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RURAL MOTOR VEHICLE CRASH MORTALITY: THE ROLE OF CRASH SEVERITY AND MEDICAL RESOURCES*

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Abstract—We did a retrospective case control study to examine the relationship between the risk of dying for Michigan motor vehicle crash (MVC) drivers and the type of county (rural/nonrural) of crash occurrence, while adjusting for crash characteristics, age, sex, and the medical resources in the county of crash occurrence. The 1987 Michigan Accident Census was used to obtain data regarding all MVC driver nonsurvivors (733) and a random sample of all surviving drivers (2,483). County of crash occurrence was defined as rural or nonrural. The crash characteristics analyzed were vehicle deformity, seat belt use, and drivability of the vehicle from the scene. Age and sex of the driver were also analyzed. Medical resource characteristics for the county of crash occurrence were measured as the number of resources per square mile for each of the following: ambulances, emergency medical technicians (EMT), acute care hospital beds, and operating rooms, surgeons and emergency physicians. Also considered were the number and level of emergency rooms in the county of crash occurrence along with the maximum level of prehospital care available (basic life support versus advanced life support) in a county. Before adjusting, the relative risk (RR) for rural MVC drivers dying, compared to their nonrural counterparts, was 1.96. Adjustment for crash characteristics, age, and sex (using logistic regression) decreased the RR to 1.51. An attempt to add medical resource variables to the model resulted in high correlation with the rural/nonrural variable, as well as with each other. This multi-collinearity prevented us from providing a simple explanation of the role of medical resource variables as predictors of survival. We conclude that almost 50% of excess rural MVC mortality, as measured by the RR, can be accounted for by difference in crash characteristics and age. Delineation of the role of medical resources will require further investigation.

INTRODUCTION

Decreasing deaths from motor vehicle crashes (MVC) is a national priority (MMWR 1988). Nationwide, the death rate from motor vehicle crashes in rural areas, which is 60% greater than in nonrural areas (Office of Technology Assessment 1989), is a matter of particular concern. In a preliminary unpublished analysis, we found that rural MVC occupants in the the state of Michigan are almost twice as likely to die as their nonrural counterparts, a finding which is as yet unexplained.

Factors that could influence MVC crash survival include crash characteristics, driver age, and availability of medical resources. Data regarding driver age and crash characteristics, such as degree of vehicle deformation and seat belt use, are available through crash data files maintained by the state. Direct measures of the availability and accessibility of appropriate prehospital and hospital resources, such as the exact time it takes for MVC victims to reach medical resources in a certain county, are currently not available on statewide data bases; but indirect measures, such as the density of medical resources and the

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level of sophistication of those resources, are available and could provide insight into the problem.

The issue of geographic variation in MVC mortality has been addressed in a limited fashion by a number of studies from other areas. Waller, Curran, and Noyes (1964), in reference to excess MVC mortality in rural California, suggested that accessibility of appropriate medical care resources could be an important contributing factor. The sole data source for this study was death certificates of traffic fatalities. No direct or indirect measurements of medical resources were made in Waller's study. Studies from Vermont (Certo, Rogers, and Pilcher 1983) and Texas (Brodsky and Hakkert 1983) proposed that better training and higher levels of service might improve the quality of care and survival of victims of rural MVCs. The former study analyzed fatally injured patients who reached the emergency department (ED) alive. No attempt was made, however, to compare different geographic regions within the state in regards to outcome, EMS resources, and crash severity. The latter study analyzed only rural areas, did not control for age, did not analyze specific components of the medical care system, and did not control for vehicle deformity and restraint use.

In Great Britain, a relationship was found between mortality and proximity to emergency facilities (Bentham 1986). This study concluded that policymakers needed to pay more attention to accessibility of trauma care and emergency services. Bentham did not control for severity of crashes, considered only one medical factor (the presence or absence of a major emergency department in the area), and studied only males between the ages of 15–24. A study of pedestrian-vehicle crashes in the state of Washington (Mueller, Rivara, and Bergman 1988) noted increased mortality in rural areas and suggested that this increased mortality could be due to less readily available hospital and prehospital resources. The investigators controlled only for posted vehicle speed limits and no other crash characteristics. Death certificate data were used to determine which patients received in-field emergency care, and elapsed time from injury to death. No specific components of the EMS system were analyzed.

In 1987, Baker, Whitfield, and O'Neil noted an inverse correlation between motor vehicle death rates per 100,000 population and the population density for United States counties. They suggested that this relationship could be due to a combination of geographic variations in the types of crashes, road conditions, and medical resources, but did no analyses to support these speculations.

A recent study from Michigan (Maio et al. 1990) that sought a correlation between the motor vehicle mortality rate (MVC deaths per 100,000 population) and density of medical resources by county in Michigan, found that only a small proportion of the variation in the motor vehicle crash mortality rate could be accounted for by the density of medical resources. This finding suggested that factors other than medical resources, such as crash characteristics, should be considered when evaluating causes of excess MVC mortality in rural areas, and that, if an important relationship between medical resources and increased rural MVC mortality existed, it would not take the form of a simple linear relationship. The present study was undertaken to address these possibilities.

PURPOSE

The purpose of this study was to examine, in Michigan, the relationship for MVC drivers between the risk of dying and the type of county (rural/nonrural) in which the crash occurred, while adjusting for crash characteristics, age, sex, and medical resources in the county of crash occurrence.

METHODS

Crash data were obtained from the Michigan State Police Traffic Accident Data File. Medical resource data were obtained from the Michigan Department of Public Health.

Crash data

Michigan motor vehicle crashes are reported in a standard format to the Michigan State Police by the law enforcement officer investigating the crash. Data from these reports are abstracted and entered into a computerized data base known as the Michigan State Police Traffic Accident Data File, which is maintained by the University of Michigan Transportation Research Institute under the title of the Michigan Accident Census File (MACF). The file for 1987 contains data for 1,320 MVC occupant nonsurvivors and 937,971 occupant survivors. Pedestrians, pedicyclists, off-road vehicle occupants, and truck, bus, and emergency vehicle occupants were excluded. Eighty-two of 83 Michigan counties have MVC data in this data base (information from one sparsely populated rural county was not reported).

The study population was selected by first obtaining a random sample of 4,000 surviving occupants from the 937,971 occupant non-fatalities in the MACF, using a computerized skip method. From these 4,000 nonfatal occupants, and from all 1,320 fatal occupants, we excluded passengers and motorcyclists. Eight hundred twelve nonsurviving drivers and 2,713 surviving drivers remained. Cases containing missing information for age, seat belt use, and post-crash drivability were also excluded, resulting in the final study group of 733 nonsurviving drivers and 2,483 surviving drivers.

Crash characteristics

The crash characteristics we included in the analysis were degree of deformation, seat belt use, and post-crash drivability of the vehicle. Degree of deformation was quantitated using the Traffic Accident Deformity (TAD) rating scale. Safety belt use was recorded as belted or unbelted. Post-crash drivability was dichotomized into towed from the scene or driven from the scene.

The TAD rating used in Michigan consists of a 7-point scale, with higher scores indicating more severe deformation of the vehicle. A rating of zero indicates no damage, a rating of 1 indicates minimal damage, a rating of 7 reflects maximum damage. To simplify analysis, deformity was dichotomized into less severe (TAD $< =4$) and more severe (TAD > 4). Cases having vehicle deformity information missing were coded as less severe deformity, based on the recommendation of one of the authors (C.C.), who has had extensive experience handling crash data. The reasons for this simplification are these: (i) crashes with minimal damage are less likely to be immediately reported, and thus the officers filling out the accident reporting form may never actually see the vehicle; and (ii) incomplete reports for these types of crashes are more likely to be tolerated by police agencies than are incomplete reports of crashes of greater deformity, which are more likely to result in injury and/or legal action.

Demographic characteristics

We defined each county as rural or nonrural using criteria from the Federal Office of Management and Budget that define Metropolitan Statistical Areas (MSA) and non-Metropolitan Statistical Areas (non-MSA) (OTA 1989). Counties that were MSAs were designated as nonrural. Counties that were non-MSAs were designated as rural. The county of crash occurrence was the county designated. This manner of definition is the same as that used in a recent request for proposal issued by the National Highway Traffic Safety Administration (1989) for a study of preventable motor vehicle crash deaths in rural areas.

Age was divided into three categories: under 26, 26–50, and over 50. Sex of the driver was also recorded. These data were obtained from the MACF.

Outcome

Survivors and nonsurvivors were defined using the criteria of the Michigan Accident Census file. Patients dying within 90 days of the crash were considered nonsurvivors; patients alive after this time period were considered survivors.

MEDICAL RESOURCE INFORMATION

Information regarding medical resources was obtained from the Michigan Department of Public Health (MDPH) Division of Planning and Policy Development, Bureau of Health Facilities, and The MDPH Emergency Medical Services (EMS) Division.

Medical resources variables

The following medical resource data were obtained for each county: total numbers of acute care hospital beds, operating rooms, physicians, emergency medicine physicians, surgeons, emergency medical technicians, and ambulances. Other medical resource variables included total number of emergency care facilities, the categorization of each emergency care facility, and the maximum level of prehospital care available in a county.

The state of Michigan divides emergency care facilities into three levels: Emergency Room (Level 1), Emergency Department (Level 2), and Emergency Center (Level 3). The criteria for these levels were developed by the MDPH Bureau of Health Care Facilities (1982). Multiple factors are considered when determining a categorization level, including types, training level, and numbers of the emergency care staff; hours of operation; types and extent of medical speciality backup support available; and the availability of various diagnostic facilities and operating rooms.

Levels of maximum prehospital care available are Basic Life Support (BLS, Level 1); Limited Advanced Life Support (Limited-ALS, Level 2), and Advanced Life Support (ALS, Level 3). In Michigan, Limited-ALS providers can perform endotracheal intubation and start intravenous solutions, but cannot administer medications.

Each emergency care facility in a county was assigned a value equal to its category designation. The values for each of these facilities for each county were summed to give a county "Hospital Emergency Service Score" used in subsequent analysis. The other, continuous variables were transformed directly into resources per square mile for analysis.

ANALYSIS

The design of the study was retrospective and case control. Cases were defined as nonsurviving drivers, controls were surviving drivers. All data analysis was done using SAS (Version 5) (SAS Institute 1986). A logistic regression model was developed to investigate the risk of death associated with MVCs that occur in rural counties. Such a regression model is specified as follows:

$$\text{logit}\,(p) = \ln\{p/(1 - p)\} = \alpha + \beta_1\chi + \beta_2\chi_2 + \ldots\ldots$$

where p is the probability that a car driver does not survive the crash, given the information x about the explaining variables. The model is similar to the well known linear regression model, but uses the link-function logit (p) instead of a directly observed variable y. The x-variables may be binary classifications such as county type. If for some variable x the probability of dying is equal for all its values, then this variable does not discriminate with respect to survival and its relative risk will be equal to one for all values. The relative risk (RR) is the incidence of disease or mortality in exposed persons to the incidence of disease or mortality in unexposed persons. An RR of 1 indicates equal risks of mortality or disease in exposed and unexposed individuals.

In our analysis the response, or outcome variable, is survival status. The explanatory variable of primary interest for which inference is made is the type of county in which the accident occurred (rural/nonrural). Multivariable models were used to adjust for other variables related to survival status, including age of driver, sex of driver, level of vehicle deformation, seat belt use, and whether the vehicle was towed or driven from the scene of the crash. Only vehicle drivers were considered in this analysis, since observations are assumed to be independent for logistic regression, and it is expected that outcomes for drivers and passengers riding in the same vehicle are correlated. Exponentiating the logistic regression parameter estimate for type of county approximates how much more likely (or less likely) a fatal outcome is for MVCs that occur in rural counties than in nonrural counties. Explanatory variables to be considered for entry into the logistic regression model were determined from an unpublished preliminary study. During that study, contingency table analysis identified several crash characteristic variables that were strongly associated with survival status: vehicle deformation, seat belt use, and whether the vehicle was towed or driven from the scene.

When deemed appropriate, goodness-of-fit for the logistic regression model was assessed by an overall chi-square statistic. Coefficients from the model were used to calculate relative risks (RR) and their 95% confidence intervals. The distribution of different catagories of crash characteristics and age were compared between rural and nonrural drivers using chi-square analysis.

The percentage of excess mortality, measured in terms of relative risks, for rural drivers that was accounted for by crash characteristics and or age was calculated by the following formula (Otten et al. 1990):

$$(RR^U - RR^A)/(RR^U - 1)$$

where RR^U represents the relative risk from the unadjusted model, RR^A the relative risk after adjustment for crash characteristics and/or age, and 1.0 the relative risk when there was no excess mortality.

RESULTS

Frequency counts and percentages for categories of crash characteristics, age, and sex by outcome status appear in Table 1. Nonsurviving MVC drivers were more likely to crash in a rural county, have a TAD score of greater than 4, have their vehicle towed, not wear a seat belt, and be over 50 years old.

Before adjustment, the relative risk of not surviving a motor vehicle crash was estimated to be 1.98 times greater for drivers in rural than in nonrural counties (Table 2). From Table 2 we can compute the risk of dying, $p/(1-p)$, where p is the probability of dying; these values are .492 and .249 for rural and nonrural counties, respectively. Taking

Table 1. Descriptive statistics for demographic and crash characteristics

	Survivors		Nonsurvivors	
	N	%	N	%
Type of county				
Nonrural	2009	80.9	500	68.2
Rural	474	19.1	233	31.8
Age				
16–25	965	38.9	247	33.7
26–50	1117	45.0	308	42.0
> 50	401	16.1	178	24.3
Sex				
Male	1525	61.4	510	69.6
Female	958	38.6	223	30.4
Vehicle Deformation				
Less Severe	2299	92.6	76	10.4
Most Severe	184	7.4	657	89.6
Seat belt use				
Used	2141	86.2	172	23.5
Not Used	342	13.8	561	76.5
Vehicle driven/Towed				
Driven	1850	74.5	8	1.1
Towed	633	25.5	725	98.9

Table 2. 2 × 2 table used to calculate risk of dying of a driver involved in a motor vehicle crash

	Non-survivors	Survivors	Total	Risk of dying (P/1-P)
Type of county	*N*	*N*		
Rural	233	474	707	0.492
Nonrural	500	2009	2509	0.249
Total	733	2483	3261	

Relative risk of dying (0.95 Confidence Interval) = 1.98 (1.64, 2.38) nonrural county values as the baseline or referent group, then, the relative risk of not surviving a motor vehicle crash in a rural county before adjustment is 1.98, with an estimated 95% CI of (1.64, 2.38).

The frequency distribution of crash characteristics and age between rural and nonrural counties are shown in Table 3. Rural crashes in our study population have greater vehicle deformity, are more likely to have the vehicle towed away, are more likely to involve an unbelted driver, and are more likely to involve a driver over 50 years of age.

Table 4 shows crash characteristics and their coded values. The design variables are coded such that the baseline or reference group is set to zero. In Table 5 the parameter estimates and their standard errors for the logistic regression model are presented. At the 0.15 level, no significant interactions are present between type of county and any of the remaining variables. At the 0.05 level, a significant interaction was found between vehicle deformation and seat belt use ($p = 0.002$). The overall chi-square goodness-of-fit statistic for this model is 53.22 with 74 degrees of freedom, indicating our model fits the data very well.

Relative risks estimated from logistic regression parameter estimates are presented in Table 6. After adjusting for vehicle deformation, seat belt use, vehicle driven/towed from

Table 3. Distribution of crash and age characteristics by type of county

	Rural		Non-rural		
	N	%	N	%	P value
Vehicle deformation					
Less severe	450	63.7	1925	76.7	
Most severe	257	36.4	584	23.3	≪.001
Seat belt use					
Used	456	64.5	1857	74.0	
Not used	251	35.5	652	26.0	≪.001
Vehicle driven/Towed					
Driven	346	49.0	1512	60.3	
Towed	361	51.0	997	39.7	≪.001
Age					
16–25	267	37.8	945	37.7	
26–50	291	41.2	1134	45.2	
> 50	149	21.0	430	17.1	0.034

Table 4. Code sheet for logistic regression

Variable	Description	Values
SURV	Outcome	Survivor = 0, Nonsurvivor = 1
RURURB	Type of county	Nonrural = 0, Rural = 1
DFRM	Vehicle deformity	Less severe = 0, More severe = 1
BELT	Seat belt usage	Used = 0, Not used = 1
DTOW	Vehicle driven or towed	Driven = 0, Towed = 1
AGE	Age of driver	0–25 = 0, 26–50 = 1, >50 = 2
SEX	Sex of driver	Male = 0, Female = 1
TTBAR	Beds/sq mile	0.00–18.27
TORMAR	Operating Rooms/sq mi	0.00–0.48
EMTOAR	EMTs/sq mi	0.00–3.01
AMBTOAR	Ambulances/sq mi	0.00–0.29
MDAR	Physicians/sq mi	0.00–3.51
SURGAR	Surgeons/sq mi	0.00–0.34
ERDAR	Emerg. Phys./sq mi	0.00–0.29
TOTSCORE	Combination of:	3
	Emerg. Centers	2
	Emerg. Department	1
	Emerg. Room	
MCA	Med. Control Auth.	
	(Maximum Level of Prehospital Care in County)	
	Advanced Life Support	1
	Limited Advanced Life Support	2
	Basic Life Support	3

Table 5. Parameter estimates and S.E.s of crash and demographic characteristics

Variable	Estimate	S.E.	*P* value
RURURB	0.414	0.185	0.019
DFRM	3.932	0.324	<0.001
BELT	3.437	0.342	" "
DTOW	3.660	0.390	" "
AGE (26–50)	0.413	0.180	0.009
(> 50)	1.488	0.391	<0.001
SEX	0.119	0.176	0.447
DFRM and BELT	−1.243	0.391	<0.002

Chi-square goodness-of-fit is 53.22 on 74 degrees of freedom.

Table 6. Relative risks for crash and demographic characteristics

Effect	Among	Relative risk
Rural		1.51
Towed		38.86
Age		
(26–50)		1.51
(> 50)		4.43
Deformity (more severe)	Belt used	50.91
Belt not used	Deformity (less severe)	31.09
Belt not used	Deformity (more severe)	457.60

Table 7. Relative risk of dying for rural MVC drivers vs. nonrural drivers before and after adjusting for effects of crash characteristics and age and percent of excess mortality accounted for by adjustment

	RR	95% CI	Percent of excess mortality accounted for
Unadjusted	1.98	1.64–2.36	Referent
Adjusted for age and crash characteristics	1.51	1.05–2.17	48%

scene, age, and sex, the relative risk for a MVC driver in a rural county becomes 1.51 (95% CI {1.05, 2,17}). The relative risks associated with crash characteristics are quite large. Being unbelted for a given level of deformity, for example, dramatically increases the risk of dying.

Table 7 shows the relative risk of dying for rural MVC drivers versus nonrural drivers before and after adjusting for crash effects and age. These effects can account for 48% of the excess mortality of drivers in rural MVCs, as measured by RR.

When an attempt was made to include the medical resource variables in the model, it was found that the rural/nonrural variable was highly correlated with medical resources (with the exception of the maximum level of prehospital care available in a county). Thus, low values of medical resources were associated with rural counties (Table 8). Moreover, medical resource variables were highly correlated among themselves (Table 9), the highest value being between beds/sq. mile and operating rooms/sq. mile (0.997, $n = 82$), the lowest between beds/sq. mile and surgeons/sq. mile (0.803). This multicollinearity precluded

Table 8. Means and medians of medical resource variables

	Rural county (N=59)			Non-rural (N=23)		
Resources/sq. mile	Median	Mean	S.E.	Median	Mean	S.E.
Beds	0.149	0.171	0.021	1.080	2.042	0.772
Oper. rms.	0.004	0.005	0.001	0.031	0.058	0.020
EMTs	0.083	0.098	0.008	0.342	0.594	0.157
Ambulances	0.009	0.012	0.002	0.029	0.051	0.013
Physicians	0.033	0.045	0.008	0.403	0.858	0.203
Surgeons	0.003	0.004	0.001	0.035	0.079	0.022
Emerg. phys	0.001	0.003	0.001	0.026	0.031	0.007
Totscore	2.000	2.085	0.211	6.000	10.000	3.101

Table 9. Correlation matrix of medical resource variables (coded variables)

	TTBAR	TORMAR	EMTOAR	AMBTOAR	MDAR	SURGAR	ERDAR
TTBAR	1.00000	0.99672	0.94063	0.91239	0.82561	0.80253	0.82519
TORMAR	0.99672	1.00000	0.93765	0.91214	0.85330	0.82288	0.85231
EMTOAR	0.94063	0.93765	1.00000	0.94808	0.85800	0.88538	0.85588
AMBTOAR	0.91239	0.91214	0.94808	1.00000	0.85129	0.85418	0.83793
MDAR	0.82561	0.85330	0.85800	0.85129	1.00000	0.96585	0.96193
SURGAR	0.80253	0.82288	0.88538	0.85418	0.96585	1.00000	0.93340
ERDAR	0.82519	0.85231	0.8588	0.83793	0.96193	0.93340	1.00000

medical resources from being entered into the model, since medical resources essentially defined the rural/nonrural situation. Thus, rural/nonrural effects on mortality could not be examined separately from those of medical resources.

DISCUSSION

The chief finding of this study is that 48% of excess rural MVC driver mortality, as defined by the RR, may be accounted for by factors on which acute medical care has no effect: crash characteristics and age. This implies that strategies to decrease excess rural crash mortality cannot overlook injury prevention and crash protection programs. On the other hand, 52% of excess rural MVC driver mortality remains possibly attributable to differences in medical care or other, nonmedical factors that could not be analyzed using the data available in this study.

This study corroborates the findings of others that mortality from motor vehicle crashes is higher in rural than in nonrural areas (Waller et al. 1964; Certo et al. 1983, Brodsky and Hakkert 1983; Bentham 1986; Baker et al. 1987). We also found, as others have, that drivers in MVCs who are unbelted, over 50, have vehicles with greater deformity, and have vehicles that are towed are at greater risk of dying (Waller, Stewart, and Hanses 1986; House, Waller, and Stewart 1982; Campbell 1984; Jones 1982). We were able to demonstrate, however, an additional important point that others have only speculated on, namely, that more severe crashes occur in rural areas. We were also able to show that almost half (48%) of the contribution to excess risk of dying in rural crashes can be explained by this higher crash severity and by age.

We can only speculate as to why rural MVC drivers are more likely to have greater vehicle damage, to be unbelted, and to be older. One source has noted that over twice as many drivers on rural interstate highways exceeded speeds of 65 mph compared with nonrural interstate drivers. High speed travel on other types of roads is also more common in rural areas (Federal Highway Administration 1982). These findings of higher speeds on rural roads are consistent with our findings of greater deformity in rural crashes. Our data, however, do not allow proof that the two findings are related.

Seat belt use has been shown to be less common in rural areas and to vary dramatically with income (Wagenaar and Wiviott 1985; Phillips 1983; Transport Canada 1985; Insurance Institute of Highway Safety 1986). It does not seem unreasonable to have found, as we did, that rural drivers are less likely to belted when involved in a crash.

Lower belt usage in rural drivers could also be due to factors relating to lower income (e.g. inability to make sure belts are properly maintained, older models of cars that did not have belts as standard equipment, educational differences), but this line of reasoning assumes that rural MVC drivers are also rural residents. On this point, Waller et al. (1964) noted that only 58%–74% of rural MVC fatalities were rural residents while 86%–89% of nonrural MVC fatalities were nonrural residents. Baker, on the other hand, believes the close correlation between the county of crash occurrence and the county of residence make it appropriate to assume that a MVC fatality for a specific county was also a resident of that county (1987). Because of conflicting opinions such as these, we would be reluctant to attribute lack of seat belt use in rural MVC drivers to lower economic status.

Our finding that rural MVC drivers are older is particularly interesting in that Baker noted no interaction between age and population density (1987): in other words, rural MVC drivers are not, a priori, more likely to be older, since rural residents in general are not older. Perhaps older drivers in rural areas are more likely to travel at higher speeds than nonrural older drivers or are less able to appropriately handle their vehicles at these higher speeds.

We have previously noted that the high degree of collinearity we found between medical resource variables and type of county variable prevented us from quantifying the role of medical resource variables in MVC survival. It was not possible, with our data, directly to analyze the effects of the individual medical resource variable within a rural/nonrural classification. It may well be that the excess mortality in rural areas not accounted for by age and crash characteristics is primarily due to a relative lack of medical resources, but one cannot rule out the possibility that there are other, as yet unobserved, variables (e.g. blood alcohol levels or emergency medical services notification times) that are responsible for the higher MVC mortality in rural areas.

LIMITATIONS OF THE STUDY

Medical resources

Our difficulty in analyzing the effects of medical resources on excess rural MVC mortality illustrates one of the major but unavoidable weaknesses of our study, namely, that the measures we used were indirect measures of the accessibility or quality of medical care. Direct measures of accessibility, such as the exact time it takes for an injured patient to have a surgeon at bedside, would be ideal. Unfortunately, data bases containing direct measures of accessibility of EMS services or of their quality do not exist in Michigan. This lack of important data has hampered other investigators (Brodsky and Hakkert 1983; Bentham 1986; Mueller et al. 1988) as well. A number of investigators have used indirect measures of accessibility and level of medical care, just as we did, rather than abandon attempts to grapple with the important issues at hand.

Another limitation related to using indirect measures is that availability of a resource does not guarantee its accessibility. For example, we were not able to determine how resource availability might vary by time of day or time of year. For EMTs, we could verify the county where their license was sent, their home of record, but not the county where they practiced. We could enumerate hospital beds and operating rooms, but could not verify whether the beds were operational, whether the operating rooms were staffed at all times, or whether injured patients were cared for in an appropriate, systematic way.

The county "Hospital Emergency Services Score" is an attempt to quantify a county's hospital emergency services in a simple way. The scoring method used assumes a linear relationship between categorization value and utility. We have no data to support this assumption. Nevertheless, we feel the scoring method used was acceptable for an initial evaluation of the relationship between a county's hospital emergency care facilities and MVC driver mortality. Another concern related to using the "Hospital Emergency Services Score" is that the emergency facilities category is self-reported by hospitals. MDPH has not verified that hospitals have identified their emergency facilities with the appropriate code since the last statewide survey in 1982.

Crash data source

While the MACF data is accurate for reported crashes, we have no way of knowing how many accidents were not reported. Accidents having minimal damage and no injuries are less likely to be reported than other types of crashes. Missing data in crash reports themselves were less of a concern. Overall, 9.7% of nonsurviving drivers' crashes were excluded because of missing data, and 8.4% of surviving drivers'. We do not believe that differences in the percentage of missing data between nonsurviving and surviving drivers biased our results.

It is also possible that the way we dichotomized TAD and assigned missing data could have altered our conclusions. Since crashes of less severe deformity were more likely to occur in nonrural counties, our decision to classify missing values as less severe may have been applied more often in nonrural counties. Excluding rather than reclassifying these cases would bias the study towards showing no change in the adjusted RR for rural MVC drivers' dying compared with the unadjusted RR.

Selection of crash characteristic variables

The crash characteristics selected for this analysis were based on those previously used to define crash severity in studies on the potentiating effects of alcohol on driver injury (Waller et al. 1986; House et al. 1982). The three crash characteristic variables chosen for our study were determined by a preliminary (unpublished) analysis of Michigan crash data. This was a univariate analysis to determine which crash characteristics had the highest association with mortality. We chose not to consider the effect of air-bags, because fewer than 1% of all vehicles in our study population had these devices. Using different crash characteristics or using different cutoff points for categorization could have changed the results of our analysis, but probably not in any important way.

Defining rural/nonrural

No single standard exists for defining rural areas. One of the problems with the MSA/non-MSA typology is that there can be significant geographic and demographic differences between non-MSAs (OTA 1989). For instance, a non-MSA that lies adjacent to an MSA should have access to more services than a non-MSA that is surrounded by other non-MSAs. The MSA/non-MSA taxonomy also fails to consider those relatively uninhabited areas within an MSA. It is possible that using different definitions for rural and nonrural could have led to some very different findings.

Competing hypotheses

One important factor related to mortality but not considered in this study was the blood alcohol concentration (BAC) of the driver (Waller et al. 1986; House et al. 1982; Evans 1990). Waller has shown that in North Carolina, given two crashes of similar severity, the driver with a higher BAC is at greater risk for more severe injury (1986). Unfortunately, only 1.9% of the 1987 drivers in the MACF had data on BAC.

Another factor not included was notification time, defined as the time from crash occurrence until first emergency medical services system notification. One would suspect that long notification times in a county are associated with increased mortality and that longer notification times are more likely to occur in rural areas. Unfortunately, we could not address this question, since no data regarding notification time is in the 1987 Michigan Accident Census File or any other Michigan database.

Study design (case/control)

Case control studies are prone to selection and misclassification bias (Schlesselman 1982). We have already discussed the problem of potential bias introduced by the fact that drivers in crashes with less vehicle damage are probably less likely to have their crash reported. Misclassification could also occur in the assignment of numerical values to other crash characteristics. For example, an officer reporting on two similar crashes might be more likely to use a higher TAD rating for a crash involving injuries than for one that did not.

Generalizability

Extrapolation of these findings to other states must be done cautiously. We have already addressed potential biases of our study, but other issues, such as regional variation in variable definitions or reporting methods, must also be considered. For instance, the hospital emergency service categorization used in Michigan is not meant to be a substitute for that of another state or for the American College of Surgeon's criteria for level of trauma center designation. Also, states may vary in the manner in which crashes are reported or vehicle damage is scored.

CONCLUSIONS

This study suggests that among drivers in Michigan, almost 50% of the excess mortality, as measured by the relative risk for rural motor vehicle crashes, may be accounted for by increased crash severity and age of drivers. The remainder of excess mortality is unaccounted for, but may relate to geographic differences in other factors such as medical care, driver BACs, or EMS notification time. Strategies to decrease the excess risk of death for rural crash drivers must include injury prevention and crash protection programs, however, since excess mortality that derives from crash characteristics cannot be reversed by medical or other post-crash interventions.

REFERENCES

Baker, S. P.; Whitfield, M. A.; O'Neil, B. Geographic variations in mortality from motor vehicle crashes. N. Engl. J. Med. 316:1384–1387; 1987.

Baker S. P., O'Neill B., Karpf R. S. The injury fact book. Lexington, Mass.: D. C. Heath, 1984.

Bentham, G. Proximity to hospital and mortality from motor vehicle traffic accidents. Soc. Sci. Med. 23:1021–1026; 1986.

Brodsky, H., Hakkert, A. S. Highway fatal accidents and accessibility of emergency medical services. Soc. Sci. Med. 17:731–740; 1983.

Campbell, B. J. Safety belt injury reduction related to crash severity and front seated position. Chapel Hill: The University of North Carolina Highway Safety Research Center; 1984.

Certo, T. F.; Rogers, F. B.; Pilcher, D. B. Review of care of fatally injured patients in a rural state. J. Trauma 23:559–565; 1983.

Dove A. F., Pearson J. C. G., Weston P. A. M.: Data Collection from Raod Traffic Accidents. Arch Emerg Med; 3:193–198, 1986.

Evans, L. The fraction of traffic fatalities attributable to alcohol. Accid. Anal. Prev. 22:587–602; 1990.

Federal Highway Administration. Highway statistics 1981. Washington, DC: Department of Transportation; 1982.

House, E. G.; Waller, P. F.; Stewart, J. R. Blood alcohol level and injury in traffic crashes. Proc Am Assoc Automotive Med, 26:329–373, 1982.

Jones, I. S. Injury severity versus crash severity for front seat car occupants involved in front and side impacts. Proc Am Assoc Automotive Med; 26:17–35, 1982.

Maio, R. F.; Burney, R. E.; Lazzara, S.; Takla, R. Correlation between motor vehicle mortality rate and density of medical resources. Prehospital Care and Disaster Medicine: 5(4):335–339; 1990.

Michigan Department of Public Health, Emergency Medical Services Division: EMS Facilities Categorization Criteria, J-284, April 1982.

MMWR. Perspectives in disease prevention and health promotion: Progress toward achieving the national 1990 objectives for injury prevention and control. Morbidity and Mortality Weekly Report 37:138–146; 1988.

Mueller, B. A.; Rivara, F. P.; Bergman, A. B. Urban-rural location and the risk of dying in a pedestrian-vehicle collision. J. Trauma 28:91–94; 1988.

National Highway Traffic Safety Administration (NHTSA). Rural preventable mortality study. RFP-DTNH22-89-R-05130. Washington, DC: NHTSA; July 1989.

Otten, M. W.; Teutsch, S. M.; Williamson, D. F.; Marks, J. S. The effect of known risk factors on the excess mortality of black adults in the United States. J.A.M.A. 263:845–850; 1990.

Phillips, B. M. Restraint system usage in the traffic population. (DOT publication no. HS-806-424.) Princeton, NJ: Opinion Research Corporation; 1983.

Schlesselman J. J. Case control: Design, conduct and analysis. New York, NY: Oxford University Press; 1982: 124–143.

Insurance Institute of Highway Safety. Toughest belt use law proves to be most effective. Status Report 21(12):1, 5–6, 1986.

Transport Canada. Estimates of shoulder seat belt use by road type for 1984 survey. Ottawa, Canada: Transport Canada; 1985.

Office of Technology Assessment. (OTA). Defining "rural" areas: Impact on health care policy research. Staff paper. GPO stock Number 052-003-01156-5. Washington, DC: Government Printing Office; July 1989: 8, 17–34.

OTA. Rural Emergency Medical Services-Special Report. OTA-H-445 (Washington, DC: US Government Printing Office); 22–23, November 1989.

Wagenaar, A. C.; Wiviott M. B. T. Direct observation of seat belt use in Michigan. UMTRI report 85-34. Ann Arbor, Mich: University of Michigan Transportation Research Institute; 1985.
Waller, J. A.; Curran, R.; Noyes, F. Traffic deaths: A preliminary study or urban and rural fatalities in California. Calif. Med. 101:272-276; 1964.
Waller, P. F.; Stewart, J. R.; Hanses, A. R. et al.: The potentiating effects of alcohol on driver injury. J.A.M.A. 256:1461-1466, 1986.