

The Rural-Urban Continuum

Variability in Statewide Serious Firearm Injuries in Children and Adolescents

Michael L. Nance, MD; Lex Denysenko, BS; Dennis R. Durbin, MD, MSCE;
Charles C. Branas, PhD; Perry W. Stafford, MD; C. William Schwab, MD

Objective: To compare rates of serious firearm injuries among children and adolescents treated in a statewide trauma system.

Materials and Methods: We reviewed the Pennsylvania Trauma Systems Foundation (Mechanicsburg) registry from January 1, 1987, through December 31, 2000, for all pediatric and adolescent patients (age 0-19 years) who sustained a serious firearm injury. Data included age, sex, weapon, geographic region, injury circumstance, and outcome.

Results: During the 14-year period, 3781 children and adolescents sustained a serious firearm injury and were treated at a participating Pennsylvania trauma center. The population was 90.7% male, with a mean age of 16.5 years. Adolescents (age 15-19 years) represented more than 85% of the study population. There were 744 deaths (19.7%). The urban counties had an average annual population-based rate of serious firearm injury of 28.3/100 000; suburban counties, 2.8/100 000; metropolitan counties, 2.4/100 000; and nonmetropolitan counties, 2.4/100 000.

Urban counties had a higher rate for all injury circumstances (unintentional, assault, and self-inflicted) than all nonurban counties. Assault was the most common overall injury circumstance (78.7%), and was the most common circumstance in urban counties (88.5%) and among adolescents (age 15-19 years [84.2 %]). Unintentional injuries predominated in nonmetropolitan counties (56.7%) and in young children (aged <5 years [50.6%] and 5-9 years [61.4%]). Handguns were the most common weapon type in all age groups, geographic regions, and injury circumstances.

Conclusions: Rates of serious firearm injuries among children and adolescents are 10-fold higher in urban than nonurban regions. Assaultive injury mechanisms predominated in urban areas, unintentional injuries in the nonurban counties. Firearm injury statistics are heavily influenced by events in the urban counties. Intervention and prevention strategies need to account for these regional discordances to optimize efficacy.

Arch Pediatr Adolesc Med. 2002;156:781-785

From the Departments of Pediatric Surgery (Drs Nance and Stafford) and Pediatrics (Dr Durbin), Children's Hospital of Philadelphia, Division of Trauma and Surgical Critical Care, Hospital of the University of Pennsylvania (Mr Denysenko and Dr Schwab), and the Center for Clinical Epidemiology and Biostatistics, University of Pennsylvania (Dr Branas), Philadelphia.

AT THE PEAK of the firearm injury epidemic in the mid-1990s, an estimated 16 children and adolescents (age 0-19 years) died each day from a firearm injury.¹ Despite declining overall national trends in fatal firearm injuries, such injuries still represent the second leading cause of death in Americans aged between 1 and 19 years.² Most reports in the pediatric population focus solely on fatal firearm injuries and have documented this high rate of firearm mortality.^{3,4} Other reports of pediatric firearm injury have been limited to a single locale, typically an urban center and, thus, characterize only a subset of the overall problem.^{5,6} The objective of this study was to investigate the variability in firearm injury that exists across the rural-urban continuum in a statewide trauma system. In addition, we focused on children and adolescents with

serious firearm injuries (both fatal and non-fatal) as they required hospitalization and/or significant use of hospital resources in treatment.

RESULTS

From January 1, 1987, to December 31, 2000, there were 3781 pediatric and adolescent firearm victims reported to the PTSF for whom a complete data set was available. Children and adolescents (age 0-19 years) represented 26.5% of the statewide population (3 179 980 of 12 022 128 Pennsylvania citizens). Characteristics of the study sample are provided in **Table 2**. The average annual rate of serious firearm injuries statewide was 8.5 cases per 100 000 children. The annual number of firearm injuries over the 14-year period varied from a low of 97 cases in 1987 to a peak of 365 cases for 1993-1994. There

MATERIALS AND METHODS

From January 1, 1987, through December 31, 2000, the Pennsylvania Trauma Systems Foundation (PTSF), Mechanicsburg, registry was reviewed for firearm injuries in pediatric and adolescent patients (age 0-19 years). The PTSF is a statewide registry of 26 participating trauma centers (adult and pediatric) within Pennsylvania. For 51 of Pennsylvania's 67 counties, a trauma center is located within the county or in an adjoining county. These 51 counties include 84% of Pennsylvania's population.⁷ By comparison to National Vital Statistics data, the PTSF database captured 64% of the children and adolescents who were fatally injured by a firearm.⁸ The remaining 36% were either treated at a nonparticipating trauma center or transported directly to the medical examiner's office. For inclusion in the PTSF, registry patients must satisfy 1 of the following criteria: length of hospital stay of 72 hours or longer, transfer from another institution, intensive care unit admission, or emergency department or in-hospital death. Patients treated and released from the emergency department, those treated at a nonparticipating hospital, or patients who died in the field were not captured in the PTSF database. Data were collected by trained trauma registrars in individual institutions and submitted to a central database. To minimize data errors, registrars attend mandatory training sessions semi-annually, one of which focuses on interabstractor reliability. Audits are also performed regularly to monitor coding accuracy of the data submitted. In addition to standard comprehensive demographic, clinical, and outcome information, a written description of the injury and circumstances was also included. For this study, we reviewed patient age at the time of injury, sex, county in which injury occurred, injury circumstance (E-code), firearm used, and patient outcome.

The state was divided into geographic regions based on rural-urban continuum (RUC) codes, a classification scheme devised by the US Department of Agriculture as a measurement of rurality.⁹ The RUC codes contain 10 distinct categories and characterize metropolitan counties by size, and nonmetropolitan counties by degree of urbanization and proximity

to metropolitan areas (**Table 1**). The RUC codes were available for all counties in the state.⁹ Metropolitan counties (n=33) included RUC codes 0 through 3 and nonmetropolitan counties (n=34) RUC codes 4 through 9. The RUC code 0 includes counties constituting a metropolitan statistical area exceeding 1 million population. For example, Philadelphia county (urban county) and surrounding counties (Delaware, Chester, and Montgomery: suburban counties) all receive a RUC code of 0. To separate the effect of the urban county from the suburban county, the 2 urban counties in the state (Philadelphia and Allegheny) were considered as a separate category—urban. The remaining RUC code 0 counties were categorized as suburban. Those counties in RUC code 1 through 3 counties were considered metropolitan. All nonmetropolitan counties (RUC codes 4-9) were considered collectively as nonmetropolitan.

Firearm injury rates were determined for the various geographic regions based on population statistics for individual counties. The population-based rate of events was calculated as the average annual number of cases per 100 000 children for the study period. The population statistics were based on the population estimates for July 1993, the midpoint of the study. Estimates were obtained for each county within the state for children and adolescents age 0 through 19 years.¹⁰

Injury circumstances were determined by the reported E-code and were compared with and supplemented by the written description provided to the PTSF. Circumstances were categorized as unintentional, assault, self-inflicted, or unknown. Assaults included those injuries in which a weapon was discharged with an inherent intent-to-injure and included drive-by shootings, cross-fire, homicides, and assaults without further specification. Self-inflicted injuries included suicide and suicide attempts. Self-inflicted cases in which intent could not clearly be identified were categorized as unintentional.

Identification of the weapon type was based on the E-code reported and the written description of the incident provided to the PTSF. Categories of firearms included handgun, rifle, shotgun, nonpowder firearm, and unknown. Specific information regarding the weapon, such as caliber or make or model was not routinely available for review.

Table 1. Definitions of Rural-Urban Continuum Codes*

Code	Description
Metropolitan Counties	
0	Central counties of metropolitan areas ≥ 1 million population
1	Fringe counties of metropolitan areas of ≥ 1 million population
2	Counties in metropolitan areas of 250 000 to 1 million population
3	Counties in metropolitan areas of < 250 000 population
Nonmetropolitan Counties	
4	Urban population of ≥ 20 000, adjacent to metropolitan area
5	Urban population of ≥ 20 000, not adjacent to metropolitan area
6	Urban population of 2500 to 19 999, adjacent to a metropolitan area
7	Urban population of 2500 to 19 999, not adjacent to a metropolitan area
8	Completely rural or < 2500 urban population, adjacent to a metropolitan area
9	Completely rural or < 2500 urban population, not adjacent to a metropolitan area

*Modified from Economic Research Service, US Department of Agriculture.⁸

were 744 deaths [19.7%] of the sample studied. The case-fatality rate for in-hospital, trauma center-treated patients showed little variation between regions, ranging from 19.5% in the urban counties to 21.4% in the nonmetropolitan counties.

GEOGRAPHIC REGION

Most firearm injuries (77.4%) occurred in urban counties, with 7.9% in suburban counties, 10.2% in metropolitan counties, and 4.5% in nonmetropolitan counties. The annual rate in the urban counties was 10-fold greater than in the next highest region (28.3/100 000 vs 2.8/100 000) (**Table 3**). Nonurban counties had similar overall annual rates of firearm injury (range, 2.4/100 000 to 2.8/100 000). The distribution of injury circumstances across geographic regions differed (**Figure 1**). Assaults, by far, accounted for the greatest proportion (88.5%) of firearm injuries in the urban regions. Assaults were also predominant in the suburban (57.0%) and metropolitan (48.1%) regions but to a lesser de-

Table 2. Characteristics of the Study Sample by Geographic Region, 1987-2000

	Urban (n = 2925)	Suburban (n = 298)	Metropolitan (n = 387)	Nonmetropolitan (n = 171)	Total (N = 3781)
Age, mean, y	16.8	15.4	16.0	14.5	16.5
% of males	91.7	88.6	88.1	84.2	90.7
Fatality, %	19.5	20.1	19.9	21.6	19.7

Table 3. Rate of Firearm Injury by Geographic Region

	No. of Population	Total*	Unintentional	Assault	Suicide	Unknown
Urban	2925	28.31	1.91	25.05	0.78	0.57
Suburban	298	2.75	0.74	1.57	0.31	0.13
Metropolitan	387	2.38	0.72	1.14	0.35	0.16
Nonmetropolitan	171	2.42	1.37	0.42	0.47	0.16
Total	3781	8.49	1.11	6.68	0.46	0.25

*Values indicate firearm injury rate per 100 000.

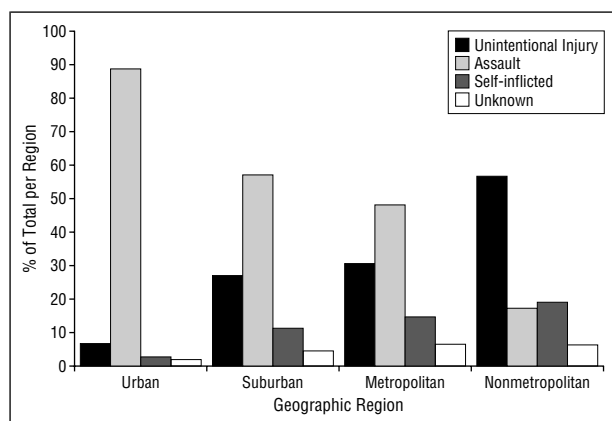


Figure 1. Circumstances of injury based on geographic region in which injury occurred.

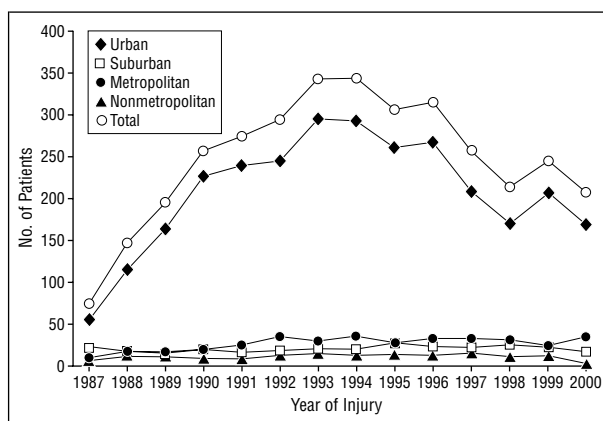


Figure 2. Trends in firearm injury by geographic region over the period of the retrospective review.

gree. In the nonmetropolitan counties, unintentional injuries were most frequent (56.7%).

The overall rate of firearm injury varied substantially over time. This variation is almost completely due to changes in the rate of firearm injury in the urban counties (**Figure 2**). The rate of injury peaked in 1993-1994 and gradually receded to levels approximately twice the rate noted at the commencement of this study. Firearm injuries in the suburban, metropolitan, and nonmetropolitan counties had far less variation over time.

AGE

The study sample was divided into 4 age groups: younger than 5 years (n=93), 5 to 9 years (n=83), 10 to 14 years (n=381), and 15 to 19 years (n=3224). The average annual rate of firearm injury differed by age. Adolescents had the highest rate of firearm injury (30.2/100 000). The average annual rate of injury was significantly lower in the nonadolescent age groups (10-14 years, 3.4/100 000; 5-9 years, 0.7/100 000; and <5 years, 0.8/100 000). Age affected the distribution of injury circumstances as well (**Figure 3**). Younger children (0-9 years) were more likely to be involved in unintentional shoot-

ings than any other injury circumstance. Assault was the most common injury circumstance for older children (age 10-19 years) including adolescents (age 15-19 years) in whom assaults accounted for 84.2% of injuries.

INJURY CIRCUMSTANCE

The rate of assaultive injuries varied over time (**Figure 4**). Coincident with the peak in firearm injuries in the urban regions in the mid-1990s was the rise in assaultive injuries. All other injury circumstances remained relatively stable over the period of review. The urban counties had a greater average annual rate for all injury circumstances than any other region (Table 3). Assaults were 6-fold more common than unintentional injuries across the statewide population. After assaults in the urban counties, unintentional injuries in the urban counties had the highest annual rate.

WEAPON

The weapon type was identified in only 55.3% of shootings. Interpretation of weapon data is thus limited. The handgun was the most common weapon type identified

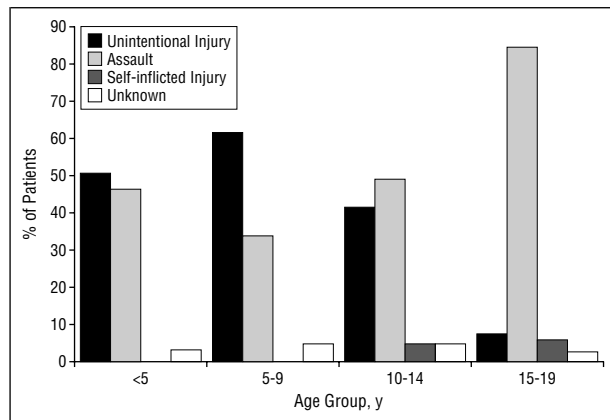


Figure 3. Circumstances of injury based on age of patient in whom injury occurred.

for all age groups and in all geographic regions. However, there were notable differences in the distribution of firearm types by geographic region. In the urban setting, when a weapon was identified, it was a handgun in 89.4% of cases. In the nonurban setting, the handgun again was the single most common weapon type identified (suburban, 78.8%; metropolitan, 61.0%; and nonmetropolitan, 36.4%); however, there was a greater proportion of other weapons noted. Long guns (shotguns and rifles) were documented with greater frequency in the nonurban counties (suburban, 15.9%; metropolitan, 33.6%; and nonmetropolitan, 57.6%) than in urban counties (8.3%).

COMMENTS

Results of this study demonstrate notable differences in serious fatal and nonfatal pediatric firearm injury characteristics based on the degree of urbanization of a community. Application of the RUC codes to the study of firearm injuries has previously been reported.^{11,12} In those studies, the population was limited to teenagers and young adults and looked at all causes of homicide (ie, firearm and nonfirearm).^{11,12} In those studies, RUC code 0 was considered a single group, the core metropolitan area. The core metropolitan region included both the central urban county as well as surrounding suburban counties that constituted the metropolitan statistical area. In the current study, the RUC 0 counties were subdivided into central, urban counties (Philadelphia and Allegheny counties) and surrounding, suburban counties. It is apparent that such discrimination is necessary as the urban counties had a different firearm injury profile than the adjacent suburban counties. Thus, intervention and prevention programs designed for use in the urban counties of Pennsylvania might not be as effective in the surrounding suburban counties despite geographic proximity.

Regional variation in firearm injuries has previously been examined in Pennsylvania for nonfatal shootings for all age groups.¹³ Firearm injury figures are heavily influenced by the urban shootings and, thus, may not reflect the injury patterns of surrounding or distant communities. In this study, despite the proximity to the urban counties, the suburban counties had firearm injury rates approximating the metropolitan and nonmetropolitan

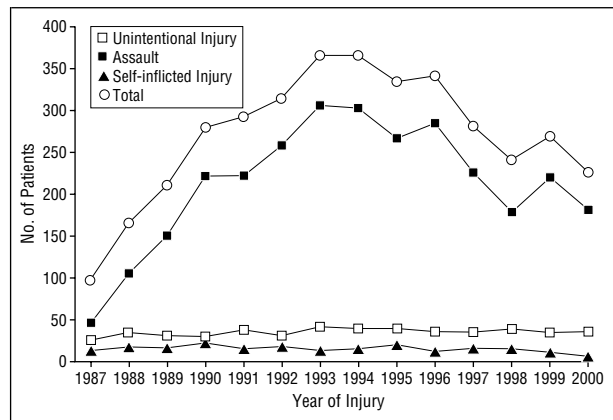


Figure 4. Trends in firearm injury circumstance over the period of the retrospective review.

counties, all significantly lower than the urban counties. Our rate of serious firearm injuries (28.3/100000) in the urban counties was similar to that previously reported for Northern Manhattan (New York) (including Harlem, 31.13/100000) for children 0 to 16 years old.¹⁴ Knowledge of the injury circumstances in a region is important to direct community-specific interventions. Again, programs designed to reduce the occurrence of urban assaultive gun violence may not be as effective for unintentional shootings, which are more prevalent in the nonurban regions. A similar approach has been suggested from a public policy viewpoint.¹⁵ As firearm mortality rates vary by regions within a state, uniform gun laws throughout a state may not be necessary nor optimal. Legislation designed and implemented within a specific locality may be more effective.

In our statewide population, older children (age 10-19 years) were typically injured by assaultive shootings (80.5%), while younger children (age 0-9 years) were more likely to be involved in unintentional shootings (55.7%). Variation in firearm injury circumstance based on age differences was also reported by Li et al¹⁶ in their population of children 14 years and younger. Children in the 0- through 4-years and 10- through 14-year age groups had an increased likelihood of assaultive injuries. Thus, firearm injury prevention initiatives should also be tailored to the age of the target population.

In a review of 10 years of pediatric gunshot wounds at an urban trauma center, a 30% increase in the number of firearm injuries was noted in the second half of the study (early 1990s). The upward trend was a reflection of an increase in assaultive injuries.¹⁷ A similar trend was noted in national statistics documenting a peak in firearm mortality in 1993-1994.¹⁸ Since that report, the incidence of fatal firearm injuries has declined across the country.¹⁸ We noted a similar trend in our serious pediatric and adolescent firearm injured population. The urban counties were responsible for most of the firearm injury cases with a peak in 1994. The yearly count has declined significantly since that peak but remains higher than those levels noted in the late 1980s when this review commenced. In the suburban, metropolitan, and nonmetropolitan counties, there has been less variation; in general, the rate remains higher than the levels documented in the late 1980s.

What This Study Adds

This study provides information about the rate of serious firearm injuries among children and adolescents based on degree of urbanization of the geographical region in which the injury occurred. Our results suggest that in Pennsylvania, multifaceted intervention and prevention strategies designed for individual communities will likely be necessary to most effectively combat firearm injuries in children within a respective geographic region.

The handgun was the most common weapon type identified in this study and was responsible for 80% of all shootings in which a weapon type was identified in the PTSF registry. This is likely an underestimation of the role of the handgun as many of the undetermined cases such as cross-fire or drive-by shootings were probably handgun related. This preponderance of handgun-related injury represents an increase from reports of prior decades when handguns accounted for 45% to 60% of firearm injuries.¹⁹⁻²² Firearm injury prevention efforts likely need to shift from elimination of the weapon to adapting and living in a world replete with firearms.

This study is confined by several limitations inherent to a review of trauma registry data. It is best used as a descriptor of trends within the groups studied. This review likely underestimates the burden of firearm injuries on children in Pennsylvania as not all firearm injuries (fatal or nonfatal) in this population are captured in the PTSF registry. However, given the inclusion criteria of the PTSF registry, it is likely that most of the serious nonfatal and treated but fatal firearm injuries were included. Given the criteria for inclusion in the PTSF registry (ie, hospital length of stay >72 hours, intensive care unit admission, or death), there is a selection bias toward the most serious firearm injuries. This also affords a unique window on those injuries that are resource intensive. Pennsylvania has a large number of registered hunters. This may effect the distribution and weapon type within the state compared with other states. Thus, results of this study may not be generalizable to other geographic regions of the country. However, Pennsylvania includes 2 large urban regions—Philadelphia and Pittsburgh—as well as several additional large metropolitan areas and nonmetropolitan regions, making it an ideal state in which to study variations in firearm injury circumstances by geographic location.

Accepted for publication April 19, 2002.

These data were provided by the PTSF registry as part of the Pennsylvania Trauma Outcome Study.

The PTSF specifically disclaims responsibility for any analysis, interpretations, or conclusions as the source of data.

Corresponding author: Michael L. Nance, MD, Department of Pediatric Surgery, Children's Hospital of Philadelphia, 34th and Civic Center Boulevard, Philadelphia, PA 19104 (e-mail: nance@email.chop.edu).

REFERENCES

1. Centers for Disease Control and Prevention resources page. National Center for Injury Prevention & Control. Fatal injuries: leading causes of death reports. Available at: <http://webapp.cdc.gov/sasweb/ncipc/leadcaus.html>. Accessed February 1, 2002.
2. Centers for Disease Control and Prevention resources page. National Center for Injury Prevention & Control. Fatal injuries: mortality (fatal injury) reports. Available at: <http://webapp.cdc.gov/sasweb/ncipc/mortrate.html>. Accessed February 1, 2002.
3. Beaver BL, Moore VL, Pecllet M, Haller JA Jr, Smialek J, Hill JL. Characteristics of pediatric firearm fatalities. *J Pediatr Surg*. 1990;25:97-99.
4. Svenson JE, Spurlock C, Nypaver M. Pediatric firearm-related fatalities: not just an urban problem. *Arch Pediatr Adolesc Med*. 1996;150:583-587.
5. Nance ML, Stafford PW, Schwab CW. Firearm injury among urban youth during the last decade: an escalation in violence. *J Pediatr Surg*. 1997;32:949-952.
6. Dowd MD, Knapp JF, Fitzmaurice LS. Pediatric firearm injuries, Kansas City, 1992: a population-based study. *Pediatrics*. 1994;94(pt 1):867-873.
7. Pennsylvania Department of Health and the Pennsylvania Trauma Systems Foundation, sponsors. *Injury Care in Pennsylvania*. Harrisburg: Pennsylvania Department of Health, 1996.
8. WISQARS (Web-based Injury Statistics Query and Reporting System). Available at: <http://www.cdc.gov/ncipc/wisqars/>. Accessed February 1, 2002.
9. Economic Research Service US Department of Agriculture briefing room. Measuring rurality: rural-urban continuum codes. Available at: <http://www.ers.usda.gov/briefing/rurality/RuralUrbCon/>. Accessed February 1, 2002.
10. Behney M, Uroda R, Copella S. *1993 State and County Detailed Population Estimates: Pennsylvania*. Middletown: Pennsylvania State Data Center, 1995.
11. Fingerhut LA, Ingram DD, Feldman JJ. Firearm and nonfirearm homicide among persons 15 through 19 years of age: differences by level of urbanization, United States, 1979 through 1989. *JAMA*. 1992;267:3048-3053.
12. Fingerhut LA, Ingram DD, Feldman JJ. Homicide rates among US teenagers and young adults: differences by mechanism, level of urbanization, race, and sex, 1987 through 1995. *JAMA*. 1998;280:423-427.
13. Sing RF, Branas CC, MacKenzie EJ, Schwab CW. Geographic variation in serious nonfatal firearm injuries in Pennsylvania. *J Trauma*. 1997;43:825-830.
14. Durkin MS, Kuhn L, Davidson LL, Laraque D, Barlow B. Epidemiology and prevention of severe assault and gun injuries to children in an urban community. *J Trauma*. 1996;41:667-673.
15. Teret SP, DeFrancesco SD, Bailey LA. Gun deaths and home rule: a case for local regulation of a local public health problem. *Am J Prev Med*. 1993;9(suppl 1):44-46.
16. Li G, Baker SP, DiScala C, Fowler C, Ling J, Kelen GD. Factors associated with the intent of firearm-related injuries in pediatric trauma patients. *Arch Pediatr Adolesc Med*. 1996;150:1160-1165.
17. Nance ML, Templeton JM Jr, O'Neill JA Jr. Socioeconomic impact of gunshot wounds in an urban pediatric population. *J Pediatr Surg*. 1994;29:39-43.
18. Anonymous. Nonfatal and fatal firearm-related injuries—United States, 1993-1997. *MMWR Morb Mortal Wkly Rep*. 1999;48:1029-1034.
19. Powell EC, Tanz RR. Child and adolescent injury and death from urban firearm assaults: association with age, race, and poverty. *Inj Prev*. 1999;5:41-47.
20. Heins M, Kahn R, Bjordnal J. Gunshot wounds in children. *Am J Public Health*. 1974;64:326-330.
21. Ordog GJ, Wasserberger J, Schatz I, et al. Gunshot wounds in children under 10 years of age: a new epidemic. *AJDC*. 1988;142:618-622.
22. Valentine J, Blocker S, Chang JH. Gunshot injuries in children. *J Trauma*. 1984;24:952-956.