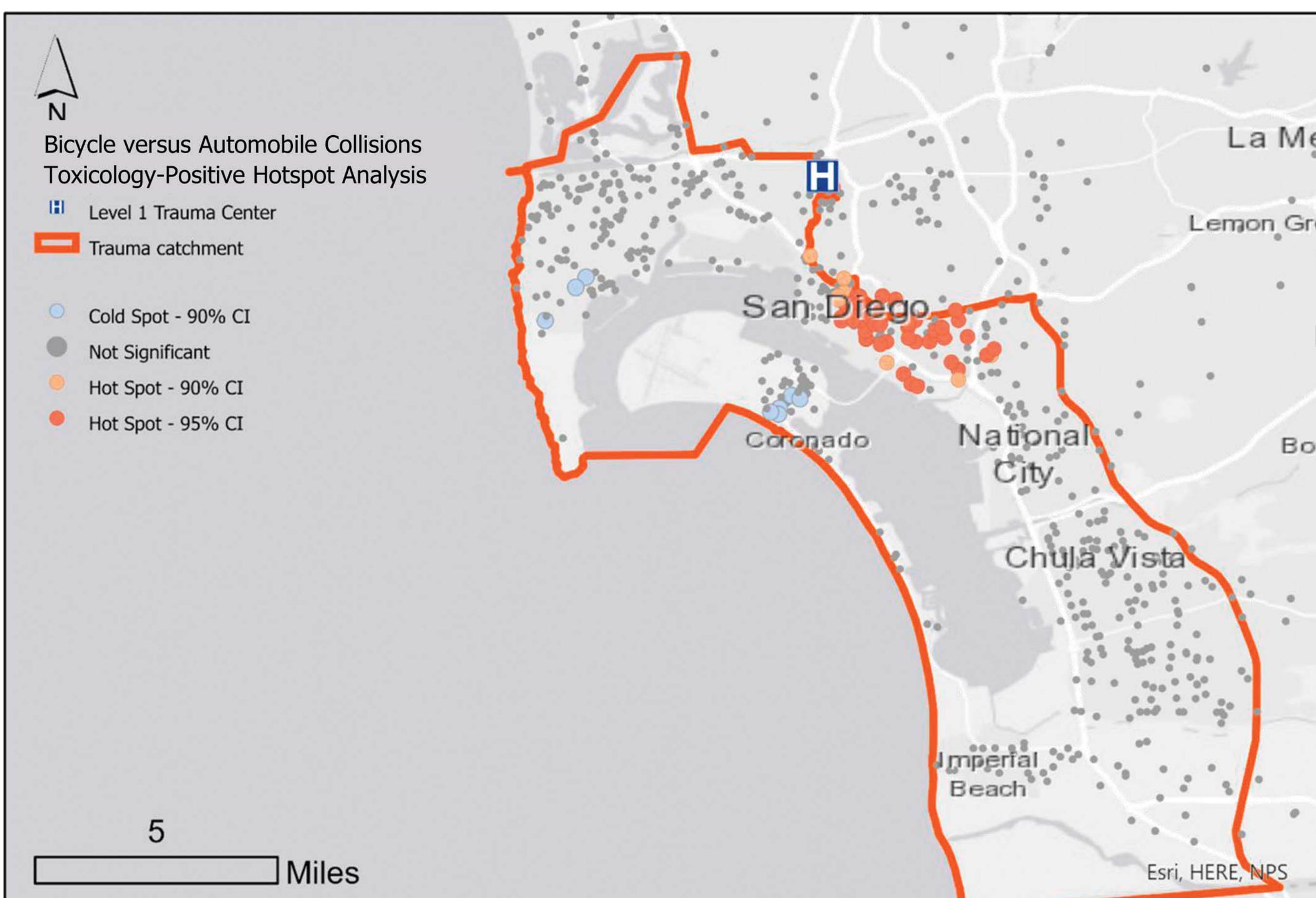


Figure 2. Bicycle versus automobile positive toxicology hotspot analysis.

home census tract poverty level percentage (OR, 0.976; 95% CI, 0.959–0.993; $p = 0.007$), and home census tract predominant education level at high school or less (OR, 0.608; 95% CI, 0.381–0.968; $p = 0.036$). Table 3B shows the binary logistic regression for predictors of positive toxicology, these were non-White persons (OR, 1.56; 95% CI, 1.008–2.40; $p = 0.046$), and home census tract poverty level percentage (OR, 1.019; 95% CI, 1.004–1.034; $p = 0.012$).

Automobile drivers were at-fault in 99 (22.8%) of 435 bicycle collisions. Injury Severity Score was not significantly increased when drivers were at fault, unless a speeding violation (n = 8, ISS 16.8 ± 9.7 vs. 9.8 ± 9.9, $p = 0.048$) or an intoxication violation was issued (n = 10, ISS 18.4 ± 16.9 vs. 9.8 ± 9.9, $p = 0.037$).

Figure 1 shows the hotspot GIS spatial analysis for helmet use, one cluster of 32 nonhelmeted bicyclist versus automobile cases was found entirely in the City of Chula Vista, CA (Getis-Org Gi* Z-Scores −3.84 to −2.84, $p = 0.014$ to 0.0006). The largest cluster of helmeted bicyclist versus automobile cases was 31 cases found entirely within the City of Coronado, CA (Getis-Org Gi* Z-Scores 2.46 to 3.91, $p = 0.014$ to 0.0001).

Figure 2 shows the hotspot GIS analysis for toxicology positive bicyclists, there was a cluster of 59 cases of toxicology positive bicyclists involved with automobile collisions entirely within the City of San Diego (Getis-Org Gi* Z-Scores 2.43 to 4.19, $p = 0.0147$ to 0.00003). These cases were in the neighborhoods of Gaslamp Quarter, Core District, City College, Sherman Heights, Grant Hill, Imperial Transit Center, Barrio Logan, and Logan Heights. The cluster of bicyclists with positive toxicology constrained an area of 3.02 sq mile, which contained 513 establishments licensed to sell alcohol in 2018.

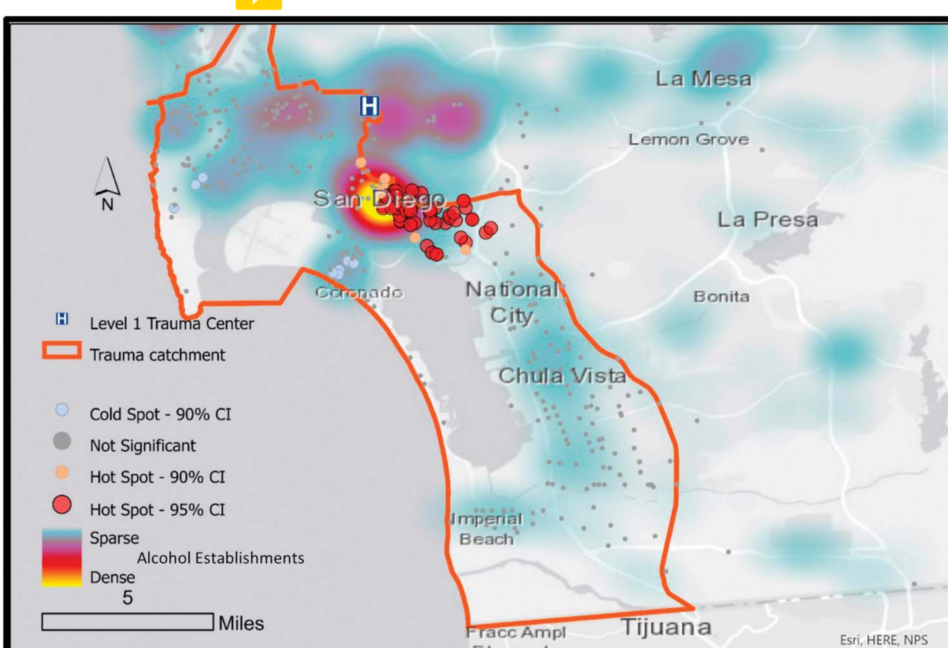
A close up of the nonhelmeted hotspots is shown in Figure 3. Geographic information systems analysis shows that the census tracts for the area incorporated by the shape shows that the mean percentage of the population who speak Spanish at home is higher compared with the remainder of the catchment (54.3% ± 18 vs. 39.7% ± 9.4, $p < 0.001$).

The location of bike lanes and collisions is shown in Figure 4. Overall, 208 (49%) of 425 collisions occurred on a bike lane. There were 6 (1.4%) collisions of on bike paths (class I), 70 (16.5%) on bike lanes (class II), and 132 (31.1%) on bike routes (class III). Mean ISS was higher for bike lane collisions than for non–bike lane collisions (11.0 ± 11.3 vs. 8.4 ± 8.4, $p = 0.007$). Helmet use was not significantly different between bike lane and non–bike lane collisions (63/152 (41.4%) vs, 63/217 (46.1%), $p = 0.56$). There was no significant difference in toxicology-positive bicyclists between bike-lane and non–bike lane collisions (100/208 (48.0%) vs. 99/217 [48.6%], $p = 0.61$).

Figure 5 shows the locations of alcoholic beverage control licenses and intoxicated bicyclist collision hotspots. Using a 2-km radius buffer, 95% confidence interval hotspots (36.8 ± 10.8 adjacent, $p = 0.01$) and 99% CI hotspots (40.8 ± 14.5 adjacent, $p = 0.002$) were located with significantly more neighboring alcohol licensed establishments than nonhotspot locations (24.7 ± 13.9).

DISCUSSION

We have shown that GIS analysis of trauma registry data matched with a traffic accident records database can identify additional risk factors for bicycle-automobile injuries. We have also shown that our injury prevention efforts will be better informed by the hotspot analysis which clearly demonstrates



Heat map of licensed alcohol establishment and intoxicated bicyclist collision hotspots.

Figure 5. Heat map of licensed alcohol establishment and intoxicated bicyclist collision hotspots.

Area analysis: Languages spoken at home.	Trauma catchment exc. shape	Area inside shape	P value
Percentage of population age > 5 years speaking Spanish at home, mean ± SD.	39.2% ± 29.3	54.3% ± 18	P<0.001
Percentage of population age > 5 years speaking only English at home, mean ± SD.	53.6% ± 28.1	39.7% ± 9.4	P<0.001

Figure 3. Bicycle versus automobile helmet use hotspot closeup analysis.

clusters in specific geographic areas of the catchment area. The ability to add census tract data to registry data shows associations of education level and poverty level on bicycle helmet use. Census tract data also provides useful information for injury prevention efforts such as the predominant language spoken at home in target areas. Trauma registries, whether trauma center-based or nationally collected, should be constructed to allow geospatial analysis.

Helmet use by bicyclists has been shown to reduce the risk of serious injury.[12–14] Despite this, we saw relatively low use of helmets in admitted bicyclists. Some of the barriers to helmet use include psychological, financial and educational issues.[15] This may be reflected in our results showing adverse census tract poverty level and educational levels having an association with lack of helmet use. Unhelmeted cyclists in this study were also less likely to be discharged to rehabilitation or long-term care facilities, this is likely due to their being relatively underinsured compared with helmeted cyclists. A meta-analysis of 21 studies shows that the effect of mandatory bicycle helmet legislation for all cyclists on head injuries results in a 20% reduction in serious injuries; however, such legislation currently seems unlikely in many US jurisdictions, except for children.[16] Nonlegislative interventions appear to be effective in increasing observed helmet use, particularly community-based interventions and those programs providing free helmets.[17] The clustering of unhelmeted bicyclists in automobile collisions provides the trauma center with good targets for injury prevention. The hotspots for lack of helmet use were predominantly at traffic light intersections on straight city boulevards, which may provide a joint opportunity with local officials and bicycle advocates to evaluate bicycle traffic safety and policies. The census tract home language data for the unhelmeted hotspots indicates that any injury prevention efforts should be culturally appropriate and made available in multiple languages.

The class of bike lane in San Diego County also influences the number of bicyclist-automobile collisions, with the signage-only "Bike Route" being the most common involved bike lane with injuries. Separating bicycles from automobiles is an obvious prevention measure and in our study is associated with very low rates of bicycle versus automobile injury. Advocacy for better classes of bike lanes, including more Class I Bike Paths is warranted.

The cluster of bicyclists with positive toxicology constrained a dense area of only about 3 sq miles containing 513 establishments licensed to sell alcohol. The injured bicyclist intoxicated by alcohol or drugs is a problem that has had relatively little research. Alcohol and cannabis are associated with increased risk of bicycle collisions and increased injury severity.[18,19] Among bicyclist fatalities in the United States in 2014, about 21% had high blood alcohol concentrations.[20] In the past 30 years, Fig 4 4/C

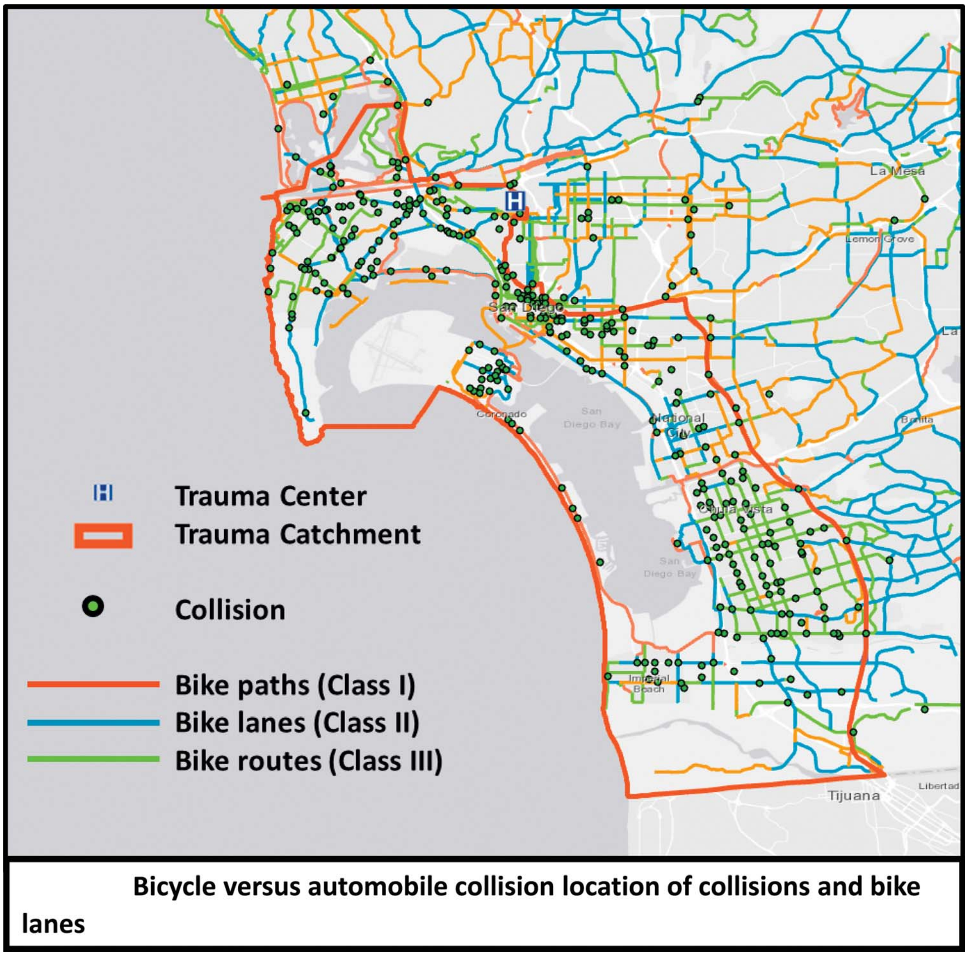


Figure 4. Bicycle versus automobile collision location of collisions and bike lanes.

targeted prevention interventions and legislation have been directed at automobile drunk drivers with a dramatic reduction in fatality numbers. However, no such efforts exist for intoxicated bicyclists. In this data set of bicycle-automobile collisions, we found many more intoxicated bicyclists than drivers. One factor in some intoxicated bicyclist collisions is a history of driving under the influence (DUI) in a motor vehicle, which in one study of
AQ5 149 injured bicyclists in the ED, found 66 (44.2%) had prior driving under the influence convictions with suspension of driving privileges.[21] There appear to be opportunities for targeted injury prevention efforts for intoxicated bicyclists in our catchment, given the small geographic area. Unfortunately, we do not have data on owned bikes versus rented rideshare bikes which became ubiquitous at the end of the study period.

The trauma registry kept by US trauma centers is largely used for quality and performance improvement, and to provide data to the Trauma Quality Improvement Program to allow national benchmarking standards.[22] Trauma registries can also be linked to emergency medical services (EMS) registries and a call has been issued by the American College of Surgeons' Trauma Quality Programs and the National Association of State Emergency Medical Services Officials, with support from the National Highway Traffic Safety Administration. They urge to creation of a universally unique and anonymous identifier to allow such linkages.[23] The addition of EMS registry data provides additional information about the prehospital care of the trauma patient and this may provide additional risk factors for analysis of outcomes as well as additional data for quality and performance improvement of EMS. The California Highway Patrol's SWITRS database is a rich source on each injury traffic collision in the state of California, providing over 122 data fields per case. Since 2002, each SWITRS record starts with a unique barcode ID number, allowing collection of scene data by law-enforcement agencies across the state. However, there has yet been no attempt to link SWITRS to EMS data in California. There have been efforts to link EMS records and traffic records in some regions of Oregon, which is accomplished by sharing of a universally unique and anonymous identifier between agencies at the accident scene.[24] However, in California, legal concerns over privacy have halted progress by the state EMS agency despite the low cost of such a useful improvement in the trauma and EMS registries. We believe that this should be an area for continued advocacy and research for trauma centers, providers, and their national associations.

Limitations of our study approach include the inability to assign financial, educational, or language characteristics to individual patients, for those variables we can only speak of the characteristics of a census tract for a patient's given home address, which is only useful for assessing associations in large groups of patients. In some cases, opiates or benzodiazepines may have been administered by EMS crews or trauma teams prior to urinalysis. It is possible that there are systemic errors that mean that many individual bicycle-automobile victims may be systemic outliers from their census tract characteristics, although we believe that the results are representative from our experience. Missing and incorrect data are always an issue for large databases, which may be why we were unable to match 20% of our bicyclists injured in automobile collisions in our catchment to SWITRS data, although we believe that the remainder in the study is a representative sample of our experience. The adoption of a secure linkage between traffic records databases and the EMS and trauma registries would resolve this issue.

Further studies of combination of traffic records databases and trauma center registries are needed to validate our approach. Although exact determination of educational level, income and languages spoken may be impractical and excessively intrusive for individual patients, use of census tract demographic data may allow for determination of likely characteristics of groups of patients for epidemiological and injury prevention purposes. The amount of GIS data available free online has exploded in the past 10 years. Future GIS analysis will include new social determinants for access to quality trauma care and trauma outcomes.

CONCLUSION

Combining trauma registry data and matched traffic accident records data with GIS analysis identifies hotspots for bicyclist-automobile collisions. The addition of census tract demographic data can provide variables useful for injury prevention efforts. Trauma center registries and national trauma registries should be constructed to allow GIS analysis. Trauma centers should champion efforts to prospectively link public traffic accident data to EMS and trauma registries.

AUTHORSHIP

J.D. and B.A. designed the study. J.D. and B.A. performed the literature search, J.D., B.A., A.S. did the data collection. J.D., B.A., and A.S. did data analysis. Critical review was done by L.G., L.K., A.B., A.L., E.R., J.W., T.C. All authors contributed to data interpretation and article preparation.

DISCLOSURE

The authors declare no conflicts of interest.
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REFERENCES

1. Centers for Disease Control and Prevention. Web-based Injury Statistics Query and Reporting System (WISQARS). 2018. Available at: http://www.cdc.gov/injury/wisqars. Accessed August 1, 2020
2. Attewell RG, Glase K, McFadden M. Bicycle helmet efficacy: a meta-analysis. *Accid Anal Prev.* 2001;33:345–352.
3. National Highway Traffic Safety Administration. Countermeasures that work: a highway safety countermeasures guide for State Highway Safety Offices, 8th editionpdf iconexternal icon. (Report No. DOT HS 812 202). Washington, DC: National Highway Traffic Safety Administration. 2015.
4. Uribe-Leitz T, Esquivel MM, Knowlton LM, Ciesla D, Lin F, Hsia RY, Spain DA, Winchell RJ, Staudenmayer KL. The American College of Surgeons Needs-Based Assessment of Trauma Systems: estimates for the state of California. *J Trauma Acute Care Surg*. 2017;82(5):861–866.
5. Horst MA, Jammula S, Gross BW, Bradburn EH, Cook AD, Altenburg J, Morgan M, Von Nieda D, Rogers FB. Development of a trauma system and optimal placement of trauma centers using geospatial mapping. *J Trauma Acute Care Surg*. 2018;84(3):441–448.
6. Uribe-Leitz T, Esquivel MM, Garland NY, Staudenmayer KL, Spain DA, Weiser TG. Surgical deserts in California: an analysis of access to surgical care. *J Surg Res*. 2018;223:102–108.
7. Hu W, Dong Q, Dong C, Yang J, Huang B. Access to trauma centers for road crashes in the United States. *J Safety Res*. 2018;65:21–27.
8. Saadat S, Rahmani K, Moradi A, Zaini SA, Darabi F. Spatial analysis of driving accidents leading to deaths related to motorcyclists in Tehran. *Chin J Traumatol*. 2019;22(3):148–154.
9. Smedley WA, Stone KL, Brown A, Farley P, Griffin RL, Cox DB, Kerby JD, Jansen JO. Use of helicopters for retrieval of trauma patients: a geospatial analysis. *J Trauma Acute Care Surg*. 2019;87(1):168–172.
10. Pitt TM, Nettel-Aguirre A, McCormack GR, Howard AW, Rowe BH, Hagel BE. Identifying motorist characteristics associated with youth bicycle-motor vehicle collisions. *Traffic Inj Prev.* 2019;20(7):744–748.
11. Banerjee S. Spatial Data Analysis. *Annu Rev Public Health*. 2016;37:47–60.
12. Dodds N, Johnson R, Walton B, Bouamra O, Yates D, Lecky FE, Thompson J. Evaluating the impact of cycle helmet use on severe traumatic brain injury and death in a national cohort of over 11000 pedal cyclists: a retrospective study from the NHS England trauma audit and research network dataset. *BMJ Open*. 2019;9(9):e027845.
13. Cripton PA, Dressler DM, Stuart CA, Dennison CR, Richards D. Bicycle helmets are highly effective at preventing head injury during head impact: head-form accelerations and injury criteria for helmeted and unhelmeted impacts. *Accid Anal Prev.* 2014;70:1–7.
14. Thompson DC, Rivara FP, Thompson R. Helmets for preventing head and facial injuries in bicyclists. *Cochrane Database Syst Rev.* 2000;2:CD001855.
15. Finnoff JT, Laskowski ER, Altman KL, Diehl NN. Barriers to bicycle helmet use. *Pediatrics*. 2001;108(1):E4.
16. Hoye A. Recommend or mandate? A systematic review and meta-analysis of the effects of mandatory bicycle helmet legislation. *Accid Anal Prev.* 2018; 120:239–249.
17. Owen R, Kendrick D, Mulvaney C, Coleman T, Royal S. Non-legislative interventions for the promotion of cycle helmet wearing by children. *Cochrane Database Syst Rev.* 2011;11:CD003985.
18. Asbridge M, Mann R, Cusimano MD, Tallon JM, Pauley C, Rehm J. Cycling-related crash risk and the role of cannabis and alcohol: a case-crossover study. *Prev Med*. 2014;66:80–86.
19. Helak K, Jehle D, McNabb D, Battisti A, Sanford S, Lark MC. Factors influencing injury severity of bicyclists involved in crashes with motor vehicles: bike lanes, alcohol, lighting, speed, and helmet use. *South Med J.* 2017; 110(7):441–444.
20. Eichelberger AH, McCartt AT, Cicchino JB. Fatally injured pedestrians and bicyclists in the United States with high blood alcohol concentrations. *J Safety Res*. 2018;65:1–9.
21. Maximus S, Figueroa C, Pham J, Kuncir E, Barrios C. DUI histories in intoxicated injured bicyclists. *J Trauma Acute Care Surg*. 2016;81(4):638–643.
22. Gotlib Conn L, Hoeft C, Neal M, Nathens A. Use of performance reports among trauma medical directors and programme managers in the American College of Surgeons' trauma quality improvement program: a qualitative analysis. *BMJ Qual Saf.* 2019;28(9):721–728.
23. National Association of State EMS Officials. Data Linkage Joint Statement Falls Church, VA2016 [accessed 8/1/2020]. Available at: https://nasemso.org/wp-content/uploads/Data-Linkage-Joint-Statement-Final- Draft-for-Team-Review_V2.pdf.
24. National Highway Traffic Safety Administration. *State of Oregon Traffic Records Assessment*. Washington, DC: 2016 January 11, 2016.
25. Ord JK, Getis A. Local spatial autocorrelation statistics: distributional issues and an application. *Geogr Anal*. 1995;27(4):286–306.

AUTHOR QUERIES

AQ1: All are correct, except M.A.J in front of Eric Raschke should by "MAJ". no periods - it is an abbreviation for army Major.

AUTHOR PLEASE ANSWER ALL QUERIES

AQ1 = Please check if authors name are correctly captured for given names (in red) and surnames (in blue) for indexing after publication.

AQ2 = Please provide highest academic degree for author Denny.

John W. Denny, BA,

AQ3 = Please check if sq. mile is correct.

sq. mile is correct

AQ4 = Please check if "sq mile" is correct.

AQ5 = Please spell out ED.

ED: Emergency Department

AQ6 = Reference 25 [originally 12] was provided in the reference list; however, this was not mentioned or cited in the manuscript. As a rule, all references given in the list of references should be cited in the main body. Please provide its citation in the body text.

AQ6: Reference 25 should appear in the place that Reference 10 is improperly cited on 3rd page, second paragraph, end of sentence: "The spatial clustering of bicycle-automobile collisions and hotspots were assessed using spa autocorrelation via the Getis-Ord Gi* statistic in ArcGIS Pro" (10)
That 10 is where Ref 25 should actually appear.

AQ7 = Please provide table caption.

AQ7: Table Caption should be "Comparison of Helmeted and Unhelmeted Bicyclists Struck by Automobile"

END OF AUTHOR QUERIES