Spatial analysis of injury-related deaths in Dallas County using a geographic information system

Adil Abdalla, DVM, MS, Mark Gunst, MD, Vafa Ghaemmaghami, MD, Amy C. Gruszecki, DO, Jill Urban, MD, Robert C. Barber, PhD, Larry M. Gentilello, MD, and Shahid Shafi, MD, MPH

This study applied a geographic information system (GIS) to identify clusters of injury-related deaths (IRDs) within a large urban county (26 cities; population, 2.4 million). All deaths due to injuries in Dallas County (Texas) in 2005 (N = 670) were studied, including the geographic location of the injury event. Out of 26 cities in Dallas County, IRDs were reported in 19 cities. Geospatial data were obtained from the local governments and entered into the GIS. Standardized mortality ratios (SMR, with 95% CI) were calculated for each city and the county using national age-adjusted rates. Dallas County had significantly more deaths due to homicides (SMR, 1.76; 95% CI, 1.54–1.98) and IRDs as a result of gunshots (SMR, 1.23; 95% CI, 1.09–1.37) than the US national rate. However, this increase was restricted to a single city (the city of Dallas) within the county, while the rest of the 25 cities in the county experienced IRD rates that were either similar to or better than the national rate, or experienced no IRDs. GIS mapping was able to depict high-risk geographic "hot spots" for IRDs. In conclusion, GIS spatial analysis identified geographic clusters of IRDs, which were restricted to only one of 26 cities in the county.

Geographic information systems (GIS) are computerized information management systems for analyzing and presenting geographic and spatial data. Over the past two decades, GIS have been used for multiple purposes, such as community policing, urban planning, environmental conservation, marketing research, disaster planning, and disease surveillance (1). However, its application in the field of injury prevention and control has been relatively limited, despite the emergence of several publications that have referred to the role of GIS in medical research and injury prevention. For example, Edelman focused on GIS utility in injury and trauma research (2), and Oppong and Denton implemented GIS to study the association between geographic distribution of HIV/AIDS and ethnic minorities in Dallas County from 1999 to 2002 (3). Other applications of GIS have included the identification of locations with a high frequency of motor vehicle collisions (MVCs) to minimize injuries and evaluate costs and outcomes of treatment (4), and the linking of burn injury incidence at a discrete geographic location to census data to determine potential socioeconomic risk factors (5).

Dallas County is the ninth largest urban county in the United States (6). It has a population of 2.4 million citizens; about half reside in the city of Dallas, and the other half reside in 25 other cities within the county (7). Crime reports for 2005 issued by the Federal Bureau of Investigation indicated a 2.4% increase in the murder rate per 100,000 inhabitants at the national level and a 2.7% increase in violent crimes in metropolitan counties with populations of 100,000 or more (8). Subsequently, *The Dallas Morning News* described the rate of injury-related deaths (IRDs) in Dallas County as one of the highest in the nation (9). From an injury prevention perspective, it is essential to determine the geographic distribution of these deaths. Such information may enable policy makers and stakeholders at county and city levels to develop local, community-based injury prevention programs to minimize the burden of injuries.

The objectives of this study were to analyze and present the geographic distribution and clustered zones of IRDs at the county and city levels using GIS, to determine the IRD rate in Dallas County and compare it with the national rate, to compare rates of IRDs among cities in Dallas County, and to identify zones with a high frequency of injuries.

MATERIALS AND METHODS

This is a population-based retrospective study of all IRDs in 2005 in Dallas County, a large urban county in Texas.

Data on injury-related deaths

Under Article 49.25 of the Texas Code of Criminal Procedure, the county medical examiner must be notified when any person dies an unnatural death or when the circumstances of death are unknown or lead to suspicion that the death was the result of unlawful means (10). Deaths that are the direct or indirect result of injury undergo a complete forensic postmortem examination. This provides an opportunity to capture

From the Department of Surgery (Abdalla, Gunst, Ghaemmaghami, Barber, Gentilello, Shafi) and the Department of Pathology (Gruszecki, Urban), The University of Texas Southwestern Medical School, Dallas, TX; and the Institute for Health Care Research and Improvement, Baylor Health Care System, Dallas, TX (Shafi).

Presented at the annual research meeting of Academy Health, June 8–10, 2008, Washington, DC.

Corresponding author: Shahid Shafi, MD, MPH, Baylor Health Care System, 1600 W. College Street, Suite LL 10, Grapevine, TX 76052 (e-mail: shahid.shafi@baylorhealth.edu).

all IRDs, including scene deaths, hospital deaths, and late deaths in Dallas County. Data collected by the county medical examiner's office consist of information obtained from scene investigations, police reports, prehospital and hospital records, and autopsy and toxicology findings. Data obtained for the current study consisted of geographic location of the injury at the level of the street address, including city and zip code, as well as mechanism of injury and demographic characteristics such as age, sex, and race.

A total of 4318 deaths were reported to the county medical examiner in 2005. All were reviewed to identify deaths due to injuries. Victims of IRDs were excluded if they were not residents of the county or if they died outside county limits. The current study focused on six specific categories of IRDs based upon the most common mechanisms of injury and by intent: gunshot wound (GSW), MVC, motor-pedestrian collision (MPC), motorcycle crash (MCC), homicide, and suicide. The final study population consisted of 670 deaths, which constituted 16% of all deaths in the county. Some patients were classified in more than one IRD category. For example, patients who died after committing suicide with a handgun were included in both the suicide and GSW categories.

Data analysis

The standardized mortality ratio (SMR) is widely used by health professionals to compare the rates of health events among areas of differing population size (11). It is the ratio of observed deaths to expected deaths as a result of a specific cause. An SMR > 1 indicates that the observed incidence is more than expected, an SMR < 1 indicates that the observed incidence is less than expected, and an SMR equal to 1 indicates that the observed incidence is as expected.

Age adjustment (age standardization), an essential measure of adjustment that differentiates the SMR from the crude rate, is the key tool that controls for comparison among group sizes. Age adjustment can be performed using the direct or indirect method. The direct method is applied when the age-specific death rate is the subject of interest; the indirect method is applied when the age-specific death rate is not the primary concern. Because our study population included all age groups, we used the indirect method of age adjustment to compare the rate of IRDs among cities in Dallas County and the rate between Dallas County and the United States. This method assured minimum bias due to fluctuating differences in population size. The study utilized population data from the 2000 US Census and the national age-adjusted rates for 2004 to estimate the expected number of deaths for each category (per 100,000 population) of IRDs at the county and city levels. National death rates for each category (per 100,000 population) were obtained from the Centers for Disease Control and Prevention (12). A 95% confidence interval (CI) was calculated to adjust for cities with fewer IRDs. The following formulae were used to calculate the expected number of deaths and SMR with 95% CI for each of the six categories of IRDs for Dallas County and for each city within the county:

- SMR = observed number of deaths (in a city)/expected number of deaths
- Expected number of deaths = city population size × national age-adjusted rate/100,000
- 95% CI of SMR = SMR ± 1.96 × standard error
- Standard error = SMR/√observed number of deaths

The SMR was interpreted as equivalent to the national rate (represented with yellow in the figures and tables) if the 95% CI overlapped 1. The SMR was considered significantly better than the national rate (represented with green) if the point estimate was <1 and the 95% CI did not overlap 1. Conversely, the SMR was considered significantly worse than the national rate (represented with red) if the point estimate was >1 and the 95% CI did not overlap 1.

Geographic data and mapping

Geographic information on the county boundaries, cities, and road networks, as well as the population estimates of the county and cities (as of January 1, 2006), were obtained from the North Central Texas Council of Governments (13). The study utilized GIS for spatial mapping of IRDs in the county. GIS technologies use computerized referenced datasets to manage, analyze, and display geographic locations and associated attribute date. Data obtained from the medical examiner's office were converted from an Excel spreadsheet into database format and imported into a geodatabase file. ArcGIS 9.2, GIS software from Environmental Systems Research Institute, was utilized to identify exact locations of each incident by a geocoding process of assigning address data to spatial locations. A point shapefile of all deaths was then created. Data were queried and processed by GIS software, joined with a spatial layer of all the cities within the county, and displayed on maps that reflected summation and pattern of distribution of IRDs by category. GIS spatial analysis and statistical tools were applied to obtain the density of IRDs per square mile (kernel density) and to identify the mean center of IRDs, as well as geographic distribution, by obtaining one standard deviation to encompass 68% of all IRDs. GIS applications were used to translate these calculations into visual analytic maps, with individual cities outlined as units of observation.

RESULTS

The study population is described in *Table 1.* A majority of IRDs occurred in young men of various ethnicities, due primarily to GSWs and secondarily to MVCs. At the county level, Dallas County experienced death rates higher than national rates due to GSW and homicide, but death rates were lower than the national levels for suicide, MVC, and MPC *(Figure 1). Table 2* shows the number of deaths and SMRs with 95% CI for each city within the county by IRD categories. These data show that the city of Dallas had a significantly worse SMR due to GSWs, homicides, and MPCs than the national rates. The rest of the 25 cities in the county experienced IRD rates that were the same as or better than the national rates, or experienced no IRDs, as was the case in the cities of Balch Springs, Cockrell Hill, Combine, Sachse, Sunnyvale, and University Park. For example, in the category of deaths due to MVC, the cities of Dallas, Duncanville, Garland, Grand Prairie, Irving,

Table 1. Demography of injury-related deaths in Dallas County

Demographic	Injury-related deaths					
	GSW (n = 294)	Homicide (n = 249)	Suicide (n = 179)	MVC (n = 115)	MPC (n = 41)	MCC (n = 22)
Age, years (mean ± SD)	34 ± 15	30 ± 14	41 ± 16	39 ± 14	37 ± 21	28 ± 11
Sex, male (%)	87	81	85	76	80	82
Race (%)						
White	32	19	61	32	17	55
Black	32	37	15	23	39	23
Hispanic	35	41	21	39	39	18
Other	2	3	3	5	4	5

GSW indicates gunshot wound; MCC, motorcycle crash; MPC, motor-pedestrian collision; MVC, motor vehicle collision.

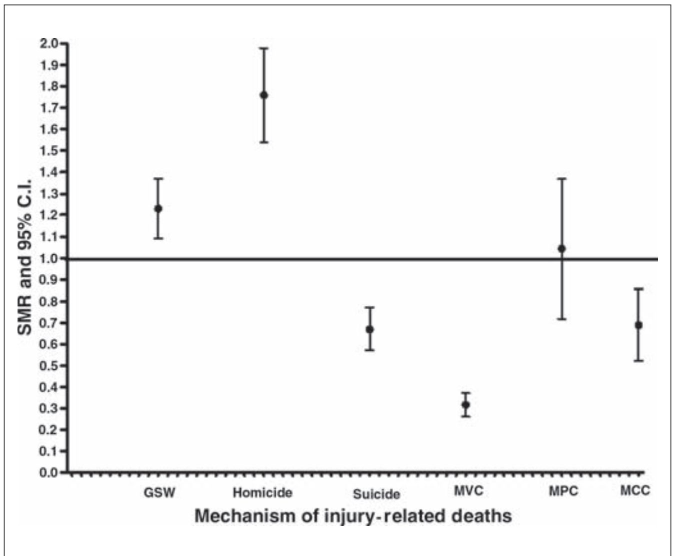

Figure 1. Injury-related deaths in Dallas County. CI indicates confidence interval; GSW, gunshot wound; MCC, motorcycle crash; MPC, motor-pedestrian collision; MVC, motor vehicle collision; SMR, standardized mortality ratio.

Lancaster, and Mesquite had significantly better SMRs. There were significantly fewer deaths due to suicide in the cities of Carrollton, Dallas, Farmer's Branch, Garland, Grand Prairie, and Irving. Some cities experienced significantly better SMRs in several categories. For example, the cities of Garland and Grand Prairie experienced better SMRs in deaths due to GSWs, homicide, suicide, and MVCs. These findings suggest that the primary reasons for the increased number of IRDs at the county level were GSWs and homicides in the city of Dallas. At the same time, the county had fewer deaths due to suicide, MVC, and MCC.

GIS mapping was used to depict this information visually, utilizing unique color codes for each city based upon its SMR *(Figure 2)*. Further, GIS spatial analysis and statistical tools were applied to locate the geographic density of GSWs, homicides, and MPCs (kernel density) utilizing the mean center of IRD with one standard deviation encompassing 68% of deaths within each category. These were found to be clustered in the city of Dallas *(Figure 3),* where the density of IRDs was at a maximum of five incidents per square mile.

DISCUSSION

The findings of this study demonstrate that IRDs in Dallas County were predominantly homicides due to GSW. However, IRDs due to homicides have been reported, in most cases, as homicide and GSW. This may explain the similarity between homicide and GSW in frequency of incidences and density at a geographic location.

Homicides due to GSW were geographically restricted to a single city, the city of Dallas. IRD rates in the rest of the cities within the county were either the same as the national rates or better. GIS mapping allowed for a clear visual depiction of the geographic location of these deaths, enabling us to identify "hot spots" of these deaths. Such visual depictions greatly enhance the legibility of the data.

Injuries are a leading cause of death and disability and are the leading cause of death in the first four decades of life (14). Previous studies have shown that the vast majority of these deaths occur at the scene of the event due to nonsurvivable injuries (15). Hence, primary prevention of injuries remains the most important strategy to reduce the burden of IRDs on society (16). Injury prevention strategies may include a combination of engineering designs, environmental modifications, education, and enforcement of specific laws, such as speeding, seat belt usage, and drunk driving. In order to maximize their impact, these strategies need to be targeted toward the communities at highest risk of injuries. GIS technology provides a way to identify these target communities, as shown in this paper and previous published studies (2–5, 17).

Our findings suggest that in Dallas County, injury prevention efforts should be targeted toward the city of Dallas. In addition, these efforts should focus on reducing injuries due to GSW and MPC. By utilizing street-level geographic information of IRD by zip code, census tract, or block, GIS technology is also able to further localize specific neighborhoods within the city of Dallas that are most likely to benefit from prevention efforts. Such analyses may also help to determine the relationship between the frequency of IRDs and the time of occurrence (day of the week, time of the day). This information may be used to further customize injury prevention interventions toward the target population.

The maps generated suggest that GIS technology has important applications in injury prevention and control. From a scientific standpoint, GIS enabled us to pinpoint high-risk geographic locations on countywide maps, which may be studied to identify potential reasons for occurrence of those injuries. For example, there may be a higher rate of deaths due to MPC at a specific intersection if there are no pedestrian crossings or if the

Table 2. Injury-related deaths in Dallas County

City	Population	Deaths	Standardized mortality ratio (confidence interval)					
			GSW	Homicide	Suicide	MVC	MPC	MCC
Addison	15,100	3	0.67 (–0.64, 1.97)	0	1.82 (–0.24, 3.87)	0	0	0
Carrollton	50,467	9	0.20 (–0.19, 0.59)	0.68 (–0.26, 1.61)	0.36 (–0.14, 0.87)	0	1.24 (–1.19, 3.67)	2.98 (–1.15, 7.11)
Cedar Hill	43,050	4	0.93 (0.02, 1.85)	0.40 (–0.38, 1.17)	0.64 (–0.08, 1.36)	0	0	0
Coppell	39,200	4	0.77 (–0.10, 1.64)	0	0.70 (–0.09, 1.49)	0	0	0
Dallas	1,272,850	485	1.71 (1.48, 1.93)	2.77 (2.39, 3.15)	0.68 (0.54, 0.81)	0.42 (0.33, 0.52)	1.57 (1.03, 2.12)	0.89 (0.44, 1.33)
DeSoto	46,950	5	0.64 (–0.08, 1.37)	0	0.78 (0.02, 1.54)	0	0	0
Duncanville	37,750	6	1.07 (0.02, 2.11)	0.90 (–0.35, 2.15)	0.48 (–0.19, 1.16)	0.36 (–0.14, 0.86)	0	0
Farmers Branch	27,950	5	1.44 (0.03, 2.85)	2.44 (0.05, 4.83)	0.33 (–0.31, 0.97)	0	0	0
Garland	223,550	35	0.50 (0.20, 0.79)	0.46 (0.09, 0.82)	0.57 (0.27, 0.87)	0.27 (0.10, 0.45)	0	0.67 (–0.26, 1.60)
Grand Prairie	156,000	15	0.32 (0.04, 0.61)	0.44 (0.01, 0.86)	0.29 (0.04, 0.55)	0.17 (0.00, 0.35)	0.40 (–0.38, 1.19)	0.48 (–0.46, 1.43)
Highland Park	8,700	1	0	0	1.05 (–1.01, 3.11)	0	0	0
Hutchins	3,000	4	10.06 (–1.32, 21.4)	11.36 (–4.4, 27.1)	3.05 (–2.93, 9.03)	0	0	0
Irving	202,750	31	0.45 (0.15, 0.74)	0.42 (0.05, 0.79)	0.45 (0.17, 0.73)	0.27 (0.08, 0.46)	0.92 (–0.12, 1.97)	0.37 (–0.36, 1.10)
Lancaster	33,450	9	2.11 (0.55, 3.66)	1.53 (–0.20, 3.26)	1.37 (0.17, 2.57)	0.20 (–0.20, 0.60)	0	0
Mesquite	136,100	31	0.74 (0.28, 1.20)	1.00 (0.31, 1.70)	0.74 (0.30, 1.18)	0.30 (0.06, 0.54)	1.38 (–0.18, 2.98)	0
Richardson	97,550	16	1.03 (0.39, 1.67)	0.52 (–0.07, 1.12)	0.84 (0.29, 1.40)	0	0	0.77 (–0.74, 2.28)
Rowlett	53,100	3	0.19 (–0.18, 0.56)	0	0.52 (–0.07, 1.10)	0	0	0
Seagoville	12,550	1	0	0	0	0.54 (0.0, 1.61)	0	0
Wilmer	3,100	3	3.25 (–3.12, 9.61)	5.50 (–5.28, 16.3)	2.95 (–2.83, 8.74)	2.20 (–2.11, 6.51)	0	0
Dallas County	2,397,350	670	1.23 (1.09, 1.37)	1.76 (1.54, 1.98)	0.67 (0.57, 0.77)	0.32 (0.26, 0.37)	1.04 (0.72, 1.37)	0.69 (0.40, 0.98)

Yellow indicates the same as the national rate; green, significantly better than the national rate; red, significantly worse than the national rate; GSW, gunshot wound; MCC, motorcycle crash; MPC, motor-pedestrian collision; MVC, motor vehicle collision.

time allocated by the traffic lights for pedestrians is inadequate for safe crossing. A cluster of deaths due to GSW may be used to increase police patrols in specific neighborhoods. A rash of car crashes on particular streets may indicate the need for better lighting, speed limit enforcement, or checks for driving under the influence. Hence, from a policy perspective, GIS mapping may be used to identify target communities, set priorities for injury prevention interventions, and allocate appropriate resources to specific communities. The visual depiction of IRDs provided by these maps represents a powerful tool to educate policy makers and stakeholders at the local, state, regional, and national level.

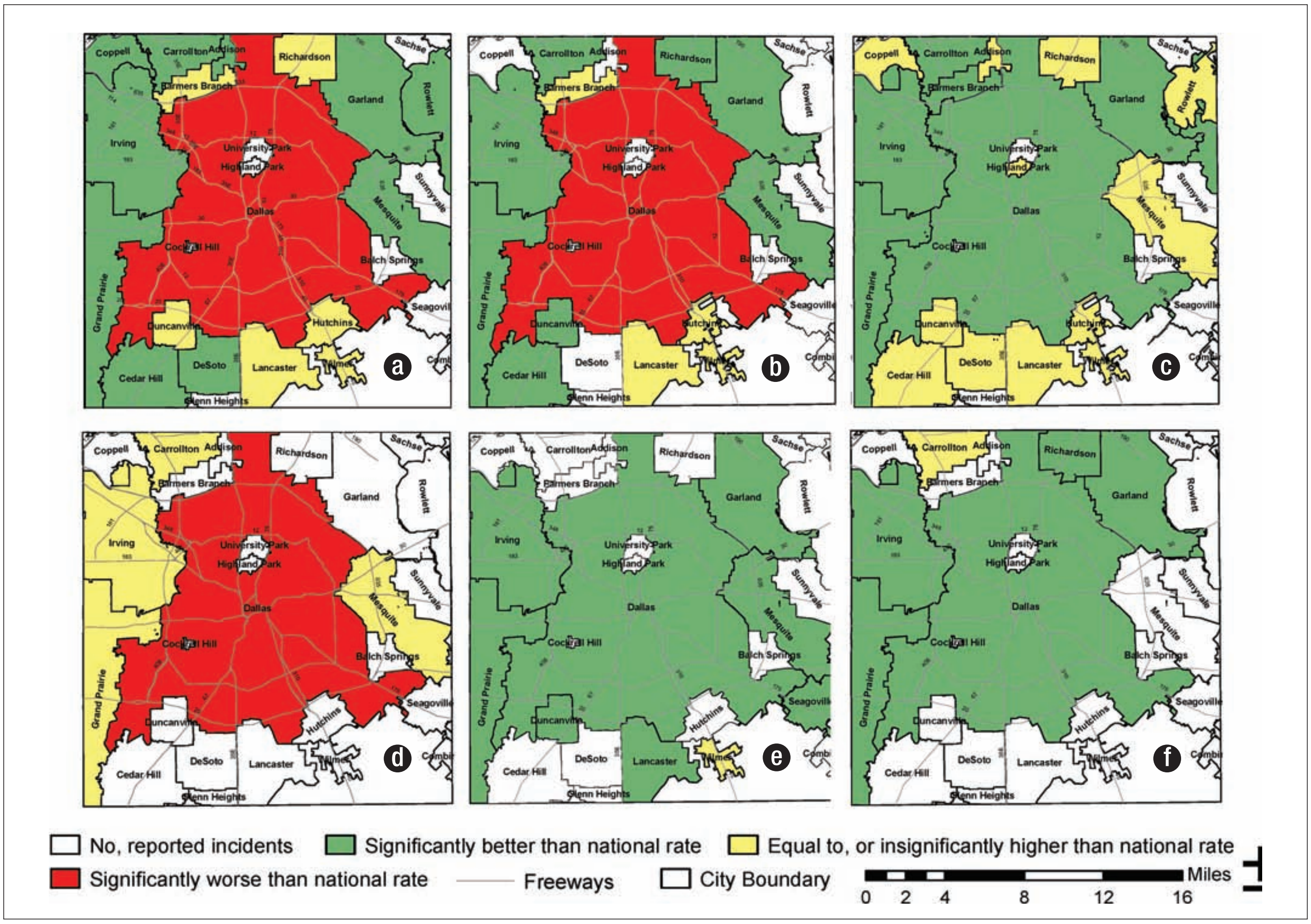

Figure 2. GIS mapping of injury-related deaths by city in Dallas County: Deaths due to **(a)** gunshot wound; **(b)** homicide; **(c)** suicide; **(d)** motor-pedestrian collision; **(e)** motor vehicle collision; **(f)** motorcycle crash.

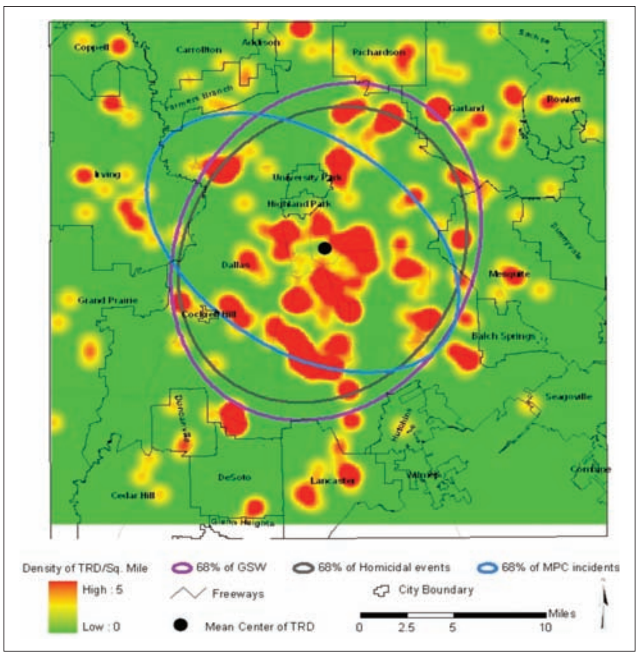

Figure 3. Density of trauma-related deaths per square mile in Dallas County, Texas, in 2005, showing GIS "hot spots" for trauma-related deaths due to gunshot wound (GSW, purple circle), homicide (gray circle), and motor-pedestrian collision (MPC, blue circle).

The study has a few limitations. Several cities had very few deaths due to injuries, resulting in potentially unstable estimates of SMRs with wide CIs. The study also did not include races other than black, white, and Hispanic in the analysis. However, races not included constituted only 4% of the county population. More detailed analysis of these data at the specific neighborhood level was not undertaken but may be necessary for devising injury prevention interventions. Such analysis is easily obtainable, as mentioned above. Although Dallas County residents who died outside the county were not captured, the primary purpose of the study was to locate high-risk areas within the county. Because of the complexity and resource intensity of IRD record retrieval arising from privacy concerns and confidentiality laws and regulations, the authors were unable to compare the incidence rate of IRDs of 2005 with that of previous years. Our study neither investigated date and time of IRD nor linked IRD rate to census attribute data. The population of the county and the cities was assumed to be constant over the study period. However, changes in population size are likely due to influx of new residents, or temporary changes during specific hours of the day or days of the week because of commuters. Finally, indirect adjustment was used based upon US national injury mortality rates. More accurate rates may be calculated using multivariate modeling.

However, we did not have the requisite data for undertaking multivariate risk adjustment.

In conclusion, Dallas County IRD rates due to GSW, homicide, and MPC were significantly higher than national rates. However, these deaths were restricted to the city of Dallas, while the rest of the cities in the county experienced IRD rates that were either the same as or better than national rates. GIS enabled us to visually depict specific geographic locations or "hot spots" of IRDs, which may be used to identify target communities for injury prevention interventions.

Acknowledgments

The authors would like to thank Dr. Ronald Briggs and Dr. Michael Tiefelsdorf in the Department of Geographic Information Systems, School of Economic, Political, and Policy Sciences at the University of Texas at Dallas for their invaluable help in this study. The authors also wish to thank Kelli R. Trungale, MLS, ELS, for editorial assistance.

1. Wiafe S, Davenhall B. Extending disease surveillance with GIS. *ArcUser* 2005;8(2):1–4. Available at http://www.esri.com/library/reprints/pdfs/arcuser_extend-disease.pdf; accessed January 20, 2012.
2. Edelman LS. Using geographic information systems in injury research. *J Nurs Scholarsh* 2007;39(4):306–311.
3. Oppong JR, Denton C. HIV/AIDS among teens and young adults (13-24) in Dallas County, TX 1999–2002. *Public Health GIS News and Information* 2006;72:22–24. Available at http://www.emro.who.int/ceha/pdf/newsletter.pdf; accessed January 20, 2012.
4. Cromley EK, Kapp M, Pope BR. Analyzing motor vehicle injuries with the Connecticut Crash Outcome Data Evaluation System GIS. *Annual Review of Public Health* 2003;24:377–381.
5. Williams KG, Schootman M, Quayle KS, Struthers J, Jaffe DM. Geographic variation of pediatric burn injuries in a metropolitan area. *Acad Emerg Med* 2003;10(7):743–752.
6. US Census Bureau. Population estimates for the 100 largest U.S. counties based on July 1, 2004 population estimates: April 1, 2000 to July 1, 2004. Available at http://www.census.gov/popest/data/counties/totals/2004/tables/CO-EST2004-08.xls; accessed January 20, 2012.
7. North Central Texas Council of Governments. Census 2000 downloadable data. Available at http://www.nctcog.org/ris/census/download.asp; accessed January 20, 2012.
8. US Department of Justice, Federal Bureau of Investigation. Crime in the United States 2005: offenses known to the police. Available at http://www2.fbi.gov/ucr/05cius/about/index.html; accessed January 20, 2012.
9. Trahan J. Police, prosecutors to crack down on career petty criminals. *Dallas Morning News,* 2005.
10. State of Texas. Code of Criminal Procedure. Available at http://www.statutes.legis.state.tx.us/Docs/CR/htm/CR.49.htm; accessed January 20, 2012.
11. Friis RH, Sellers TA. *Epidemiology for Public Health Practice*. Sudbury: Jones and Bartlett Publishers, 2004.
12. Centers for Disease Control and Prevention. Injury prevention and control: data and statistics (WISQARS™). Available at http://www.cdc.gov/injury/wisqars/fatal.html; accessed January 20, 2012.
13. North Central Texas Council of Governments. Population estimate 2007. Available at http://www.nctcog.org/ris/demographics/population/PopEst2007.swf; accessed January 20, 2012.
14. Centers for Disease Control and Prevention. Deaths and mortality. Available at http://www.cdc.gov/nchs/fastats/deaths.htm; accessed January 20, 2012.
15. Trunkey DD. Trauma. Accidental and intentional injuries account for more years of life lost in the U.S. than cancer and heart disease. Among the prescribed remedies are improved preventive efforts, speedier surgery and further research. *Sci Am* 1983;249(2):28–35.
16. Stewart RM, Myers JG, Dent DL, Ermis P, Gray GA, Villarreal R, Blow O, Woods B, McFarland M, Garavaglia J, Root HD, Pruitt BA Jr. Seven hundred fifty-three consecutive deaths in a level I trauma center: the argument for injury prevention. *J Trauma* 2003;54(1):66–70.
17. Cromley EK, McLafferty S. *GIS and Public Health*. New York: Guilford Press, 2002.