A Population-Based Multivariate Analysis of the Association of County Demographic and Medical System Factors with Per Capita Pediatric Trauma Death Rates in North Carolina

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Objective

This study analyzed the association between demographic and medical system factors and the pediatric trauma death rate in North Carolina.

Summary Background Data

Trauma is the leading cause of death in children. Various medical system factors have been suggested to reduce pediatric morbidity and mortality rates, but the association with these rates has not been tested.

Methods

Data were obtained from the North Carolina medical examiner's database. The dependent variable was the county per capita pediatric trauma death rate. Twenty-one demographic and medical system measures were selected as independent variables.

Results

Nine hundred forty-one pediatric trauma deaths from 1986 to 1989 were included in our sample. Multivariate analysis identified the variables most highly associated with the dependent variables. The presence of advanced life support (ALS) training was the only medical system factor associated significantly with pediatric trauma death rates. Trauma centers, emergency (911) telephone access, and other medical resource variables had no significant association.

Conclusions

The study confirms other reports showing that demographic factors have an important predictive association with the trauma death rate in children. Advanced life support was the only medical system resource associated significantly with pediatric trauma death rates. This study underlines the significance of pre-hospital care in the treatment of pediatric trauma.

Trauma kills more children than any other disease and is more common among the poor and minorities, and in rural areas.[1-4] Attention has been focused increasingly on pediatric trauma as a serious public health problem. As a result, various medical system changes have been suggested to decrease childhood deaths caused by injury.[3,5] Child safety seats, bicycle helmet laws, seat belt laws, and the implementation of pediatric advanced life support training from emergency medical services (EMS) are some interventions to decrease morbidity and mortality of childhood injury. Unfortunately, few of these suggested interventions have been tested.

This study used a statewide, population-based database to assess the association of county demographic and medical system factors with county per capita pediatric trauma death rates. This database includes information on all trauma deaths in North Carolina. Population-based studies to explore epidemiologic concerns can provide a more complete understanding of trauma death in children and can give insights into the possible effects of medical system factors on pediatric trauma deaths. Identifying the demographic variables that place children at greater risk for death due to injury and the medical system factors that are strongly associated with lower per capita trauma death rates may encourage progress in a number of areas. It may facilitate optimal development of trauma systems, use of resources to minimize the morbidity and mortality of injury, and development of appropriate injury prevention programs.

MATERIALS AND METHODS

Data Source

Data on the trauma deaths in the state were obtained from the North Carolina medical examiner's database. The N.C. Medical Examiner System was established in 1967 and contains all deaths due to injury (unintentional injury, suicide, and homicide). This database contains information on all 16,814 trauma-related deaths in North Carolina between 1986 to 1989, regardless of the time of death after injury. This information was corroborated by the North Carolina Office of Vital Statistics, which records all resident deaths in North Carolina. Of the 16,814 trauma-related deaths in North Carolina from 1986 to 1989, 13,100 occurred in individuals who lived in the county in which they sustained their injury. This subgroup of individuals was selected for further analysis.

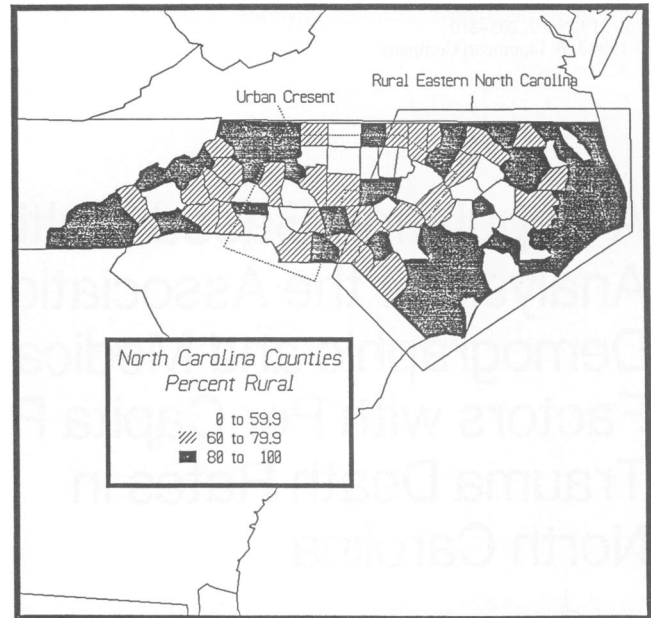Only children younger than age 15 at the time of death

Figure 1. Rural urban distribution of North Carolina counties.

were selected for the study sample. The reasons for excluding children in the 15- to 18-year age group were as follows: children older than age 15 are more likely to be operators of motor vehicles and, unlike their younger cohorts, may be drivers in motor vehicle crashes; children older than age 15 are physically more like adults than younger children; and the causes of death in children aged 15 to 18 years are more similar to those of adults than of younger children.

North Carolina Demographic Factors

There are 100 counties in North Carolina, combining rural and urban areas (Fig. 1). For this study, a county was designated as rural if more than 60% of its population lived in open countryside or in towns with populations less than 2500.

Studies have shown relationships between population demographics and traumatic injury.[6-8] County demographic descriptors were analyzed to determine their relationships to per capita pediatric trauma death rates. Twenty-one county descriptors were selected from those available from the State Office of Management and Budget. The descriptors are listed in Table 1. To select candidate variables, a preliminary group of descriptors was chosen, based on general categories of interest. Preliminary t tests were run on this group to select reasonable candidate variables for further multivariate analysis. The descriptors fell into the following categories: geographic, educational, socioeconomic, occupational, environmental, and medical factors. For this study, the North Carolina Office of Emergency Medical Services
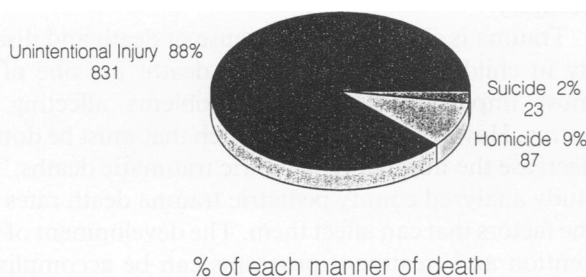
Table 1. COUNTY DESCRIPTORS

Geographic
    Population Density
    Percent rural area in county
    Rural (Y/N)
    Total population
Socioeconomic
    Mean family income
    Mean personal income
    Percent non-Caucasian
    Percent unemployed
Environment
    Miles of primary highways
    Highway exposure
Medical Resources
    No. of hospital ICU beds
    No. of hospital discharges
    No. of ED outpatient visits
    No. of general surgeons
    No. of certified general surgeons
    No. of blood banks
    No. of neurosurgeons
    No. of hospital admissions
    Trauma center in county
    Advanced life support in county
    911 in county

(NCOEMS) definition of an advanced life support (ALS) county was used. It defines an ALS county as a county that contains one or more EMS trained at or above the emergency medical technician (EMT)-D level.
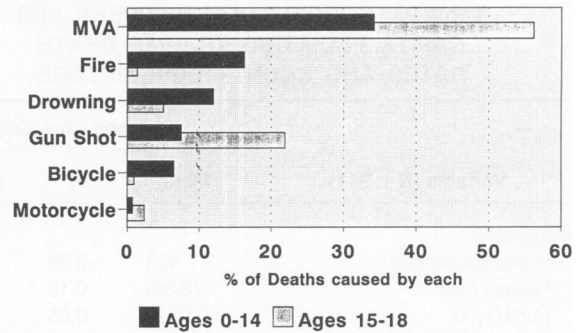
Statistical Analysis

The data were analyzed using a relational database program and an IBM-compatible computer. The file was then converted into a SAS (Statistical Analysis Systems, SAS Institute Inc., Cary, NC) data file for further analysis. The relationship of each independent variable to per capita pediatric county trauma death rates was analyzed using Pearson correlation coefficients for continuous variables and Student's t test for comparing dichoto-

Figure 2. Manner of trauma deaths in children younger than 15 years.

For NC 1986-1989

Unintentional Injury 88%
831

Suicide 2%
23

Homicide 9%
87

% of each manner of death

Means of Death

Figure 3. Comparison of means of death between ages 0 to 14 years and 15 to 18 years.

For NC 1986-1989

■ Ages 0-14 ▨ Ages 15-18

% of Deaths caused by each

mous and categorical variables (i.e., 911 telephone service, presence of trauma center, and presence of ALS or basic life support). Stepwise multiple linear regression and stepwise discriminant analyses were used to derive a multivariate model to predict pediatric county trauma death rates.

RESULTS

Children younger than 15 make up 21% of North Carolina's population. There were 13,100 trauma-related deaths in North Carolina between 1986 and 1989; 7% (941) of these deaths occurred in children younger than 15. The mean per capita county trauma death rate was 2/10,000 children per county.

Accidents (88%) were the leading cause of death for children younger than 15 years, followed by homicide (9%) and suicide (3%) (Fig. 2). Motor vehicle crashes (34%), fires (16%), drownings (12%), gun shot wounds (8%), and bicycle accidents (6%) were responsible for the majority of deaths in children younger than 15 years. The remaining 23% of deaths were a result of other events. Deaths in children age 15 to 18 years overwhelmingly were caused by motor vehicle crashes (56%) and gun shot wounds (22%) (Fig. 3).

Boys were over-represented, with 605 (64%) deaths among boys and 336 (36%) deaths among girls. There were 519 (55%) deaths among Caucasians, 381 (40%) deaths among African Americans, and 41 (4%) deaths among individuals of other races (the majority being Native Americans). African Americans make up approximately 20% of the population of North Carolina; therefore, they are over-represented in trauma deaths in children.

Univariate Analysis of the Association of Per Capita County Pediatric Trauma Death Rates with County Demographic Variables and Medical System Factors

Geographic Descriptors

Of the four geographic variables studied, two were found to be negatively correlated with per capita county

Table 2. CORRELATION BETWEEN PER CAPITA PEDIATRIC TRAUMA DEATH RATES AND COUNTY DESCRIPTORS

Variable (N = 941)	Pearson Corr. Coeff.		
	Mean	R	p Value
Geographic			
Population density	133	−0.29	0.014
Percent rural	73.8%	0.16	0.020
Rural (Y/N)	81/19*	0.25	0.197
Total population	641	−0.21	0.080
Socioeconomic			
Mean family income	$15,328	−0.20	0.093
Mean personal income	$8,850	−0.22	0.063
Percent non-Caucasian	23.3%	0.24	0.040
Percent unemployed	2.4%	0.22	0.066
Environment			
Miles of primary highways	139	0.16	0.175
Highway exposure	4877	−0.03	0.796
Medical resources			
No. of hospital ICU beds	12.08	−0.23	0.054
No. of hospital discharges	8158	−0.22	0.061
No. of ED outpatient visits	24587	0.21	0.081
No. of general surgeons	7.03	−0.20	0.101
No. of certified general surgeons	5.73	−0.19	0.108
No. of blood banks	0.97	−0.22	0.071
No. of neurosurgeons	0.04	−0.09	0.479
No. of hospital admissions	8171	−0.22	0.060
Trauma center (Y/N)	8/92*	−0.21	0.075
ALS (ALS/BLS)	76/24*	−0.34	0.003
911 (Y/N)	59/41*	−0.26	0.030

* No. of each occurrence.

Table 3. RESULTS OF MULTIVARIATE ANALYSIS (R^2 = 0.247)

Variable	Type III SS	F Value	p Value
Percent unemployed	5.37	8.96	0.004
ALS	4.62	7.72	0.007
Number miles primary highway	4.56	7.62	0.007
Rural	1.59	2.65	0.107

visits. Only two (presence of ALS and access to 911-telephone service) reached statistical significance (p = 0.003 and p = 0.030, respectively). The number of hospital intensive care unit beds was of borderline statistical significance (p = 0.054).

Multivariate Analysis of the Association of Per Capita County Pediatric Trauma Death Rates with County Demographic Variables and Medical System Factors

Univariate analyses identified a number of county descriptors and medical resources that were associated significantly with the per capita pediatric trauma death rates. Ordinary least-squares multiple linear regression was used to evaluate the association of multiple independent variables with the per capita pediatric county trauma death rates. Those variables found to be associated significantly with per capita pediatric county trauma death rates were the unemployment percentage, the presence of ALS, the primary highway mileage, and rurality (Table 3).

Discussion

Traumatic injury is the fourth leading cause of death in the United States.[9-11] It is responsible for more deaths than cancer and cardiovascular disease combined.[12] The awareness of trauma as a public health epidemic has grown in recent years;[13] this has led to the development of more effective methods of prevention and treatment of injury.

Trauma is also the leading cause of death and disability in children.[2-4] Injury-related deaths are one of the most important health-care problems affecting the young. However, there is still much that must be done to decrease the number of pediatric traumatic deaths. This study analyzed county pediatric trauma death rates and the factors that can affect them. The development of prevention and treatment programs can be accomplished only through identification and quantification of specific demographic and medical system factors that significantly affect pediatric trauma death rates.

The association of a variety of county demographic

pediatric trauma death rates (population density; R = −0.29, p = 0.014 and total population; R = −0.21, p = 0.020). Rural percentage was found to be correlated positively with per capita pediatric county trauma death rates (R = 0.16, p = 0.020) (Table 2). The less populated, more rural areas had a higher per capita death rate.

Socioeconomic

There were four socioeconomic measures of county status tested. The non-Caucasian percent of the population was the only variable associated significantly with pediatric trauma mortality rates (R = 0.24, p = 0.040).

Environment

The number of miles of primary highway and the miles of highway exposure were not related to pediatric trauma death rates.

Medical Resources

Each of the 11 medical resource variables studied correlated negatively with pediatric trauma mortality rates, except the number of emergency department outpatient

and medical system factors with the per capita pediatric county trauma death rates in North Carolina were analyzed. Several demographic variables and medical system factors were expected to demonstrate an association with the pediatric mortality rate. We hoped that identifying factors associated with trauma death would aid in the development of trauma systems and the use of resources to provide more effective treatment of pediatric trauma. This information could also be instrumental in developing appropriate injury prevention programs for children.

In this study, children were under-represented in the total population of trauma deaths; children make up 21% of the total population, but only 7% of trauma deaths occur in patients younger than age 15.

In this population-based study, the only medical system resource factor associated significantly with per capita pediatric county trauma death rate was the county level of EMS certification. No other medical resource factors were significant by multivariate analysis, including number of hospital intensive care unit beds, number of hospital discharges, number of emergency outpatient visits, number of general surgeons, number of neurosurgeons, number of hospital admissions, presence of trauma centers, and access to 911-telephone service. However, by univariate analysis, both the presence of ALS and the presence of 911-telephone service were significant.

It has been assumed that ALS does not affect the outcome of trauma.[14–16] This is the first study that has demonstrated the positive association of ALS with decreasing trauma death rates in children. Such information is important because of the controversy over "scoop and run" *versus* ALS interventions for pre-hospital care in trauma.[17] This study suggests that counties with pre-hospital providers who are trained to ALS level experience can decrease per capita pediatric trauma death rates.

Special facilities, equipment, and personnel are necessary to achieve an optimal outcome for the injured child.[5] Children often receive poor medical care from unprepared and disorganized systems; this can result in death or long-term disability.[5] Our study findings support the hypothesis that increased levels of training in the pre-hospital care phase can improve outcomes in pediatric trauma. In children with head injuries, the early endotracheal intubation provided by ALS-trained caregivers may be necessary to eliminate airway obstruction and restore breathing. However, our study was not able to demonstrate an association between any other medical system factor and pediatric injury deaths.

Adult emergency medical service systems exist in every region of the United States, but little attention has been paid to the development of emergency medical systems for the injured child.[5] In response to this problem, pediatric advanced life support (PALS) training for

emergency medical technicians has been developed. This training focuses on the special considerations and needs of the pediatric patient in an emergency. Currently, there is insufficient information on PALS and its availability in North Carolina counties. At this stage, it can only be speculated that the presence of PALS training could further reduce per capita pediatric trauma death. When sufficient information becomes available, there should be further study on this subject.

Univariate analysis showed population density, total population, rural percentage, and non-Caucasian population percentage to have a significant association with per capita pediatric county trauma death rates. Multivariate analysis showed rurality, unemployment percentage, and primary highway mileage to have a significant association with per capita pediatric county trauma death rates. The findings of the multivariate analysis suggest that children younger than 15 years are at greater risk for trauma deaths if they reside in a poor, rural county with numerous miles of primary highways and no access to ALS.

The association between the primary highway mileage and per capita county trauma death rates in children may be related to an association between highway miles and deaths due to motor vehicle crashes. Education on preventing motor vehicle crashes and enforcement of laws enacted to prevent accidents (speed limit, seat belt, child restraint, and driving-while-impaired laws) should prevent pediatric trauma deaths.

The associations between rurality and unemployment percentage and per capita pediatric county trauma deaths may be related to a variety of factors. Rural counties with high unemployment often are lower in all measures of socioeconomic status. This low socioeconomic status may impact on the type of medical resources available in the county, the quality of the resources available, and the type of treatment that the patient seeks. Other studies have indicated similarly that pediatric and adult trauma deaths are more likely to occur in rural areas rather than in urban areas.[19,20]

Males were over-represented in the sample of trauma deaths in this study. Although in North Carolina the male population younger than 15 years is approximately 51%, 64% of trauma deaths in children younger than 15 years between 1986 and 1989 were in boys. Although patterns of fatal trauma differ among countries, the high incidence of trauma among boys has been observed in many countries.[21] Further study into the causes of increased trauma in male children is necessary.

Although African Americans represent 23% of the North Carolina population, they accounted for 40% of all deaths due to injury in children younger than 15 years. Deaths and disability due to injury occur disproportionately among poor people, many of whom belong to minority groups.[1] Studies that identify the race- and

cause-specific risk factors that predispose African American children to higher death rates due to injury are necessary to reduce this incidence.[1] Injury prevention programming should be targeted at both the African American and male pediatric populations.

An unpublished study by our group on trauma death rates in total populations indicated that various factors are associated with per capita trauma death rates. In this study, univariate analysis revealed that some factors associated with per capita trauma death rates in the total population are also associated with per capita trauma death rates in children. However, some variables differed in significance between the two populations. For example, the presence of a trauma center in the county had no significant association with per capita pediatric trauma death rates in North Carolina counties, but it was associated significantly with the per capita trauma death rates in the population as a whole.[20] In a study of trauma death rates in the elderly, the only variable found to be associated significantly with elderly mortality rates of North Carolina is the non-Caucasian population percentage.[22]

The results of multivariate analysis of pediatric trauma and trauma in populations as a whole differed. Percent unemployment and the presence of ALS were the only two variables that were associated highly with per capita trauma deaths in both populations. The presence of a trauma center in the county again was associated significantly with per capita trauma death rates in the population as a whole, but not with per capita trauma death rates in children.

Although there is a common association of county descriptors, such as measures of rurality and socioeconomic status with per capita trauma death rates in both adult and pediatric populations, the types of medical system resources that are associated with decreased per capita trauma death rates vary between the two groups. Pediatric trauma should be distinguished from adult trauma in its relationship to medical system factors. Many county descriptors are associated with an increase or decrease in the risk of death from pediatric trauma. This information can aid government agencies and health-care providers in using their resources in a more efficient and economic manner. The expansion of the availability of ALS, particularly in rural counties, may lower significantly the per capita pediatric county trauma death rate. Pediatric trauma is a serious health-care problem, and this study suggests a need for improvement of prevention and treatment programs for pediatric trauma through appropriate medical system resource adjustments.

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