Murder's Margin: Estimating the Impact of Health Care on the Lethality of Attacks

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Submitted to the Department of Economics of Amherst College in partial fulfillment of the requirements for the degree of Bachelor of Arts with Distinction

April 22, 2005

Acknowledgements

First, I'd like to think my advisor, Professor Jessica Reyes, without whose guidance and encouragement this work could never have been completed. I'd also like to thank my parents and brother for support and useful suggestions and conversations. Special appreciation goes out to two late-night readers and their inexhaustible patience.

1. Introduction

Assault and murder are usually considered to be two distinct categories of crime. In fact, however, they represent two possible outcomes along a continuum of severity for attacks. More severe attacks are more likely to be murders, while less severe attacks are more likely to be assaults. The final outcome of an attack is determined by two sets of factors: the severity of the attack itself and the health care which follows the attack. Thus, far more than criminal intent and behavior determines the distinction between murder and assault. This paper examines the impact of medical resources on the survival or death of violent assault victims.

What ultimately defines a crime as a murder is the fact that the victim dies. Because trauma care is effective at saving lives and because of differences in the availability of such care, it is possible for two identical attacks in different locations to have different outcomes. In one, the victim dies because he cannot access trauma care fast enough or the care he receives is not of a high enough quality. In the other, the victim lives. In such a case, health care makes the difference between murder and assault. This implies that there is a margin with respect to health care between aggravated assault and murder.

This suggests that the perspective used to analyze murder and assault ought to be reconsidered. The question of what causes murder is ambiguous. Murder describes a violent attack with the particular outcome of the victim's death. To ask why an event is a murder could be to ask why there was a violent encounter in the first place, or to ask why that encounter resulted in death. There are two distinct questions here which each require an answer in order to explain a murder. This separation of murder into its two components is a hallmark of the lethality perspective, which focuses on the question of why some attacks result in death. That is the perspective of this paper as it attempts to identify the impact of health care on murder and assault rates.

This paper examines the impact of access to trauma care on murder rates, on the hypothesis that more and better care will reduce murder rates by turning murders into aggravated assaults. Therefore, health care should reduce the lethality of attacks: there should be more assaults per murder in the presence of good trauma care. A particular measure of lethality, percent lethality, is used. This is the ratio of murders to assaults and murders, and it measures the percentage of violent attacks that are fatal. Crime data is from incident-by-incident records in the NIBRS. This crime data is combined with data on health care resources in the Bureau of Health Professions Area Resource File(ARF). These data include the number of doctors, nurses, hospitals and beds. Additionally, demographic and crime data are used to control for differences in the severity of attacks between locations and across time. As expected, most medical variables are found to have negative effects on lethality. The elasticity of lethality with respect to nurses per capita is -2.69, with respect to hospitals per capita -1.43 and with respect to beds per hospital -1.75.

Section 2 reviews background information. This includes analyses of the lethality of assaults, evaluations of the trauma care system and criminological and sociological explanations of crime. Section 3 discusses the data and presents three stages of the model's development: a theoretical model, an ideal empirical model and an actual empirical model. Section 4 presents regression results from those models. Section 5 offers an interpretation of the results and some perspective on their size and importance. Section 6 concludes with suggestions for further research.

2. Background

Perspectives on Murder

The fundamental difference between an assault and a murder is the death of the victim. The point is both obvious and subtle. Murder involves, by definition and therefore of necessity, the victim's death, while assault necessarily involves the survival of the victim. At the same time, an acknowledgement of this fundamental fact gives rise to a new perspective on murder: murder and assault are both possible outcomes of any violent encounter and this outcome may be the result of factors unrelated to criminal intent and behavior. Rather than examining murders and assaults separately, the two should be examined together as possible products of a violent encounter, with the fundamental goal of determining why some victims in such encounters die and others survive.

Two explanations of crime are traditionally offered by sociology and criminology: a cultural one and a structural one. The cultural perspective explains differences in homicide rates by appealing to differences in cultural treatment of violence, interpersonal relations and weapon ownership. One such assertion, made by Gastil (1971), is that there is a distinctly Southern culture leading to higher murder rates in the South and among those who have emigrated from the South. There are many elements to this culture, including: a tendency to carry guns and knives, leading to more serious violence; residual effects of the persistence of dueling long after it had ended in the North; killings by mobs and organized groups, including lynchings; an exaggerated sense of honor; and a tendency to apply laws against violence less strictly. Gastil finds that this culture explains violence more effectively than demographic variables like race and socioeconomic variables like poverty.

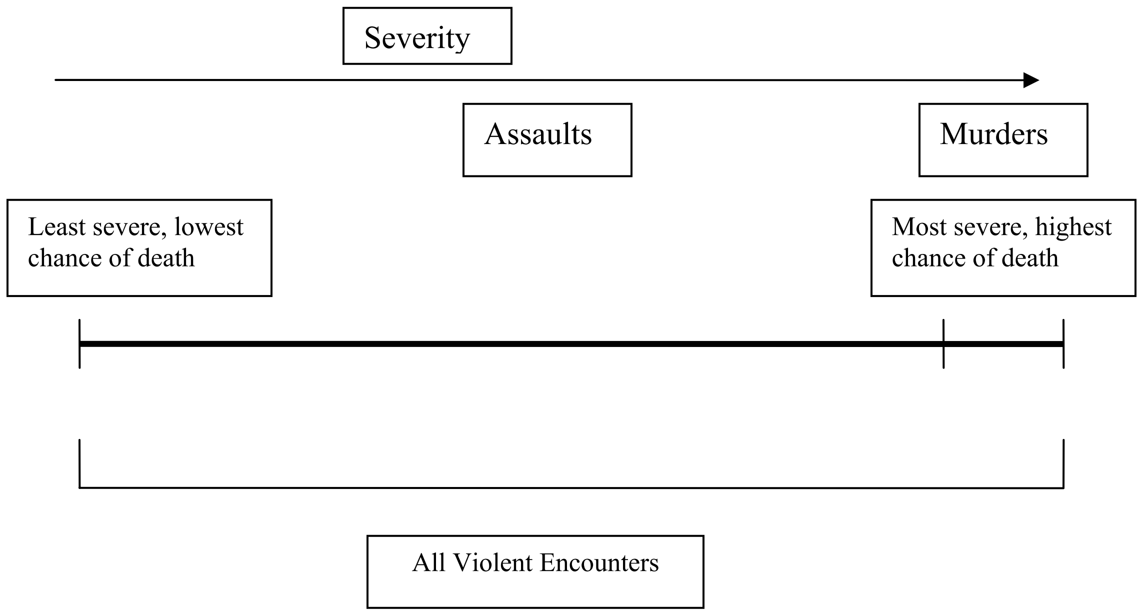
The other traditional perspective is a structural one which focuses on these demographic and socioeconomic variables. This perspective attempts to explain differences in murder rates by appealing to characteristics of the population, and proxies for those characteristics, such as racial composition, poverty, economic inequality, education and home ownership. While both the cultural and structural perspectives provide some insight into homicide rates, attempts to test such theories generate conflicting results(Long-Onnen & Cheatwood, 1992). Part of the reason for the lack of clear results is that such theories attempt to explain too much. The same factors which are proposed to explain differences in homicide rates are also relevant to differences in violence more generally. Thus what is really being offered is an explanation for differences in rates of all violent crime; such an explanation assumes that all violent crime rates move together and for the same reasons. However, as discussed above, murder may be different. Murder is the product of two things: the existence of a violent attack and its severity. The factors in question explain the first component, the rate of violent incidents, but do not address the second. An investigation of differences in the murder rate should be broken down into two separate questions: Are there more attacks, and are attacks more likely to be lethal?

The alternative to both cultural and structural perspectives is the “lethality perspective.” The focus of this theory is not on differences in violent crime in general but rather on murders explicitly. The theory lumps together homicides and aggravated assaults into a single category of violent attacks, some of which are fatal while others are not. Differences in the number of homicides between two locations are essentially the product of two phenomena; first, differences in the number of violent incidents and second, differences in the lethality of such incidents. The lethality perspective is concerned primarily with the second effect and so its adherents look not at murder rates, which are the aggregate result of both effects, but rather at percent lethality: the ratio of the number of murders to the combined number of murders and aggravated assaults. This ratio yields the percentage of serious violent encounters which result in death and differs substantially between locations. A high value for the ratio indicates that assaults are likely to be deadly, while a lower value indicates the opposite.

An attack occurs with a particular severity. This places an individual along a continuum of possibilities. At some point along that continuum is a cutoff between murder and assault: without health care, injuries beyond a certain severity are fatal. There is a margin between assault and murder such that, when an attack is sufficiently close to the margin, an increase in severity will make it a murder rather than an assault. The effect of medicine is not to alter severity, which is a product of the attack itself, but rather to move the margin between assault and murder. With care, an individual can survive an attack that would have killed him without care.

The difference in the lethality of assault between locations can be due to two main factors. The first is severity, including the use of weapons, especially guns. Severity is used in its essentially common sense here but may be more explicitly defined. For a given level of health care, a higher level of severity corresponds to a higher chance of death from an attack.

Figure 2.1 – The Severity Continuum



An ideal measure of severity would be obtained by directly examining each wounded individual and diagnosing how life-threatening his wounds are. If attacks in one area tend to be more severe than attacks in another, a greater percentage of victims in the first location should die. The second main factor is medical care. If trauma care has any effect, then the sooner a victim receives such care and the better the quality of the care, the more likely the victim is to survive. Trauma care shifts the location of the margin between life and death. In Figure 2.1, this corresponds to shifting the line separating murder and assault to the right. There are injuries which are fatal at one level of health care but not fatal at a higher level of care.

Severity

Severity is one of the two main factors that contributes to the outcome of a violent attack. One of the most important factors influencing severity is use of a weapon, particularly a gun. Incidents in which a firearm is used are far more likely to be deadly than those in which no weapon is used. This may be partly due to the fact that those who carry deadly weapons are more likely to be serious criminals or willing to inflict violence (Kleck and McElrath, 1991). Felons who reported that they had used guns in the crime for which they were imprisoned had a greater number of assaults and arrests than others. In an attack where a handgun is fired, the chance of death is 38% higher than for an attack without a weapon. Other studies show more dramatic results. Felson and Messner (1996) find that assailants with guns are 40 times more likely to kill their victims than those without guns, while assailants with knives are between 4 and 5 times more likely to kill their victims.

Weaver et al (2004) provide a more comprehensive analysis of factors. They find that, for both victims and assailants, being male increased the likelihood of a lethal encounter. Crimes committed in the course of felonies were substantially more likely to be fatal, with attacks relating to drug deals 7 times more likely to be fatal and those related to other felonies 12 times more likely to be fatal. Use of a firearm made the victim 12 times more likely to die, while use of a knife made the victim 2.5 times more likely to die. Generally, these results agree with those in Kleck (1986), Kleck and McElrath (1991), and Felson and Messner (1996) in their general scope if not in exact magnitude. Several variables available in the NIBRS, including weapon, offender-victim relationship, criminal circumstances, and age and gender of both assailant and victim are good proxies for predicting the severity of an attack.

Trauma Care

A large medical literature suggests that emergency care does make a difference. While this literature does not all address criminal assault directly, it demonstrates that emergency care has a significant effect on trauma victims. Much of the literature focuses on the impact of acute trauma care on death rates in motor vehicle accidents. As in the case of violent attacks, some of those injured in motor vehicle accidents will survive even without medical care and some will die even with the best medical care. Brodsky and Hakkert(1983) cite an Australian study(Stepheny, 1973) that concluded, based on 1000 post-mortem examinations, that if the fatal accidents had occurred right next to a hospital, 21% of the casualties could have been prevented. A similar study in Vermont (Waller and Jacobs, 1971) found that 23% of fatalities had injuries that were possibly non-fatal. While both studies indicate that a large majority of fatalities could not have been prevented, they also indicate that cases exist where medical intervention could have made the difference between life and death. Both studies are also unable to count people on the other side of the margin: those who had potentially fatal injuries but survived due to the care they received. While some fatal injuries could have been prevented with sufficient health care, this indicates nothing about the percentage of non-fatal injuries that could have been fatal without health care.

Brodsky and Hakkert(1983) attempt to isolate injuries on the margin by looking at a severity ratio whose numerator is the number of fatalities and whose denominator is the number of incapacitating injuries. The reasoning behind this approach is that those who survive a crash because of trauma care are unlikely to be completely healthy but will be left with an incapacitating injury. A person with minor wounds would probably have survived even without health care and thus was never on the margin between life and death. The category of incapacitating injury is not a technical medical term but a category used by the Texas Highway Department to describe injuries which prevent a person from walking or driving. By limiting its analysis to only fatalities and incapacitating injuries, the study is able to consider only those whose injuries are severe enough to put them on the margin between life and death so that trauma care becomes the determining factor. The higher the ratio of fatalities to incapacitating injuries, the more likely it is that a person who is involved in an accident which puts him on the margin between life and death will die. Testing along this margin, Brodsky and Hakkert find that EMS services do have some impact, with severity ratios 54 percentage points lower in regions with good access than in regions classified as remote.

Testing the Link Between Health Care and Murder

These motor vehicle studies indicate that emergency medicine has some impact on the health outcomes of one class of trauma victims, those involved in crashes. If such treatment does improve health outcomes for trauma victims more generally, then it should also improve outcomes for victims of violent attacks. It is now possible to form a model of the outcome of an attack by putting together the key factors: severity and trauma care. For each violent encounter, there are three relevant sets of characteristics that predict: those of the incident, those of the victim, and those of the offender. All of these characteristics, some of them unmeasurable, come together to produce a certain severity of injury in the victim. This severity then interacts with health care to produce a final health outcome for the victim. This paper is concerned only with whether the victim lives or dies, not with the actual continuum of long-term health outcomes which may result.

The theory that access to and quality of medical care alters murder rates was first tested in a series of papers by Doerner. The driving idea is to "[view] violence as a process and lethality as more than the simple by-product of the offender-victim interaction" (Doerner, 1983, p. 1). Medical resources are generalized into a Medical Index that measures all aspects of emergency care. When this Medical Index is included in regressions with a Structural Poverty Index, where the mean homicide rate(murders per population) is the dependent variable, it does not have a significant effect. This suggests that medical resources in themselves have little effect or are so strongly correlated with the Structural Poverty Index that the effects of the two different variables cannot be properly sorted out (Doerner, 1983). However, because the study uses only the homicide rate, it fails to fully address the nature of murder. Two places may have the same homicide rate but vastly different health care and lethality, distorting the results of any analysis which relies on homicide rates.

Further investigations yield more promising results regarding the impact of medical resources. An analysis of crime in all 67 counties of Florida is able to make use of more detailed information on medical resources. Doerner and Speir (1986) make significant advances from the previous work. Two dependent variables are used, the homicide rate and the percent lethality, the number of murders over the number of murders and aggravated assaults combined. In their theoretical model, they divide trauma care into field treatment, emergency room care and postoperative recovery. The only available data, however, were rough measures of hospital services. Rather than using a general index for medical resources, the study uses more detailed data on the number of hospital beds, number of licensed physicians and number of licensed nurses. However, the study yields unusual estimates of the impact of medical resources. A positive correlation was found between the number of doctors and the homicide rate. One explanation is that the measure of physicians does not accurately measure the concentration and type of services because it includes all doctors, not just those working in trauma care. Similarly problematic is a positive coefficient for the number of hospital beds; the authors again point out that gross hospital beds is not a good proxy for emergency room care. Substantial multicollinearity is also a problem.

A further paper by Doerner (1988) returns to the topic of lethality and medical resources using more detailed medical data. The only data available in Doerner and Speir (1986) were rough measures of hospital services. This study uses much more detailed medical data and both homicide rates and percent lethality serve as dependent variables. Basic ambulance service was found to be the most important influence on lethality. A similar analysis in Long-Onnen and Cheatwood (1992) using data from all 306 counties in five mideastern states(Maryland, Delaware, Pennsylvania, Virginia and West Virginia) supports the general conclusion that medical resources reduce lethality. This study does not include ambulance data but follows the same basic structure and model as the

Doerner studies, using percent lethality as the dependent variable. The number of licensed physicians, number of registered nurses, and number of hospital beds all had significant and negative effects on lethality.

While the above studies did control for socioeconomic and demographic factors, they all failed to control for severity. When analyzing murder statistics to determine the impact of medical resources, it is important to account for differences in the severity of attacks between regions and time periods. Differences in the severity of violent encounters will, medical resources remaining constant, alter the percent lethality. If attacks in one location tend to be more severe, a higher percent lethality will result because victims are more likely to die. This elevated statistic does not reflect a difference in the effectiveness of trauma care but rather the increased severity of assaults in the location.

Harris et al. (2001) analyze lethality making use of these conclusions about severity. This study finds that, controlling for severity, lethality dropped by between 54% and 76% between 1964 and 1999. Reinforcing the point, the study also found yearly drops in lethality for various weapons of between 2.5% and 4.5%. The latter finding is particularly important in establishing the impact of trauma care. It is unlikely that severity changes from year to year for a given weapon type. Therefore the drop in lethality for a given weapon type is best explained by medical resources. Two county-level analyses support this conclusion. These analyses show a strong correlation between lethality and medical resources. They do contain two significant problems, however. First, no county or year dummy variables are used. Second, aggregate rather than per-capita measures of health care are used. This biases the estimator because a higher value of an independent health care variable may simply be due to a larger population and not indicate any improvement in services.

Existing literature provides all of the pieces necessary to assess the impact of health care on lethality but no study properly assembles all of those pieces. The effectiveness of the trauma care system has been evaluated for motor vehicle crashes, and the factors influencing severity have been analyzed. What remains is to put health care and severity together in a model with appropriate controls in order to accurately predict the effects of health care.

3. Data and Model

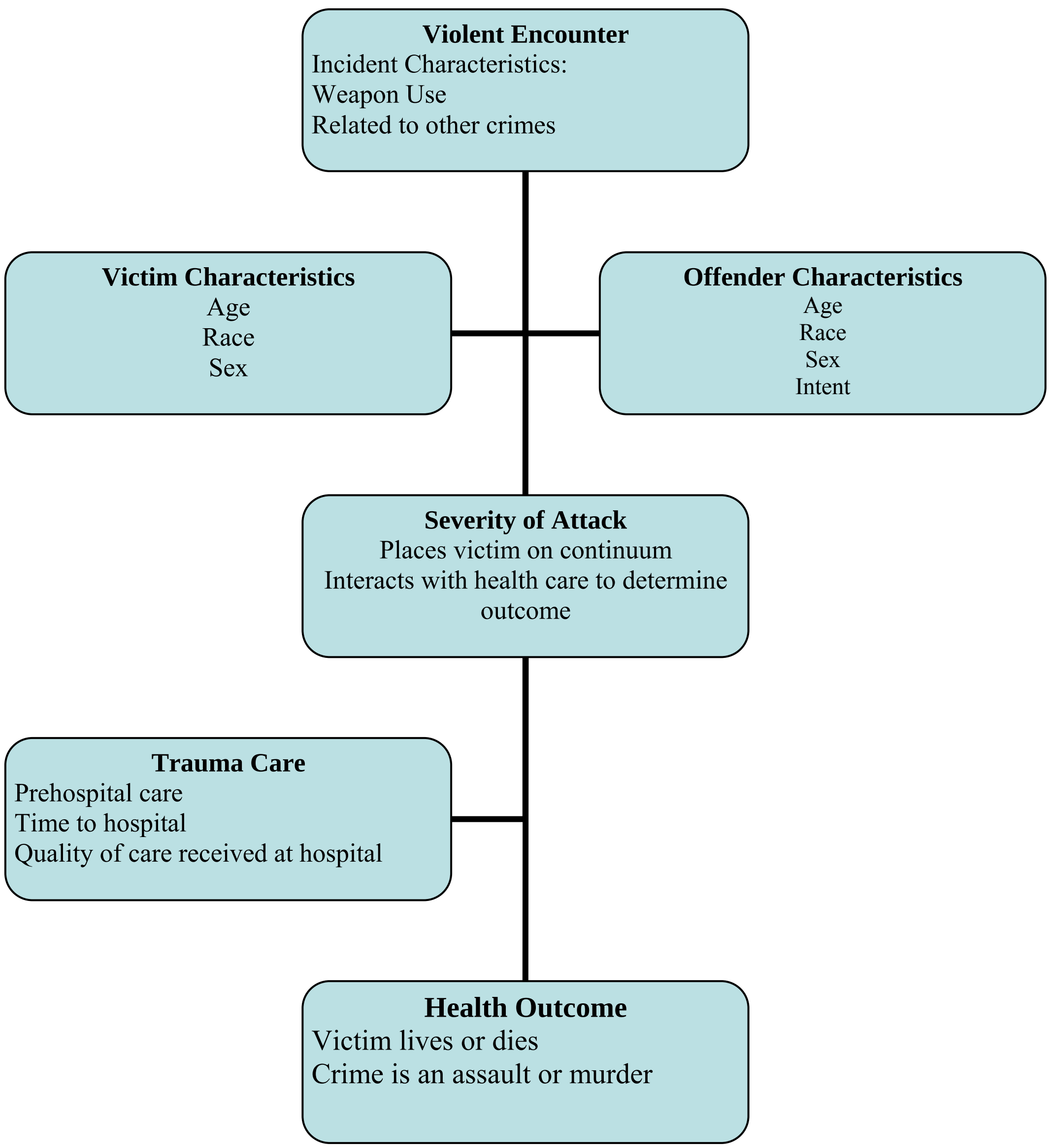
Theoretical Model

There are many factors that alter the composition of crime but not its level and, similarly, many that affect the level of crime but not its composition. The focus of this paper is on the composition of violent crime, not its level. However, consideration of some of the factors that might be included in a model of the level of crime will serve to clarify this distinction. For instance, poverty increases the rate of violent crime but has no certain impact on the lethality of attacks. There is no particular reason to think, before analyzing the data, that poorer assailants will be more or less lethal.

While percent lethality has already been mentioned , it is an aggregate statistic for grouped data and the model is easier to present and understand on an incident-by-incident basis. The incident-by-incident equivalent to percent lethality is mortality, assuming a value of 1 if the incident is a murder and 0 if the incident is an aggravated assault. The average value of mortality for a set of incident-by-incident data is the same as the value of percent lethality for the whole set of data.

In an ideal model, mortality depends on the severity of injuries, health care, both pre-hospital and at the hospital, and the response time of emergency services. The chart below demonstrates how these factors interact to produce a health outcome and, by extension, a crime outcome.

Figure 3.1 – Flow Chart of Severity and Trauma Care



1) Mortality= f(Severity, time, HC_{ph}, HC_h)

Mortality should be increasing in time and severity and decreasing in both pre-hospital and at-hospital care. The greater the severity, the more likely a victim is to die. Health care is the other contributing factor and the better the care a victim receives, the more likely he is to live.

None of the above factors in the model of the composition of crime will appear in a model of the level of crime. Instead, the level of violent crime will depend on population density, poverty, unemployment, weapon ownership, the racial composition of the population and similar socioeconomic and demographic characteristics.

Ideal Empirical Model

Theory makes some strong predictions about the way in which mortality will depend on the factors described above. It is obvious that, the more severe an attack is, the higher the chance that it will be fatal. Time should be divided into a set of dummy variables to mark crucial five minute intervals, since there are critical periods for receiving trauma care following serious injury.(find source, < 20 and > 20 mins). T will stand for this set of dummy variables. Particularly, mortality is much more likely for those arriving at the hospital more than 20 minutes after trauma. Health care, both pre-hospital and at the hospital, should make mortality less likely. However, theory indicates that health care may have diminishing returns, so mortality should depend on a function of health care with a flexible functional form.

2) $\text{Mortality} = \alpha_1\text{Severity} + \alpha_2\, T + \alpha_3\, HC_{phQ} + \alpha_4\, HC_{hQ}$,

Where the Q subscript indicates that the variable is a spline with cutoffs at each quartile. Further, there will be interaction effects between both severity and time with the health care variables. This is simply based on the belief that the effects of health care are different for more severe injuries and similarly differ depending on how quickly a patient is brought in. Thus the final form of the ideal empirical model is:

3) $\text{Mortality} = \alpha_1\text{Severity} + \alpha_2\, T + \alpha_3\, HC_{ph} + \alpha_4\, HC_h + \alpha_5\, \text{Severity} * HC_h + \alpha_6\, \text{Severity} * HC_{ph} + \alpha_7\, T * HC_{ph} + \alpha_8\, T * HC_h$

Depending on the findings regarding diminishing returns, the above regression may or may not include health care variables split into quartiles.

Measurement Difficulties

Because of practical difficulties, it is not possible to test the model above. These difficulties in obtaining good health care and severity data are detailed below.

Severity

A main concern in the above model is measuring severity. While there is a way to measure severity directly, it cannot be used in the present analysis. Emergency rooms use a number of different scales to assess those arriving with injuries. All such scales have values that correlate positively with mortality, indicating that they are likely to be effective measures of severity(Allen, 1986). However, there is no way to use the data from such evaluations and match it to individual cases in the NIBRS. Therefore, rather than one of these direct emergency room measures of severity, various proxies must be used. Here structural analyses, in both criminology and sociology, have examined characteristics that increase the likelihood for an encounter to end in death (Weaver et al., 2004).

Two possible categories of proxies emerge. One consists of variables that describe the physical facts of the encounter: when and where it took place, what weapon was used, etc. The other set of variables describes the circumstances of the encounter and itself serves mainly as a proxy for intent. Some variables, such as weapon use, fit into both categories: those with more serious criminal intent may choose weapons, so weapons indicate intent, but they also are a predictor of lethality even when controlling for intent. The fact that some variables are mixed in this way is not problematic because the ultimate concern of the present analysis is only with severity and not its components. For a given individual, estimated severity becomes:

4) $S' = \beta1 \text{ Gun} + \beta2 \text{ Knife} + \beta3 \text{ Victim Age} + \beta4 \text{ Victim Male} + \beta5 \text{ Offender Age} + \beta6 \text{ Offender Male} + \beta7 \text{ Circumstances},$

Where S' is estimated severity, gun and knife are dummy variables for the use of a gun or knife in an attack, Victim and Offender Age represent a set of dummy variables for 5 year age ranges, Victim and Offender Male are dummy variables and Circumstances is a set of dummy variables for other circumstances of the attack relevant to severity, including whether the attack occurred in the course of another felony and whether it was drug-related.

Health Care

Health care is the other important factor that contributes to the outcome of a violent attack. Like for severity, proxies for health care are necessary. It is impossible to find data on the actual health care resources available to an individual at the time of an attack, so generally available resources within a given area, either state or county, must be used instead. More health care resources will be positively correlated with higher population; areas with more people will have more doctors, hospitals, beds and other resources without any improvement in average care relative to less populous areas. It is important to correct for this by using per capita rather than raw health care resources. Per capita resources provide a better measure of actual available services and thus of the quality of care received.

5) $$\text{Mortality} = \alpha_1 \text{Severity} + \alpha_2 T + \alpha_3 HC_{ph}/\text{Population} + \alpha_4 HC_h/\text{Population} + \alpha_5 \text{Severity} * HC_h/\text{Population} + \alpha_6 \text{Severity} * HC_{ph}/\text{Population} + \alpha_7 T * HC_{ph}/\text{Population} + \alpha_8 T * HC_h/\text{Population}$$

In fact, however, no data was available concerning the time it took for a victim to reach a hospital or for the prehospital care received. As a result, neither factor is included in the final regression. In fact, since no good specific measures of emergency room care were available, only general health care variables reflecting the general capacity and quality of the entire system are included.

Data

This model uses incident-by-incident data from the NIBRS. For each crime reported, this contains data on the type of crime, the victim's age, the victim's race, injuries sustained, weapons used, the offender's age, the offender's race and some special circumstances for assaults and murders. Only offenses classified as homicide and aggravated assault were used in the analysis.

For the entire period there are 8667 murders and 608,572 aggravated assaults. The sample years are between 1996 and 2001. 22 states reported to the NIBRS during this period. Over the entire sample, the lethality is 1.4%. Table 3.1 summarizes the crime variables. Several important trends emerge. Guns are far more likely to be used in murders than assaults, a product of their more lethal nature. It is also true that guns may be used by people with lethal intent and thus the gun variable involves more than simply the use of a gun. Murders are also more likely to be committed in the course of another felony and to be drug-related.

Table 3.1 – Summary of Crime Variables

	Percent of assaults	Percent of murders	Percent of total attacks
Use of a gun	18%	61%	19%
Use of a knife	20%	14%	20%
Drug-related	0.24%	3.10%	0.28%
Part of another felony	0.26%	3.30%	0.31%

The impact of these variables on lethality is presented in Table 3.2 As suggested by their use in a large percentage of murders, attacks involving guns appear 3 times more likely to be lethal than those which do not involve guns. Such attacks are lethal 4.51% of the time, compared to only 1.40% of the time for all attacks. Drug-related crimes are lethal roughly 11 times more often than those which are not drug-related, and attacks occurring in the course of a felony are similarly more lethal. The sex of the offender and victim make little difference to lethality.

Table 3.2 – Crime Variables and Lethality

Attack Characteristic	Lethality
NIBRS Sample Average	1.40%
Gun used	4.51%
Knife used	0.97%
Drug-related	15.35%
Involves another felony	15.12%
Victim is Male	1.66%
Offender is Male	1.48%

Participation in the NIBRS is not mandatory and each agency within a state may decide whether or not to participate, so the sample is not necessarily representative of national or statewide crime patterns. Location is identified by state, so state-level demographic and health care data are used from the Area Resource File. The analysis therefore makes use of statewide health care variation and incident-specific information on circumstances influencing severity.

For the NIBRS regressions, the summary of variables in Table 3.3 indicates that health care resources do vary significantly between states. There are particularly disparate extreme values for hospitals, where the maximum value is 7.4 times the minimum and 3.5 times the mean, and doctors, where the maximum value is 5.3 times the minimum value and 3.1 times the mean. There is substantially less variation in the number of nurses per capita. While doctors per capita has a rescaled mean of .191 with a standard deviation of .114, nurses per capita has a mean of .861 and a standard deviation of .169. With a mean 7.5 times that of doctors per capita, the standard deviation of nurses per capita is only 50% greater than that for doctors. This is somewhat puzzling because it implies that the ratio of doctors to nurses changes considerably from place to place as doctors per capita fluctuates while nurses per capita varies little.

Table 3.3 - Summary of Health Care Variables

	Mean	Standard Deviation
Doctors per capita[a]	0.191	0.114
Nurses per capita[a]	0.861	0.169
Hospitals per capita[b]	0.292	0.183
Beds per hospital	157.87	62.69

a - Rescaled by 100 for readability
b - Rescaled by 10,000 for readability

Demographic data are summarized in Table 3.4. Demographics generally vary less than health care variables but population density is an exception. The standard deviation of population density is more than twice its mean value. This is mainly a result of some very high values for population density.

Table 3.4 – Summary of Demographic Variables

Demographic Variable	Mean	Standard Deviation
Percent White	0.783	0.1546
Percent Urban	0.7208	0.1546
Percent Poor	0.1216	0.0332
Population Density	11861.8	24289

There are twenty-two states included in the sample. Health care data for Iowa, Michigan, Ohio and Texas are reported in Table 3.5. These are chosen as somewhat representative states and all reported a substantial number of incidents to the NIBRS[1]. These data indicate substantial variation between states in health care resources. This is particularly true of hospitals per capita, with nearly three times as many in Iowa as in Michigan or Ohio. Nurses and doctors per capita vary much less, by contrast. This phenomenon is not limited to the selected states and points to a broader observation about the variation in health care between states. Personnel like nurses and doctors actually provide care directly, while hospitals do not. Thus personnel variables per capita roughly describe the amount of care per individual. By contrast, hospitals per capita describe the

[1] Iowa reported 43,599 aggravated assaults and 464 murders between 1995 and 2001. Michigan reported 89,344 aggravated assaults and 1,182 murders, Ohio reported 12,073 aggravated assaults and 315 murders, and Texas reported 15,034 aggravated assaults and 287 murders. See Appendix I for more information on reporting.

way in which health care resources are organized and utilized. Thus, the greater variation in hospitals per capita indicates that there is more variation in the way the health care system is organized than in personnel resources. This will prove to be an important point in later evaluations of the trauma care system.

Table 3.5 – Demographic and Health Care Variables for Selected States

Health Care	Average of Reporting States	Iowa	Michigan	Ohio	Texas
Doctors per capita	0.191	0.14	0.178	0.188	0.16
Nurses per capita	0.861	1.03	0.881	1.05	0.675
Hospitals per capita	0.292	0.41	0.176	0.169	0.255
Beds per hospital	157.87	115.85	181.04	210.79	138.78
Demographics					
Percent white	0.783	0.94	0.799	0.845	0.709
Percent urban	0.721	0.607	0.751	0.774	0.825
Percent poor	0.122	0.092	106.19	0.106	0.155
Population density	11861.8	1731.3	11864.06	10746.25	9373.76

Empirical Model

Ideally, all health care and severity data would be available. However, because much of it is not and must be proxied and estimated, the model in 5) cannot be tested empirically. It must be adapted to fit the available data. Severity can be estimated directly for each case because data is available for each aggravated assault or murder. Therefore severity is predicted with a set of dummy variables for age and circumstances:

VMale – dummy variable for whether a victim was male

OMale – dummy variable for whether an offender was male

Gun – dummy variable for whether a gun was involved

Knife- dummy variable for whether a knife was involved

Felony – dummy variable indicating whether the attack occurred during another felony

Drug – dummy variable indicating whether the attack was drug-related

Age is separated into 5 year ranges with a dummy variable for each range for both offender and victim age.

6) $$S' = \beta_1 \text{ Vmale} + \beta_2 \text{ OMale} + \beta_3 \text{ Gun} + \beta_4 \text{ Knife} + \beta_5 \text{ Felony} + \beta_6 \text{ Drug} + \beta_7 A_v + \beta_8 A_o$$

Four health care variables are used: nurses per capita, doctors per capita, hospitals per capita and beds per hospital. There are both state and year dummy variables. Data on the time it took for a victim to reach the hospital was not available and the time variables are omitted. Because the dependent variable only takes on values between 0 and 1, a probit regression is appropriate. Equation 7 presents the full model with interaction terms.

7) $$\text{Mortality} = \varphi(\alpha_1 S' + (\alpha_2, \alpha_3, \alpha_4, \alpha_5) H + (\alpha_6, \alpha_7, \alpha_8, \alpha_9)(S' * H) + \alpha_{10} S_d + \alpha_{11} Y_d) + \varepsilon$$

This model can be tested using the available health care data. It includes the effects of health care and severity as well as the interaction between them. Although it differs substantially from the theoretical model presented in 1), it provides a useful form and adheres to the general ideas laid out in the theoretical model.

4. Results

The model that will ultimately be tested has been set forth. It is first necessary, however, to resolve some issues about the form of the health care variables. To begin analyzing the data, two separate sets of regressions are used, one with personnel variables and the other with facility variables. The regressions are separated because the two sets of variables stand for very different components of the health care system. Hospitals per capita and beds per hospital do not measure the size of the health care system but instead represent the way in which it is organized. By contrast, doctors and nurses actually provide care and the personnel variables represent the size of the system. The initial analysis also tests for diminishing returns to determine which, if any, health care variables ought to be included as splines.

Personnel variables are total nurses per capita, including both LPN's and RN's[2], and doctors per capita. Doctors per capita is, unfortunately, not a very specific measure. We would prefer data on emergency medicine specialists or doctors devoted to patient

[2] Although RN's have more training and somewhat different duties than LPN's, they are similar enough in function to be included here together. An analysis more concerned with the very specific components of health care might include them separately since they are likely to have slightly different marginal returns.

care. Unfortunately, in the ARF these data are of very poor quality with many missing values. Further, while patient care doctors is probably a better measure than overall doctors, using emergency medicine specialists would have underestimated trauma care resources since not all doctors working in emergency rooms are emergency medicine specialists.

Facility variables are hospitals per capita and beds per hospital. Hospitals per capita does not directly measure medical resources because, for a given quantity of medical resources, a state could have a varying number of hospitals depending on the size of each hospital. In fact, average size is measured by beds per hospital, a standard gross measure of capacity in health care. What hospitals per capita instead measures is access. For a given population density, an increase in hospitals per capita should make it easier for some parts of the population to reach a hospital. In the particular context of trauma care, more hospitals per capita should reduce the time it takes to reach a hospital and therefore improve outcomes that are time-sensitive.

Personnel

Table 4.1 shows a series of regressions including personnel variables for health care. The first regression in Table 4.1 includes only the health care variables, without controls for severity, state and year dummies, or demographic variables. The coefficients have the expected negative sign and are both significant. This seems to confirm the hypothesis but the regression fails to control for factors that significantly alter lethality. The second regression includes incident-related controls for the severity of the attack.

Table 4.1 – Health Professionals Regression

Basic and Spline regression results
Numbers in parentheses are standard errors

	Regression			
Basic Variable	1	2	3	4
MD's per capita	-2.29** (.366)	-1.05** (.285)	16.77** (3.27)	14.86** (4.72)
Nurses per capita	-1.36** (.131)	-.313** (.103)	-5.01** (1.45)	-4.41** (1.63)

Spline	1	2	3	4
MD's per capita				
First quartile	13.97** (1.87)	10.57** (1.40)	10.37 (12.91)	.878 (18.46)
Second quartile	-10.99** (4.46)	-4.23 (3.36)	19.88** (9.12)	9.57 (11.71)
Third quartile	37.05** (4.07)	27.32** (3.06)	44.61** (7.87)	43.65** (8.97)
Fourth quartile	-14.03** (.823)	-9.50 (6.14)	15.65** (4.22)	9.11 (6.09)
Nurses per capita				
First quartile	-3.07** (.404)	-2.96** (.306)	-10.28** (1.97)	-7.64** (2.19)
Second quartile	1.84 (1.48)	-.385 (1.12)	-3.69 (2.92)	-4.92 (3.41)
Third quartile	.349 (1.10)	3.97** (.826)	-7.08** (2.62)	-3.54 (2.96)
Fourth quartile	.873 (.547)	1.02** (.405)	-10.81** (3.12)	-5.55 (4.25)

Health Care Variables	Yes	Yes	Yes	Yes
Severity Controls	No	Yes	Yes	Yes
Year & State Dummies	No	No	Yes	Yes
Demographic Variables	No	No	No	Yes

*- Significant at the 90% level
** - Significant at the 95% level

Offender and victim age are cut into 5 year categories beginning with 15-19 and then a 50-plus category. Victim and offender sex are represented by a dummy variable. There is a dummy variable for use of a gun, use of a knife, whether the attack was drug-related, and whether the attack took place in the course of another felony[3]. The coefficients on nurses per capita and doctors per capita remain negative and highly significant.

With the addition of state and year dummy variables in regression 3, the coefficient on nurses remains negative and significant. For doctors, however, a switch in sign occurs in this regression. Further analysis revealed that it was mainly the addition of state dummy variables which altered the sign of the coefficient. This is a very unusual result and contrary to the hypothesis that medical care reduces lethality. It demands further investigation. Regression 5 controls for demographic variables: the percent of the population that is white, the percent that is poor, the percent that is urban, and the population density. The coefficient on nurses per capita remains negative and is significant, while the coefficient on doctors per capita is still positive and significant.

One possible explanation for the sign on doctors per capita is that the return to doctors varies across different margins. The next set of regressions use nurses and doctors per capita, split into quartiles, as the health care variables. Table 4.2 describes the cutoff points of each spline for the health care variables. This is an attempt to detect returns that vary depending on the margin.

[3] Coefficients for these dummy variables are available for the full regression in Table 4.5. They are omitted here in the partial regressions.

Table 4.2 – Quartiles of Health Care Variables

	25th percentile	50th percentile	75th percentile
Doctors per capita[a]	0.164	0.203	0.235
Nurses per capita[a]	0.735	0.858	0.999
Hospitals per capita[b]	0.184	0.254	0.372
Beds per hospital	113.03	143.79	192.64

a - Multiplied by 100 for readability
b - Multiplied by 10,000 for readability

However, the results from these regressions do not support this hypothesis. In regressions 3 and 4, which include state and year dummy variables, the coefficients on the quartiles of doctors per capita are all positive, though most are insignificant. The results do not justify including doctors per capita as a spline in the combined regression with all health care variables. This is also true for nurses per capita, which is mainly negative but insignificant in the spline regressions. No obvious diminishing returns or critical values are present. The reasons for the positive coefficient on doctors per capita remain a mystery. The issue will be reexamined later in a regression including all health care variables.

Facilities

The same set of regressions is run with hospitals per capita and beds per hospital as health care variables. Using simply beds per capita would result in colinearity with hospitals per capita and effectively includes the number of hospitals twice on the right hand side of the regression. This is because total beds is just the number of beds

Table 4.3 – Facilities Regression Results

Basic and Spline regression results
Numbers in parentheses are standard errors

Basic Variable	Regression 1	2	3	4
Hospitals per capita	-152.90** (26.77)	-61.77** (20.186)	-970.34** (303.77)	-778.18* (407.67)
Beds per hospital[a]	.029** (.00779)	-0.0661 (0.0593)	-.13** (.045)	-.104** (.0477)

Spline	1	2	3	4
Hospital per capita				
First quartile	-2382.41** (247.82)	-1178.14** (186.17)	-1118.12** (191.06)	-2747.56** (598.97)
Second quartile	-2968.84** (269.74)	-2385.70** (205.38)	-2236.80** (207.85)	-2348.26** (488.42)
Third quartile	2228.91** (203.20)	1043.08** (153.92)	1032.67** (158.26)	-1817.45** (575.59)
Fourth quartile	-157.40** (33.55)	-39.97* (24.12)	-40.07* (24.14)	-479.80 (341.97)
Beds per hospital[a]				
First quartile	.021 (.0143)	-0.0196 (0.0105)	-0.0155 (0.0109)	-0.0965 (0.1201)
Second quartile	-.0508 (.0536)	-0.0628 (0.0404)	-0.1074** (0.0462)	-0.0149 (0.0672)
Third quartile	-1.06** (.13)	-0.4377** (0.0969)	-0.3398** (0.1022)	-0.7351** (0.1895)
Fourth quartile	.0303 (.0232)	0.066** (0.0169)	0.066** (0.017)	-0.3276** (0.076)

Health Care Variables	Yes	Yes	Yes	Yes
Severity Controls	No	Yes	Yes	Yes
Year & State Dummies	No	No	Yes	Yes
Demographic Variables	No	No	No	Yes

a - Scaled by 1,000 for readability
* - Significant at the 90% level
** - Significant at the 95% level

multiplied by the number of hospitals with that many beds. The results for this regression are displayed in Table 4.3. Regressions 3 and 4 are most important because they include dummies that help to control for unobservable state characteristics. In regression 3, hospitals per capita and beds per hospital both have negative coefficients and are significant. Beds continue to have a negative coefficient and are significant in regression 4. The coefficient on hospitals remains negative and is significant.

The spline regressions does not reveal strong evidence of diminishing returns. The only noteworthy instance is the fourth quartile of hospitals. For this quartile, the value of the coefficient is much higher than for the other quartiles. However, because this is quartile's sign is negative, just like the other quartiles, neither hospitals per capita nor beds per hospital is included as a spline in the combined regression.

Full Regression

I now test equation 7), the full regression with all health care and severity variables. First, regressions with severity variables and health care variables are run separately. The results of these regressions are in columns 1 and 2 of Table 4.4. The basic complete form of the full regression includes demographic and severity controls, state and year dummy variables, and all the health care variables: hospitals per capita, beds per hospital, doctors per capita, and nurses per capita. The results of this regression are shown under the heading 3 in Table 4.4. The sign on the coefficient for hospitals is negative but not significant. The coefficient on beds per hospital is negative and significant. The coefficient on nurses per capita has the expected sign and is significant. For doctors per capita, however, the coefficient remains positive and significant.

The major severity controls have the expected signs and are all significant. The use of a gun increases the probability of death during an attack by 3.7 percentage points, while use of a knife increases that chance by .38 percentage points. If the attack was

Table 4.4 : Combined Regression Results

	1	2	3
Doctors per capita	21.31** (4.64)	-	16.68** (4.79)
Hospitals per capita	-239.48 (452.95)	-	-684.91 (446.96)
Beds per hospital[a]	-.141** (.0601)	-	-0.1557** (0.0475)
Nurses per capita	-7.49** (2.04)	-	-4.40** (1.80)
Gun	-	.037** (.0007)	.037** (.0007)
Knife	-	.0039** (.0004)	.0038** (.0004)
Drug-related	-	.067** (.006)	.067** (.0059)
Other Felony	-	.111** (.008)	.111** (.0079)
Population Density[a]	-	.00548** (.00172)	0.00286 (.00185)
Percent Poor	-	-1.18** (.495)	-.748 (.529)
Percent White	-	-.754** (.239)	-.739** (.257)
Percent Urban	-	-.492** (.121)	-.521** (.128)

Health Care Variables	Yes	No	Yes
Severity Controls	No	Yes	Yes
Year & State Dummies	Yes	Yes	Yes
Demographic Variables	No	Yes	Yes

a - Scaled by 1,000 for readability
* Significant at the 90% level
** Significant at the 95% level

drug-related, it was 6.7 percentage points more likely to be fatal. If the attack occurred in the course of another felony, it was 11.1 percentage points more likely to be fatal. All of these factors are expected to increase lethality.

By contrast, the expected signs for the demographic controls are not clear. Population density serves as a proxy for a lot of other factors. One of them is whether the area is rural or urban. In this capacity, it is uncertain what, if any, effect it should have on lethality. Population density is generally believed to increase the rate of crime but it is uncertain what effect, if any, it should have on the composition of crime. The case is similar for the percentage of the population that is poor. Poverty may increase the rate of crime but its effect on composition is uncertain. Ultimately, the best strategy for dealing with this uncertainty was simply to include the available demographic variables and see whether they had a significant effect on lethality, knowing they ought to effect the rate of crime.

Both population density and percent poor were insignificant. Percent white and percent urban both had negative coefficients and were significant. All four demographic variables were included in all regressions on the full set of health care variables. Percent white and percent urban both continue to have negative coefficients and to be significant. Percent poor remains insignificant, while population density has a positive coefficient that is significant in some future regressions.

Variations on the basic regression form are included in Table 4.5. Regressions 1 and 2 include interaction terms. Regression 1 includes interactions between the severity terms knife and gun and hospitals per capita. This is on the hypothesis that the impact of medical resources, and particularly of hospitals, will be different depending on the type

Table 4.5 : Combined Regression Results with Interaction Terms

	1	2	3
Doctors per capita	16.56** (4.79)	35.29** (14.70)	15.57** (4.78)
Hospitals per capita	-687.38 (446.88)	-820.07* (458.30)	-1077.39** (417.01)
Beds per hospital[a]	-.1304** (.0482)	-.148** (.0498)	-.1167** (.0478)
Nurses per capita	-4.40** (1.80)	1.317 (4.64)	-
Gun	.0374** (.00213)	.037** (.0007)	.037** (.0007)
Knife	.00173** (.000904)	.0038** (.0004)	.0039** (.0004)
Drug-related	.0668** (.0059)	.0668** (.0059)	.0667** (.0059)
Other Felony	.111** (.0079)	.111** (.0079)	.111** (.0079)
Population Density[a]	.00287 (.00185)	.00198 (.00196)	.00436** (.00174)
Percent Poor	-.751 (.529)	-.793 (.531)	-.755 (.529)
Percent White	-.738** (.257)	-.736** (.257)	-.832** (.254)
Percent Urban	-.520** (.128)	-.487** (.13)	-.567** (.126)
Gun * Hospitals per capita	-4.54 (25.44)	-	-
Knife * Hospitals per capita	74.85** (31.12)	-	-
Doctors per capita * Nurses per capita	-	-2167.45 (1620.30)	-

a - Scaled by 1000 for readability
* Significant at the 90% level
** Significant at the 95% level

of wound. Because the factors used, gun and knife, also contribute to severity, there is a difference not merely of type but of severity. Thus the interaction terms partially test the hypothesis that the impact of a hospital varies depending on the severity of the wound. A more complete test would require testing more interaction terms between severity variables and health care variables or using an instrumental variable to represent severity and then interacting this term with health care variables. The coefficient on the interaction between gun use and hospitals per capita is negative but insignificant. The coefficient on the interaction between knife use and hospitals per capita is positive and significant. Therefore hospitals have less of a negative impact on lethality for knife wounds than on other types of wounds.

Regression 2 includes an interaction term between doctors per capita and nurses per capita. The coefficient is negative but not significant, indicating that doctors and nurses are not complements in the treatment of trauma victim.

Regressions 3 eliminates nurses per capita from the regression. Because nurses and doctors often increase together, it is possible that the correlation between the two biases the coefficient on doctors per capita. In fact, regression 4 does not support this, but does support the conclusion that including nurses per capita results in upward bias in the coefficient on hospitals per capita. The coefficient on hospitals per capita goes from -684 in regression 1 to -1077 and becomes significant.

Interpretation

These estimated impacts on lethality are substantial and have major implications for the effect of medical resources. Elasticities are presented in Table 4.6. For all variables, the response of lethality to changes in health care is elastic. For doctors, since the estimated coefficient have a positive sign, the estimated elasticity is positive. For the other variables it is negative. Nurses have a particularly strong effect on lethality with an elasticity of -2.69. This suggests, unusually, that the factor with the least variation is the one where variation matters most when considering lethality.

Table 4.6 - Elasticities

	Elasticity
Doctors per capita	2.28
Nurses per capita	-2.69
Hospitals per capita	-1.43
Beds per hospital	-1.76

Table 4.7 presents lethality statistics for all states in the NIBRS. Two values are given for each state. The first is the actual percent lethality in that state. The second is what the percent lethality would be if the state had health care equal to the national average. This is obtained by predicting the value of lethality from regression 1 using health care variables with values at the national average. Certain states stand out. Lethality in Colorado is 1.71%, roughly the national average, but would be .96% if health care were equal to the national average. Iowa's percent lethality increases from 1.04% to 2.71%, and Kansas's rises from 1.27% to 6.23%. Utah's falls from 1.9% to .98%, and West Virginia's more than doubles from 1.54% to 3.26%.

Table 4.8 summarizes health care variables from these states with large changes in lethality. Most notable is the large number of hospitals per capita, high above the national average, in states with significant increases in lethality when health care variables are at the national average. 1.3 percentage points of Iowa's increase are due to the difference in hospitals; this is 78% of the total increase. For Kansas, 2.2 percentage points of the increase are due to hospitals. This is 44% of the total increase. In the case of West Virginia, .9 percentage points of the increase is due to the difference in hospitals. This is 52% of the increase.

Table 4.7 – Lethality by State

State	Actual Lethality	Predicted lethality with national average health care variables
Colorado	1.71%	0.96%
Connecticut	1.57%	1.02%
Delaware	0.88%	0.87%
Idaho	1.23%	1.61%
Iowa	1.04%	2.71%
Kansas	1.27%	6.23%
Massachusetts	0.37%	0.36%
Michigan	1.32%	0.92%
Ohio	2.54%	2.31%
South Carolina	1.33%	1.13%
Tennessee	1.59%	1.97%
Texas	1.87%	1.63%
Utah	1.90%	0.98%
Virginia	2.83%	2.39%
West Virginia	1.54%	3.26%

Hospitals per capita is not a measure of the raw size of the health care system. It reflects only in a very limited way on the amount of care, since hospitals can be of any size. In fact, Kansas had roughly half the beds per hospital of the national average, indicating that Kansas hospitals were roughly half the size of the average hospital in the

Table 4.8 - Summary of Health Care Variables, States With Strong Lethality Effects

	National Average	Colorado	Iowa	Kansas	Utah	West Virginia
Hospitals per capita	0.292	0. 2	0. 436	0.565	0.23	0.373
Beds per hospital	157.87	136.58	109.76	87.17	102.81	140.36
MD's per capita	0.191	0.24	0.17	0.21	0.2	0.22
Nurses per capita	0.856	0.69	1	0.94	0.53	0.861

country. At the same time, hospitals are twice as numerous in Kansas as they are nationally. A significant reduction in lethality results from having a lot of small hospitals, although Kansas must have roughly the national average number of beds per capita. Hospitals represent how the health care system is organized rather than its size, and may highlight a broader point: because of the immediate nature of trauma care, the organization of the trauma care system is more significant than its size.

While most health care variables eventually took on coefficients with the expected sign after properly controlling for severity, state and year differences and other factors, the sign of doctors remained positive and significant. This is both puzzling and initially implausible; it seems unusual to think that adding doctors will worsen the health of trauma care patients. This is especially true in light of the case made earlier that trauma care has been proven to improve the health outcomes of trauma victims.

There are several related explanations for the apparent correlation between doctors per capita and lethality. One is that doctors per capita is simply too gross a measure of the health care system. This is an accusation which can just as easily be leveled at the other variables, which are also gross measures of health care rather than being particularly related to trauma. However, nurses operate mainly in hospitals, beds are measured only in hospitals, and hospitals actually have a direct impact on trauma care. That is, the other variables must be measuring something related to trauma care. Doctors per capita, however, has little necessary connection to hospital work, where trauma care takes place. If this is true, variation in doctors per capita corresponds poorly to variation in trauma care resources.

This points to a second possible explanation. One reason why doctors per capita might not be a good measure of trauma care resources is that such resources may be nearly fixed. Trauma seems like a first priority in health care and is, by definition, necessary care. Thus it may be that the needs of the trauma care system are fulfilled early in the distribution of medical resources. To phrase this another way, the elasticity of trauma care resources relative to the supply of doctors may be low. Even a large change in doctors per capita may correspond to a very small change in doctors devoted to emergency care. Thus there may not be, in the data, a margin across which there are substantial differences in trauma care. Unfortunately, it is impossible to test this hypothesis without substantial data on emergency-room specific resources. If this data were available, it would be used in the regressions rather than doctors per capita. It is possible only to put forth possible reasons for the positive coefficient on doctors per capita.

5. Conclusion

Murder rates differ substantially between locations. They differ for two reasons. First, in some places, there are more violent incidents. Second, the lethality of those incidents varies by location depending on the severity of attacks and on the availability of medical resources. The first is a point about the rate of violent crime, while the second concerns the composition of that crime. Considering only the levels results in an incomplete picture of crime and, in the case of murder, yields the oversimplification that some crimes simply are murders while others are assaults. This is a distinction founded on a belief in the impact of criminal intent and behavior.

While both intent and behavior are important, a significant amount of the variation in lethality, and therefore in murder rates, is also due to variation in health care resources. Generally speaking, increased health care facilities and professionals have a negative effect on lethality. Doctors are an exception, with a positive estimated coefficient, and are discussed in Section 4. It is now possible to tell a complete story about the lethality of an attack, where health care and the severity of the attack are the two components.

First, an attack takes place with a certain severity. This depends on both objective features of the situation, such as the use of a gun, and the intent of the attacker. The intent of the attacker cannot be directly measured but can be represented by certain demographic variables. The severity of the attack also depends on characteristics of the victim, particularly age and sex. Victims over 45 or under 15 were more likely to die than those between 15 and 45. The severity of the attack is then influenced by medical resources and a final health outcome is produced.

These findings serve to validate the use of the lethality perspective. Health care does alter the chances that a violent encounter will result in death and therefore must be considered when studying murder. In examining murder rates it is important to consider both the process that leads from a violent incident to death and the number of violent incidents in the first place. The findings of this paper on severity and the impact of medical resources suggest that any attempt to reduce murder rates can consider several stages of the process that can produce a murder. The murder rate can be reduced either by reducing the number of violent encounters or by changing the composition of those encounters. Thus health care and severity can be important pieces of any policy attempt to reduce murders. It may be that a reduction in guns and an increase in hospitals are better ways to reduce crime than additional policing.

However, examining just the composition of crime is as severely flawed as examining only the overall level. Some steps, such as gun control, would certainly decrease average severity, according to estimates in this paper. Yet their ultimate effect, which is the greatest concern, is ambiguous because the effect of gun ownership on the number of violent encounters is uncertain. Decreases in gun ownership may lead to more violent encounters; if this is the case, then murders may actually increase if gun ownership falls.

The results of this study suggest several avenues for future research. First, this paper begins to decompose lethality into its health care components. Differences in lethality can be further decomposed into health care and severity components in an attempt to understand how each factor contributes to the ultimate outcome. A difference in lethality between locations can then be explained by a difference in severity and a difference in health care.

The results also suggest that access to a hospital is a very important factor. However, only a very rough measure of hospital access, hospitals per capita, was used. Particularly because the data used here are state data, they may not accurately reflect access for large portions of the sample. With detailed data on the location of an attack and the location of nearby hospitals, it would be possible to study this connection more accurately by using the actual distance to the nearest hospital. This would avoid the necessary assumption of this paper that every individual within a state has equal access to a hospital, where the level of that access is based on the number of hospitals per capita in the entire state.

Much like hospital access, severity is also measured only roughly in this paper. It is proxied by demographic factors and objective features of the incident, such as the use of a gun, but there is the potential for a large amount of unmeasured variation in the actions of the assailant. The way in which a weapon is used may be just as important as the fact of its use, but this paper is unable to explicitly account for such differences and particularly is unable to completely account for the intent of the assailant. If severity could be measured directly, there would be no need to create proxies for intent. One possibility is to find data that includes a scoring system for trauma so that each injury is scored according to some standard scale of severity. Then severity does not have to be estimated and intent never needs to be considered. Such an approach would avoid the difficulty that accompanies any attempt to estimate severity, thereby including any number of unmeasured factors. These possibilities for future research build on the demonstration in this paper that health care does have a negative effect on lethality.

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Appendix 1

NIBRS Reporting by Year

	NIBRS Assaults	UCR Assaults	UCR Murders	% Reporting, Assaults	% Reporting, Murders	NIBRS Lethality	UCR Lethality
1996	58127	925146	18107	0.063	0.039	0.012	0.019
1997	70597	953258	17140	0.074	0.049	0.012	0.018
1998	84117	914755	15849	0.092	0.068	0.013	0.017
1999	93469	858358	14470	0.109	0.100	0.015	0.017
2000	122234	866736	14844	0.141	0.131	0.016	0.017
2001	132790	863781	18230	0.154	0.116	0.016	0.021

Appendix 2

Lethality Impacts

	Movement in Independent Variable	
	1%[a]	**1 Standard Deviation**
Doctors per capita	-0.02	0.0190152
Nurses per capita	-0.025	-0.007436
Hospitals per capita	0.0319	-0.012533853
Beds per hospital	-0.0377	-0.009760833

a - Scaled by 100 for readability