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Determination of manner of death based on gunshot wound entry site and bullet trajectory

Rosemary Leigh Pennefeather

To the Graduate Council:

I am submitting herewith a thesis written by Rosemary Leigh Pennefeather entitled "Determination of manner of death based on gunshot wound entry site and bullet trajectory." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Anthropology.

Murray Marks, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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DETERMINATION OF MANNER OF DEATH BASED ON GUNSHOT WOUND ENTRY SITE AND BULLET TRAJECTORY

A Thesis
Presented for the
Master of Arts
Degree
The University of Tennessee, Knoxville

Rosemary Leigh Pennefeather
May 2003

DEDICATION

This thesis is dedicated to my parents, Dennis Pennefeather and Jackie Pennefeather, who always encouraged me to reach for my goals, to my siblings, Shannon Gardner and David Pennefeather, to my best friend, Ted Blegen and the rest of my family and friends who help me to be strong and to meet challenges with wisdom and humor.

ACKNOWLEDGEMENTS

I wish to thank all those who helped me in completing this Master of Arts in Anthropology. I thank Dr. Murray Marks for his guidance throughout this process, from developing a research design to completing the written presentation of this thesis. I thank Dr. William McCormick for use of his collection of autopsy reports as well as the Office of the State Medical Examiner of Tennessee for the use of archived autopsy reports. I thank Mike O'Neil for his assistance in the statistical analysis of the data. I thank Dr. Richard Jantz for his explanation of the logistic regression results from this study. I thank Dr. Lee Jantz for her ideas and invaluable suggestions throughout this research.

I thank my family, friends and fellow students, whose support and encouragement made this work possible.

ABSTRACT

The purpose of this study is to determine if there are patterns in gunshot wound entry site and in bullet trajectory in homicide and suicide victims. Once patterns are shown to exist, differences between homicidal gunshot wounds and suicidal gunshot wounds are statistically analyzed to determine the strength of the different patterns.

Data on gunshot wound entry site and bullet trajectory were collected from two sources of autopsy reports from the state of Tennessee: a collection housed by Dr. William McCormick, MD offered autopsy records from 1988 through 1998, and the Office of the State Medical Examiner in Nashville, Tennessee offered archived autopsy reports from 2000 and 2001. A total of 123 individuals are included in this study, 72 were victims of suicide and 51 were victims of homicide.

Chi-square tests of bullet entry patterns showed that entry sites in the right temple or mid-chest were more likely to be suicides, while those gunshot wounds that occurred on the dorsal surface of the body or in the abdomen were more likely to be homicides.

Logistic regression was used to analyze bullet trajectory and resulted in an equation (Score = Exp(-.550+(1.805*B_F)+(1.902*Torso)-(1.853*R_L))). This equation illustrates that bullets that enter the torso and bullets that travel from the dorsal to the ventral surface are more likely to be homicides, while bullet trajectory from the right to the left is more indicative of suicide. The equation was tested on an additional sample of 6 homicide and 24 suicide victims. Homicides were identified correctly in 66.7% (4 of 6) cases while suicides were correctly identified in 83.3% (20 of 24) cases.

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CHAPTER 1

INTRODUCTION

Firearm-Related Injury

Firearm-related injury is the second leading cause of injury death in the United States second only to motor vehicle-related injuries (Beaman et al 2000, Cherry et al 1998). In a study of firearm-related injury from 1992 through 1995, Beaman et al (2000) looked at all gunshot-related injuries and grouped injury according to intent. The categories included unintentional (accidental), self-inflicted (intentional), assaultive and those gunshot wounds (GSWs) inflicted during legal intervention. Of these four groups, my study focuses on the final three, combining assaultive and GSWs inflicted during legal intervention into one broad category. For this research there is no need to differentiate between murder, manslaughter, and self-defense.

Suicide

In the study by Beaman et al (2000: p 261), the three-year period of 1992 through 1995, self-inflicted GSWs accounted for 49.5% of all firearm-related deaths and for 6.6% of the non-fatal firearm-related injuries. Suicidal deaths in 1997 numbered 17,566 and made up 54% of firearm-related deaths in that year (Rosenberg et al 1999). After compiling information about regional trends for suicide, the Centers for Disease Control (CDC) reported that suicide was the ninth leading cause of death in the United States in 1994 (Table 1). During the years 1990 through 1994, the same study found that

Table 1: First Nine Leading Causes of Death, 1994 (From NCHS, 2002)

Rank	Cause of Death	Number of Deaths in U.S.
1	Heart Disease	732,409
2	Malignant Neoplasms	534,310
3	Cerebro-vascular	153,306
4	Chronic Low Respiratory Disease	101,628
5	Unintentional Injury	91,437
6	Pneumonia and Influenza	81,473
7	Diabetes	56,692
8	HIV	42,114
9	Suicide	31,142

death by firearm injury was the leading method of suicide in all regions of the United States (CDC 1997). In 1994 alone, 7.2 (0.0072%) out of every 100,000 individuals in the United States used a gun to commit suicide and of 31,142 suicides that year, 64.7% of men and 41.5% of women committed suicide by using firearms (National Center for Health Statistics—NCHS 1996). Perhaps the high rate of self-inflicted, firearm-related death is not surprising as suicidal GSWs are more likely to be lethal than other means of committing suicide (Rosenberg et al 1999). According to the CDC (1997), the three leading causes of suicide death are firearms, strangulation and overdose. Other methods include inhalation, cutting, drowning, falls and "other."

It is easy to recognize groups with the highest risk of suicide when sex, ancestry, and age are taken into account. In a study by Kaplan and Geling (1999) from 1989 to 1993, White men were the highest risk. Out of the 139,566 suicides that took place between 1989 and 1993, 103,884 (74.4%) were white males. The second highest group at risk was White women with

26,064 (18.7%) of the 139,566. Both Black men and women had the lowest risk with 8,006 (5.7%) and 1,612 (1.2%) of the 1989 to 1993 suicide deaths, respectively. All groups experienced the greatest suicide risk between the ages of 20 and 39. Firearm-related death constituted 59.2% of the 139,566 suicide deaths studied by Kaplan and Geling.

When gun type preference by suicide victims is investigated, research indicates variation between United States and Swedish samples. For example, Druid's 1997 research involving a Swedish sample of homicide and suicide victims, two-handed weapons (rifle, shotgun) were most often used. These weapons were used in approximately 65% of the suicide deaths in that sample while handguns were used only 20% of the time). Similarly, a second Swedish study revealed that 64% of firearm suicides involved the use of two-handed firearms while only 32% involved the use of a handgun (Karlsson 2000). In a Texas study, only 25% of suicide victims used two-handed weapons while handgun use caused the remaining 75% of firearm suicide deaths (Stone 1992). Another U.S. study from Washington State found that 64.0% of suicide deaths during the years 1976 through 1978 were caused by a handgun use while 36% were caused by using a two-handed weapon (Eisele et al 1981). The preferred use of handguns in the United States is not surprising given the ease with which people are able to purchase handguns in this country.

Finally, researching suicidal firearm death, the number and characteristics of GSWs are of interest. Firearm-related suicides are generally

characterized by a single GSW (Druid 1997, Eisele et al 1981), but it is possible to observe suicide victims with more than one GSW. If multiple GSWs are present in a suicide investigation, all but one wound must not be immediately lethal (Introna and Smialek 1989). The main characteristic of suicidal GSWs is the expectation that wounds will demonstrate soft tissue characteristics of contact or close range shots (Druid 1997, Stone 1992).

Homicide

While suicide rates have been increasing, moving from 10.9 (0.0109%) per 100,000 individuals in 1962 to 12.0 (0.012%) per 100,000 individuals in 1994 (Kaplan and Geling 1999), homicide rates have been dropping since their most recent peak in 1991. However, even with the decrease from 9.8 to 5.7 per 100,000 individuals in 1999 (Fox and Zawitz 2001), homicide will always be a social concern in the United States. As with suicide, firearms are most often used to cause death in homicides. Between 1992 and 1995, assaults resulted in 46.0% of firearm-related fatalities and 72.3% of non-fatal firearm-related injuries (Beaman et al 2000). In 1999, 10,118 (65.1%) of the 15,530 homicides were inflicted by firearms. In the years between 1976 and 1999 homicides were most often committed with handguns (Figure 1) (Fox and Zawitz 2001).

When U.S. victims of homicides are broken down into groups by sex, ancestry, and age, those groups with higher risks are evident. Men, once again, are more likely to be homicide victims. The homicide victimization

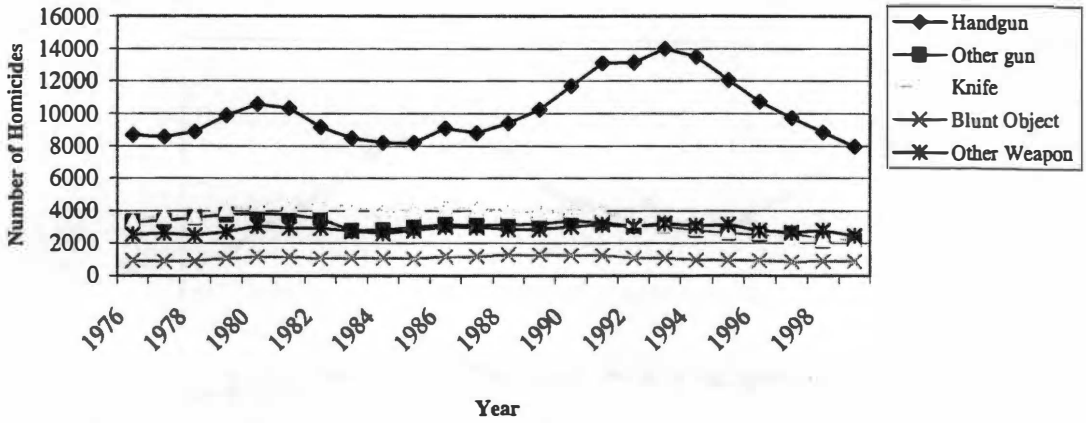

Figure 1: Weapon Type Used in United States Homicides 1976-1999 (After Fox and Zawitz 2001)

rate for men has fluctuated during the period between 1976 and 1999. It has only been during the last decade that a steady decline is seen. Like collective averages seen above, the most recent peak in the numbers for male homicide victims occurred in 1991. During that year, 78.1 % (19,270) of 24,664 homicides were male. The number of male homicide victims declined to the 1999 numbers when 15,513 homicides were committed. Of those victims, 11,713 (75.5%) were male. The victimization rates for women from 1976 to 1999 have declined slowly (Figure 2). The most recent peak in numbers for female homicide victims occurred in 1993 when 5,550 (22.7%) of the 24,487 homicide victims were female. By 1999, only 3,800 (24.5%) of the 15,513 homicide victims were female. Homicide rates continued to decline in 1999 for both sexes, but men were 3.2 times more likely to be homicide victims then women (Fox and Zawitz 2001).

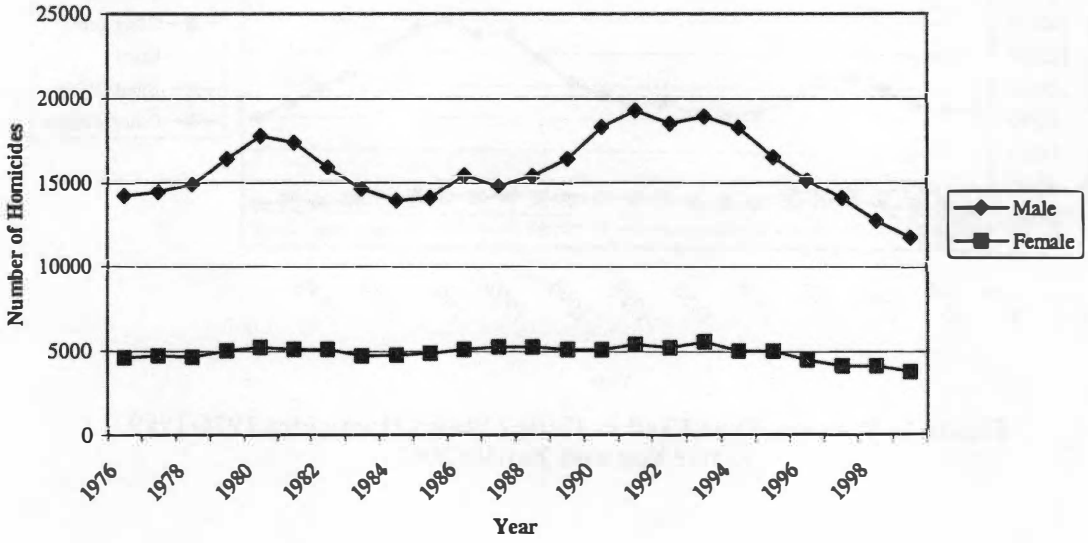

Figure 2: Homicide Victimization by Sex 1976-1999
(After Fox and Zawitz 2001)

When ancestry is considered, 32.4 (0.0324%) per 100,000 of the population of Blacks were murdered during the twenty-two-year period between 1976 and 1999. During that same period, only 5.1 (0.0051%) per 100,000 of Whites suffered the same fate. In fact, during 1999, Whites were 1/6 as likely to be murdered as Blacks (Fox and Zawitz 2001).

Finally, homicide victims tend to be younger: 17.0 (0.017%) per 100,000 of the population are homicide victims between 18 and 24 years of age. The second highest victimization rate occurs for those from 25 to 34 years at 14.6 (0.0146%) per 100,000 of the population. As age increases, homicide risk declines (Figure 3).

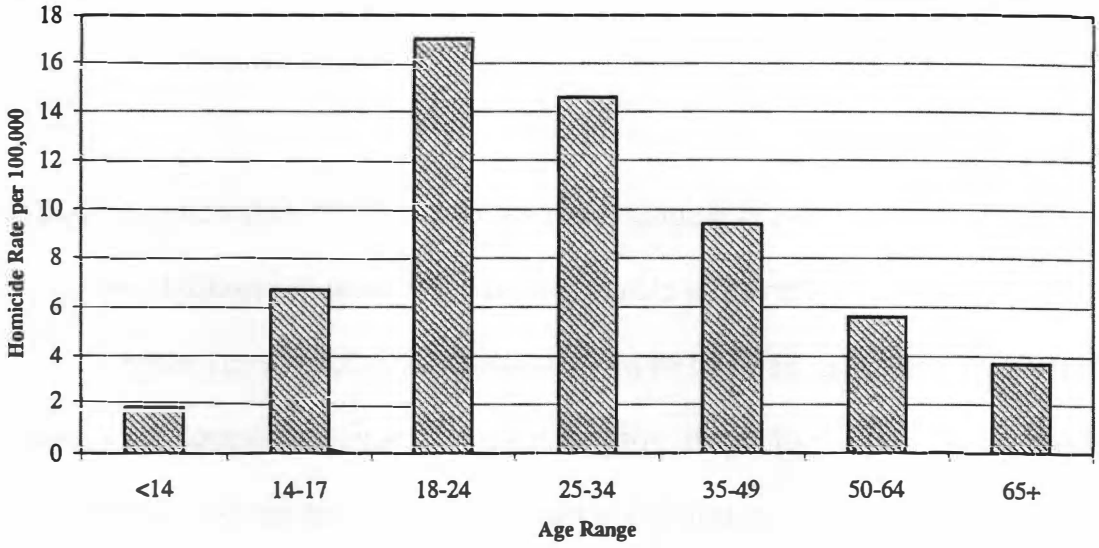

Figure 3: Homicide Victimization by Age 1976-1999
(After Fox and Zawitz 2001)

Suicide and Homicide as Manner of Death

Self-inflicted and homicidal GSWs make up a majority of the second leading cause of injury death—firearm-related fatalities—at 49.5% and 46% respectively. Crime scene investigators, therefore, are familiar with firearm-related fatalities. In the State of Tennessee, autopsies are required for victims of violent death including all firearm-related fatalities (McCormick, personal communication). In cases of violent death evidence is collected from a variety of sources in the effort to define the manner of death. Investigators assemble details from the crime scene, from witnesses, and from the decedent's past. The forensic pathologist collects information from the decedent himself at

autopsy. Once the variables are pooled, a determination of homicide or suicide can be made.

Statement of Purpose

This research involves a statistical analysis of GSW entry site and bullet trajectory. Patterns that reveal a clear separation between homicidal and suicidal GSWs can then be used in investigations as evidence to answer questions about manner of death. Although I have focused research on a single aspect of firearm-related fatalities, it is not my intention to suggest that this method of data collection should replace or supercede any other means of determining manner of death. Rather, this study provides research and analysis of ideas that most forensic pathologists understand through personal experiences. For example, several studies have analyzed the patterns of entry wounds in suicide victims (Azmak et al 1999, Druid 1997, Eisele et al 1981, Isiklar and Lindsey 1998, Karlsson 1998, 1999, Quatrehomme and Iscan 1997, 1998a, 1998b). It is the experience of most pathologists that regions including the temple, the mouth, and the thorax are most often chosen for self-inflicted GSWs (Druid 1997, Eisele et al 1981, Karlsson 1999). The areas of preference are referred to as suicide areas. Few investigators will disagree that suicide areas exist, but Eisele et al (1981) suggested "Most forensic pathologists have formed opinions about the relative frequencies of various sites for suicidal gunshot wounds." They note, "Although perpetuated in print, these conclusions are for the most part based on personal experiences (p

480)." It is only when this personal experience is supported by findings from data collection and analysis that statements about characteristics of suicidal GSWs can be made. An understanding of what patterns may be found in suicidal GSW is of use to forensic pathologists.

Statistical analyses of firearm fatalities are not new. Some studies are limited to a single characteristic: a specific situation whether it is use of a specific gun or ammunition type (Amirjamshidi et al 1997, Dowling et al 1988, Jones et al 1987), wound location (Azmak et al 1999, Isiklar and Lindsey 1998, Quatrehomme and Iscan 1997, 1998a, 1998b), or manner of death (Eisele et al 1981, Stone 1992). Investigators first demonstrate that a characteristic is present or more representative of either homicide or suicide. My research includes this type of analysis, and the purpose is to demonstrate a significant regularity in the GSW entry site and bullet trajectory of suicidal GSWs that can be separated from homicidal GSWs. I recognize there is a "next step" beyond the scope of this paper. In his research detailing the use of 'Forensio-metrics', Karlsson (1998, 1999) compares a multitude of characteristics of both homicide and suicide in an attempt to differentiate between the two. Karlsson suggests that consideration and comparison of all variables is more effective when comparing homicide to suicide. In his research on firearm-related deaths, Karlsson (1999) used a test data set to correlate 15 variables to either homicide or suicide. Once the variables had been correlated, they were ranked and weighted. In this way he developed a model with an estimated sensitivity of 89% when classifying homicide

correctly. I suggest, then, although it is important to recognize patterns in GSWs for the determination of manner of death, we should, like Karlsson, also explore the possibility of establishing standards for multivariate analysis in future studies.

CHAPTER 2

MATERIALS AND METHODS

Sample Population

In an effort to analyze differences between the trajectory of homicidal and suicidal GSWs, I have accessed two different sources of autopsy reports, all from the state of Tennessee (Figure 4). The first collection of reports is from the work of William F. McCormick, M.D., who was a Deputy State Medical Examiner for 25 years. Dr. McCormick gave me access to his autopsies performed over 10 years from 1988 to 1998. These autopsies were performed at the Upper East Tennessee Forensic Center at Quillen College of Medicine in Johnson City, Tennessee. These autopsies are of individuals who died in Washington, Carter, Sullivan and some surrounding counties in Upper East Tennessee. From the records, a total of 77 autopsies were used in this analysis, with 60 suicides and seventeen homicides. I also obtained records from the Office of the State Medical Examiner in Nashville, Tennessee, from autopsy reports from 2000 and 2001. Copies of all autopsy reports from the state of Tennessee are housed at the Office of the State Medical Examiner. With these autopsy reports, I was able to collect data from Central and Western Tennessee for my statistical analysis. Autopsy reports from Davidson, Dyer, Gibson, Hamilton, Montgomery, Shelby, Weakly, and Williamson Counties added information from 34 homicides and 12 suicides to this study. There are a total of 123 individuals in this study, 72 of whom were suicide victims and the remaining 51 were homicide victims (Table 2).

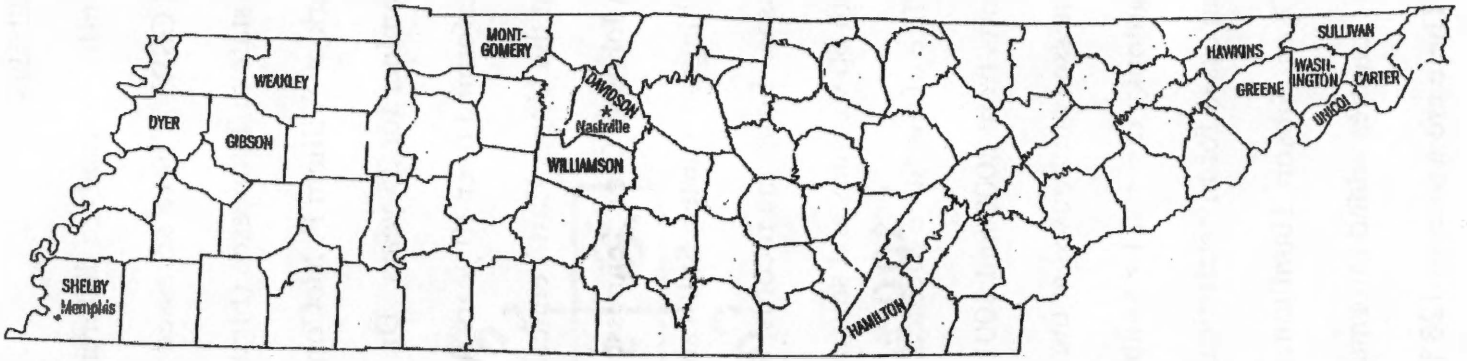

Figure 4: Map with Tennessee Counties Represented in This Study (After U.S. Census Bureau Map 2002)

Table 2: Homicide and Suicide Victims
(From Tennessee Autopsy Reports 1988-2001)

	Homicide		Suicide	
	Male	Female	Male	Female
Black	24	5	3	0
White	15	4	54	14
Other	2	1	1	0
Total	41	10	58	14
Sample Totals	51		72	

Data Collection Methodology

I have based my data collection methodology on Druid (1997) which first suggested that bullet trajectory differed between homicidal and suicidal GSWs. There are several statements to make before I explain how the data was analyzed. When a bullet enters a human body, it travels along a course that can be parallel to, or can deviate from three planes in the body. These planes are the sagittal, which separates the body into right and left sections, the coronal, which divides the body into front and back regions, and transverse, which separates the body into upper and lower portions (Bass 1995, Stern 1997, White and Folkens 2000). To describe a case of a bullet that travels along a parallel course, a hypothetical individual is struck in the chest and the bullet travels in an anterior to posterior direction. That bullet travels parallel to two planes: the sagittal and the transverse.

Alternatively, with the same point of entry, if the bullet deviates from one or both planes, angles of difference can be measured. These angles are

created between the actual bullet path and the path that the bullet would have followed had it remained parallel (Figure 5).

To obtain these angles, I used a coordinate data system. The x-axis was the measurement of the distance right lateral (negative) or left lateral (positive) of the midline. The y-axis was the distance below the top of the head (negative), in the case of the McCormick autopsy reports, or above the heel (positive), in the case of the autopsy reports housed at the Office of the State Medical Examiner. Coordinates were created for both entry sites and bullet termination or exit sites.

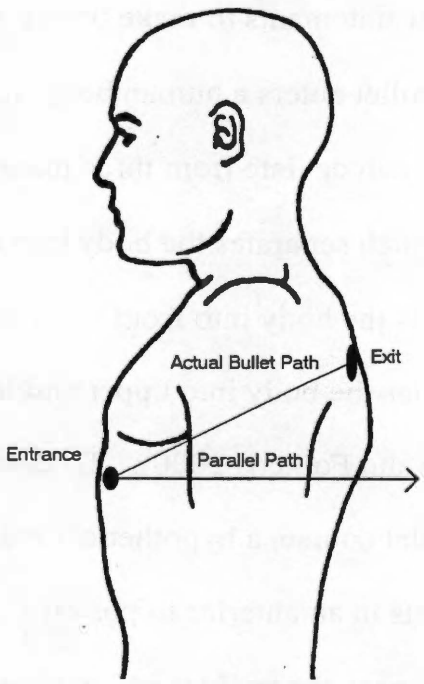

Figure 5: Angle created by deviation from transverse plane

Once coordinates for entry and bullet termination or exit wounds were established (Table 1-A), a right triangle was produced with the hypotenuse linking the coordinates of the entrance with the coordinates of the bullet termination or exit (Figure 6). Because the length of the triangle legs were known, it was possible to use the Pythagorean theorem to determine the length of the hypotenuse, and from there to use the inverse of sine to determine the remaining two angles. Following Druid (1997), if an angle was less than 10 degrees, it was considered to be parallel to the plane. Once the deviation of the bullet path from the planes was established, it was recorded in a three-letter description. A bullet can travel to the anterior (F), to the posterior (B), superiorly (U), or inferiorly (D), or to the right (R), or to the

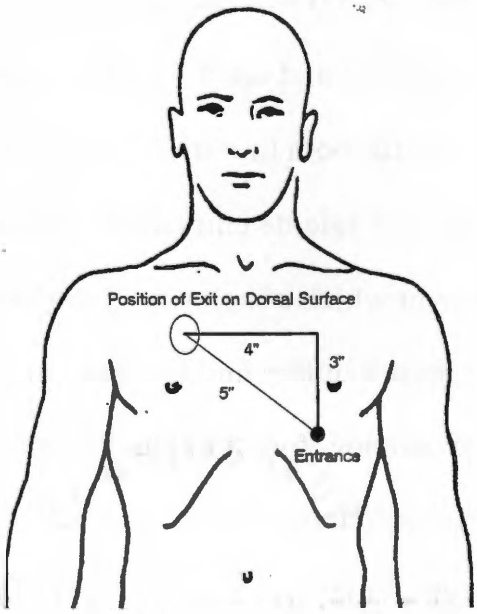

Figure 6: Right triangle production—exit wound lies 3 inches above and 4 inches to the right of the entrance wound. Pythagorean Theorem determines length of hypotenuse.

left (L). A final possibility would be a bullet traveling parallel (P) to a plane, with no deviation from front to back, or up or down, or to the right or to the left. If we take the preliminary example, given above, of the bullet that enters the chest and travels parallel to both the sagittal and transverse planes, it would be described as BPP: the path is to the posterior (B), but neither up or down, or right or left (Figure 7). If we change that scenario to describe a bullet path that is to the posterior, up and to the right, the descriptor would then be BUR (Figure 8).

Once each entrance/exit pair was designated a descriptor, they were separated into groups based on the generalized location of the entrance wound. Entrance sites included in this study remained consistent with those sites analyzed in Druid's article (1997) and included right and left temple, right, left and mid-neck, mouth, left chest and other. A Chi-square test was performed on this group of entry sites for both this study and Druid's published data to reveal trends in homicide and suicide entry sites. These areas were chosen because they are the sites at which a majority of the suicidal GSWs occurred. Homicidal GSWs were more random and occurred at sites that would never appear in a case of GSW suicide, for example, the dorsal surface of the body. Although, during the data collection I noted wounds to the appendicular skeleton, I have limited this study to bullet trajectory in the axial skeleton.

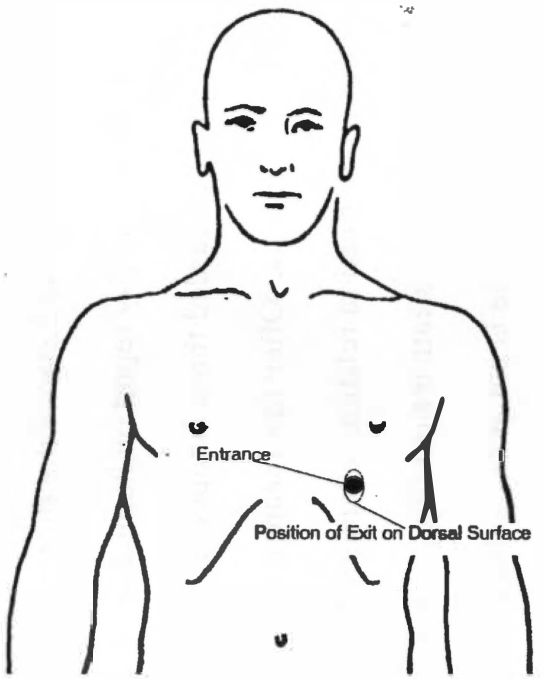

Figure 7: No deviation from transverse or sagittal planes

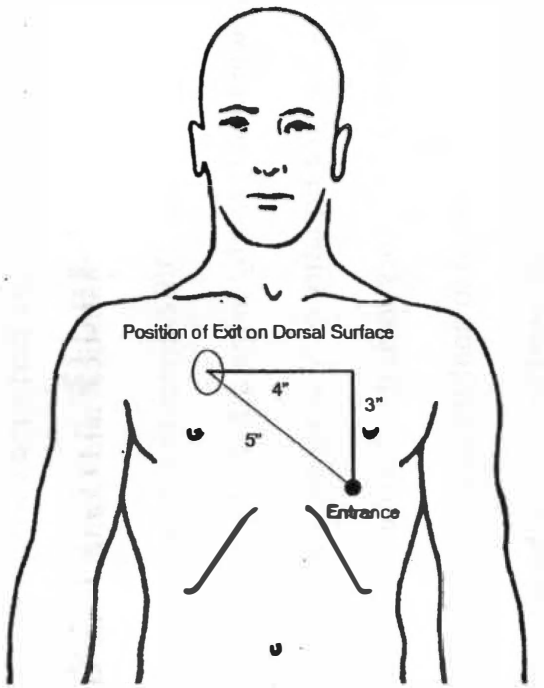

Figure 8: Deviation from transverse and sagittal planes

Data collection also included information about the age, sex, and ancestry of each individual as well as noting the number of GSWs that each individual suffered and the distance the shot was fired from the victim. I was unable to use every autopsy report on homicidal or suicidal GSWs that was available to me. I discarded those autopsy reports that did not have the necessary measurements. Often this meant that GSW entry points in the mouth or those described in relation to landmarks on the body as well as GSWs caused by shotguns rather than rifles or handguns could not be used. Because of this, my sample is not as complete as might be desired and statements made about frequency of GSW entry sites or two-handed firearm use are missing a portion of data.

Statistical Analysis

After the data were collected and organized, more complex analysis was possible. All statistics were performed with assistance from the University of Tennessee—Knoxville Statistical and Computational Consulting Center and using SPSS software. Differences in the mean ages of homicide and suicide victims were analyzed by using a T-Test for independent samples and Levene's Test for Equality of Variances. Preliminary statistics looking at bullet entry and trajectory used the Pearson Chi-Square test. Logistic regression was also used to analyze bullet trajectory trends.

The Chi-square test used to analyze bullet entry included only those entry sites listed above. The Chi-square test used to analyze trajectory looked

only at directions including to the posterior (B), to the anterior (F), cranially (U), caudally (D), to the right (R), and to the left (L). It did not take into account the entry site of each wound. Logistic regression considered direction and also noted when entry site occurred in the torso.

Initially, Logistic Regression was attempted by breaking the sample in to groups based on entry site and the various three-descriptor trajectory sets. This method of sample division created sub-samples that were too small to reveal recognizable, usable patterns. In an effort to arrange the data in a form that could be analyzed by logistic regression, several steps were taken. First, the series of three-descriptor sets were separated into three different groupings: direction along the sagittal plane (towards the ventral surface or towards the dorsal surface), direction from the transverse plane (cranial or caudal), and direction along the coronal plane (to the right or to the left). Binary code was used to indicate bullet direction in association with each plane. Both categories for each plane received a zero if, rather than to the front or to the back, upwards or downwards, or to the left or the right, the course of the bullet remained parallel to that plane (Table 1-B).

Once the data were arranged in this manner, area of entrance was simplified. The data for the logistic regression noted if the bullet entered the torso, differentiating a torso entrance wound from a head entrance wound. After the logistic regression was completed, three characteristics were noted as possible predictors of homicide or suicide.

CHAPTER 3

RESULTS

Tennessee Sample Homicide and Suicide Characteristics

This study included 72 suicides and 51 homicides. Preliminary analysis of the data from these cases included age, sex, and ancestry, number of entrance wounds, type of firearm used, and distance the muzzle was from the victim. As noted in Chapter 1, these factors may be used to support determination of manner of death. White males make up the largest group of suicide victims, for example, while Black males tend to make up the majority of homicide victims. Bullet trajectory is combined with this basic analysis, and the results below reveal the characteristics that define GSWs as homicide or suicide.

Age

Although both homicide and suicide victims included teenagers, suicide victims in this sample had a wider age range and an older mean age at death. The youngest suicide victim was sixteen while the oldest was 78 years. The mean age at death was 47 years. The greatest number of suicides (13 individuals) occurred for the 30-34-age range. The number of deaths peaked a second time for the 55-59-age range, and again for the 65-69-age range (Figure 9).

The youngest age for homicide victims in this sample was fourteen years. The age range for homicide deaths was not as broad as for suicide

deaths. The oldest homicide victim was only 52 years. The mean age at death for homicide victims was 31, but the age range with the most individuals represented was the 35-39-age group with ten individuals (Figure 10). The age-at-death means, 47 and 31, were significantly different.

Sex

In the sample of suicide victims, the majority was male (Figure 11). There was a total of 72 suicide victims, and 58 (80.6%) were male. The remaining 14 (19.4%) were female.

Males also dominated those who were homicide victims. Although the sample size was smaller, with only 51 victims represented, the percentages

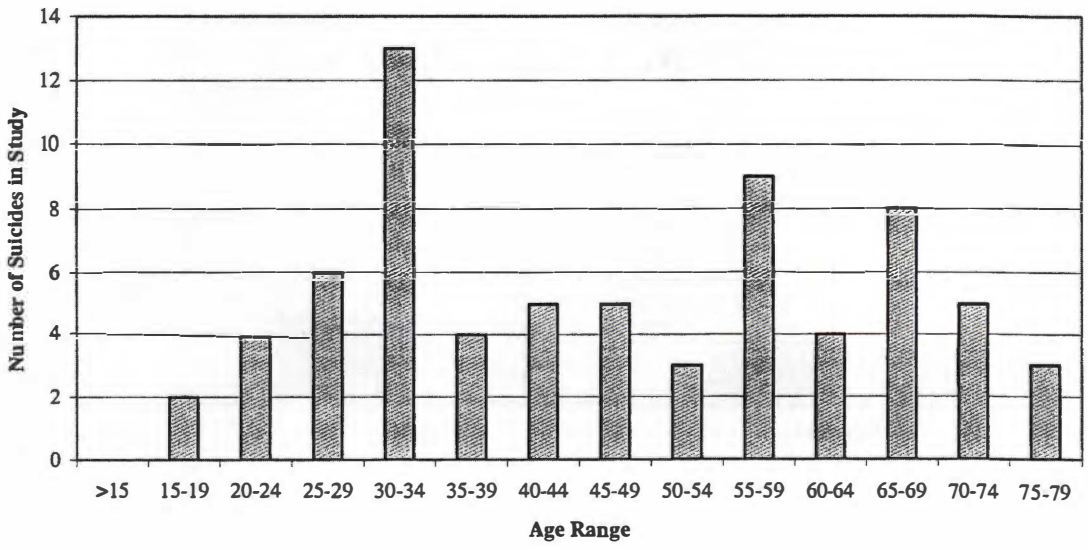

Figure 9: Suicide Death by Age
(From Tennessee Autopsy Reports 1988-1998 and 2000-2001)

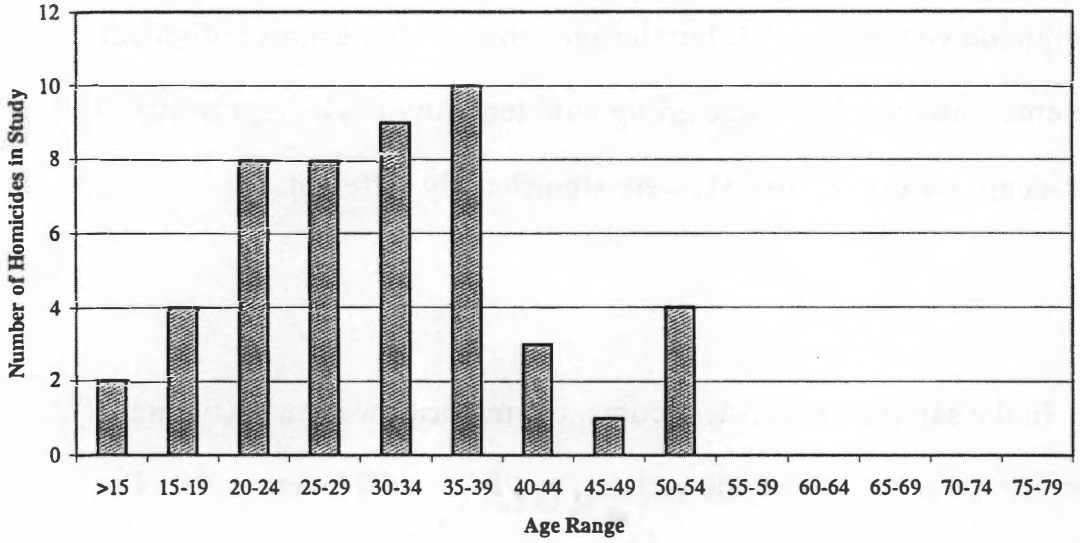

Figure 10: Homicide Death by Age
(From Tennessee Autopsy Reports 1988-1998 and 2000-2001)

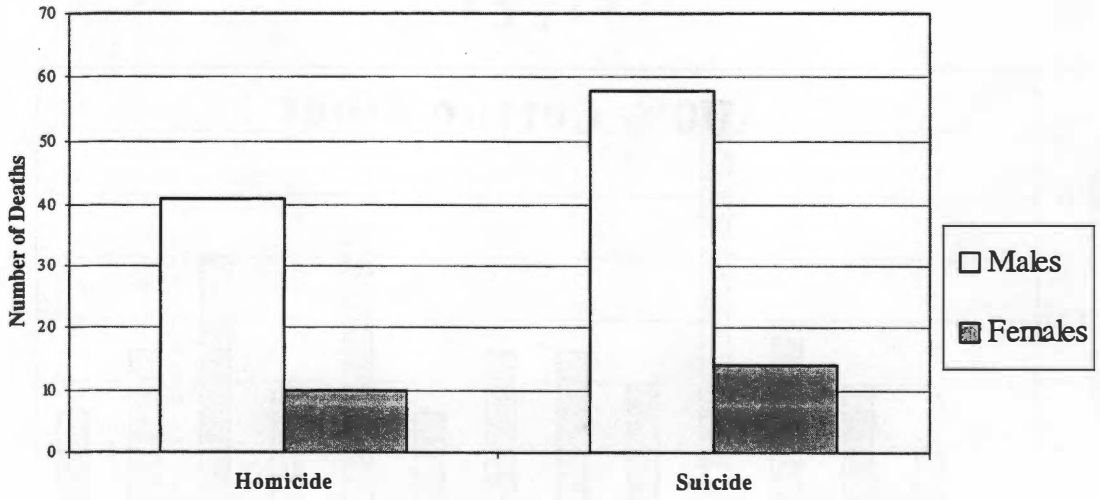

Figure 11: Homicide and Suicide Deaths by Sex
(From Tennessee Autopsy Reports 1988-1998 and 2000-2001)

were similar. Of the 51 victims, 41 (80.4%) were male. Ten (19.6%) female victims made up the remaining.

Ancestry

The sample population included very little variation in ancestry: a majority were White individuals. Blacks and other populations were represented in small numbers. Those individuals who were included in the "Other" category included three people of Latin American or Hispanic descent and one described as being of Arabic descent.

Whites made up the majority of suicide victims with 68 (94.4%) out of the 72. Only three Blacks (4.2%) and a single individual (1.4%) designated as "Other" were included among the suicide victims.

If both ancestry and sex are considered, a majority of the suicide victims are White males. Out of the 58 male suicide victims, 54 (93.1%) were of European descent. White females were the second largest group. Of the fourteen female suicide victims, all were White. The remaining three Black suicide victims (5.2%) and the "Other" suicide victim (1.7%) were male (Figure 12).

The homicide victims followed the expected pattern as noted in Chapter 1. While the majority of suicides were White males, Black individuals made up the majority of homicides, representing 29 (56.9%) out of the 51 individuals in this sample. The second largest group of homicides was White,

Gunshot Wound Entry Sites

Data collection of the full range of entry sites included right, left and mid-dorsal head, right and left temple, right, left and mid-face, mouth, chin, right, left and mid-neck, right, left and mid-chest, right, left, and mid-back, and right and left abdomen. The GSWs that entered the dorsal surface of the body as well as the abdomen were found only in homicide victims. With so great a variety of entry sites, analysis was difficult and the entry sites in the statistical analysis were limited to right and left temple, mouth, right, left and mid-neck, left chest and other. The choice of these entry sites was consistent with Druid's paper (1997), and focused analysis on entry sites that could be found in both homicides and suicides. The unlikely or impossible entry sites for suicide victims, those on the dorsal surface and in the abdomen, are grouped in the "other" category.

In the sample of suicide victims, 74 GSWs were present, all of which were included in this analysis. In the sample of homicide victims, 123 entry wounds were present. However, only 67 of those entry wounds were associated with usable measurements or occurred in the axial skeleton.

In the sample of suicide victims, the greatest number of entry wounds was found at the right temple with 36 (48.6%) occurrences (Table 3). This is in contrast to the 4 (6.0%) right temple GSWs in the homicide victims sample. The second greatest number of suicidal GSWs entered the left chest, with 17 of the 74 (23.0%). It was just as likely, however, for a homicidal GSW to

Table 3: Gunshot Entry Wound Site Frequency
(From Tennessee Autopsy Reports 1988-2001)

Gunshot Wound Entry Site	Homicide	Suicide
Right Temple	4	36
Left Temple	4	6
Mouth	0	3
Right Neck	2	0
Anterior (Mid) Neck	1	1
Left Neck	3	0
Right Chest	5	0
Anterior (Mid) Chest	1	9
Left Chest	16	17
Other	31	2
Total Number of Entry Wounds	67	74

enter the left chest; 16 of the 67 (23.9%) homicidal entry sites were found in the left chest.

When entry site is analyzed using a chi-square test, two points of entry can be separated by manner of death (Table 4). GSWs that occurred in the right temple or in the mid-chest region are more likely to be suicides than homicides. Because the sample size was so small (139 GSWs), further differentiation was not possible for this sample. Druid's sample (1997) included 331 GSWs: 112 homicidal and 219 suicidal injuries. Although bullet entry and trajectory were noted, no statistical analysis occurred at that time. If his numbers are analyzed using the chi-square test, a greater number of entry sites that indicate suicide rather than homicide are revealed (Table 5). These include the right temple, mouth, forehead, left and anterior neck and the left chest.

Table 4: Chi-square Test Results
(Tennessee Sample)

How*Where Cross-tabulation

	Where		Left Chest	Left Neck	Left Temple	Mid Neck	Mouth	Other	Right Neck	Right Temple	Total
How	Homicide	Count	48	9	12	3	0	111	6	12	201
		Expected Count	47.4	4.8	14.4	2.4	4.3	67.5	2.9	57.4	201
	Suicide	Count	51	1	18	2	9	30	0	108	219
		Expected Count	51.6	5.2	15.6	2.6	4.7	73.5	3.1	62.6	219

Chi-Square Test

	Value	df
Pearson Chi-Square	145.719	7
Likelihood Ratio	166.725	7
N of Valid Cases	420	

Table 5: Chi-Square Test Results
(After Druid 1997)

How*Where Cross-tabulation

	Where		Forehead	Left Chest	Left Neck	Left Temple	Mid Neck	Mouth	Other	Right Neck	Right Temple	Total
How	Homicide	Count	18	27	6	15	6	9	192	12	30	315
		Expected Count	30.3	49.5	10.4	14.1	17.8	58.6	75.7	10.1	48.5	315
	Suicide	Count	72	120	25	27	47	165	33	18	114	621
		Expected Count	59.7	97.5	20.6	27.9	35.2	115.4	149.3	19.9	95.5	621

Chi-square Tests	
Pearson Chi-Square	381.148
Likelihood Ratio	396.539
N of Valid Cases	936

Logistic Regression

The strongest predictor is entry site in the torso, which is six times more likely to indicate homicide rather than suicide (Exp(B) 6.702). The second strongest indicator of homicide is when the bullet travels in a dorsal to ventral direction. A dorsal to ventral bullet path is six times more likely to indicate homicide rather than suicide (Exp(B) 6.080). Finally a bullet path from right to left is six times more likely to be suicide rather than homicide (Exp(B) .157) (Table 6).

When the GSWs from this sample were analyzed using the findings from this logistic regression, several patterns appear. Suicidal GSWs that entered the mid and left chest regions were more likely to be misdiagnosed as homicides. Homicidal GSWs that entered the right temple and face regions

Table 6: Logistic Regression Results (Tennessee Sample)

Logistic Regression
Variables in the Equation

		B	S.E.	Wald	Df	Sig.	Exp(B)
Step 1*	R_L	-1.793	0.376	22.753	1	0.000	0.166
	Constant	0.928	0.286	10.492	1	0.001	2.529
Step 2**	R_L	-1.637	0.403	16.536	1	0.000	0.195
	Torso	1.641	0.406	16.317	1	0.000	5.161
	Constant	-0.114	0.386	0.086	1	0.769	0.893
Step 3***	B_F	1.805	0.546	10.910	1	0.001	6.080
	R_L	-1.853	0.439	17.808	1	0.000	0.157
	Torso	1.902	0.448	18.011	1	0.000	6.702
	Constant	-0.550	0.430	1.640	1	2.000	0.577

* Variable(s) entered on step 1: R_L

**Variable(s) entered on step 2: Torso

***Variable(s) entered on step 3: B_F

were misdiagnosed as suicides (Table 1-C).

The logistic regression yielded an equation that can be used to determine manner of death using binary code to describe the three characters: bullet direction from back to front, bullet direction from right to left, and torso entry. The equation is:

Score = Exp(-.550+(1.805*B_F)+(1.902*Torso)-(1.853*R_L)),

Homicide is indicated when scores are greater than one while scores indicating suicide fall between zero and one. The equation was tested using a small sample of homicides and suicides not included in the earlier analysis. This sample, from McCormick's autopsy reports, included individuals from 1986, 1987 and 1993. There was a total of 30 individuals in this sample: 24 suicide victims, 6 homicide victims. Each autopsy report was analyzed as described in the first chapter, with information collected with regards to age, sex, ancestry, weapon type, caliber size, and GSW particulars. Once data collection was complete, the necessary information was entered into the equation. With this equation, four of the six (66.7%) homicides were correctly identified, while the remaining two (33.3%) were erroneously grouped with the suicides. The suicides were more accurately scored; 20 of the 24 (83.3%) suicides were accurately identified and only four of the 20 (16.7%) were incorrectly identified as homicides (Table 7).

Table 7: Additional Tennessee Sample used to test equation exp(-.550+(1.805*B_F)+(1.902*torso)-(1.853*R_L)

Logistic Regression Equation

	B-F	F-B	U-D	D-U	R-L	L-R	Torso	
Homicide	0	1	1	0	0	1	1	3.8651481
Homicide	0	1	1	0	0	1	1	3.8651481
Homicide	0	1	1	0	1	0	0	0.09255058
Homicide	0	1	1	0	0	1	0	0.57694981
Homicide	1	0	1	0	0	1	1	23.4999901
Homicide	1	0	1	0	0	1	1	23.4999901
Suicide	0	1	0	0	1	0	0	0.09255058
Suicide	1	0	0	1	1	0	0	0.56270487
Suicide	0	0	0	1	1	0	0	0.09255058
Suicide	0	1	1	0	0	0	1	3.8651481
Suicide	0	1	0	1	1	0	0	0.09255058
Suicide	0	1	0	1	1	0	0	0.09255058
Suicide	1	0	0	1	1	0	0	0.56270487
Suicide	0	1	0	1	1	0	0	0.09255058
Suicide	1	0	0	1	1	0	0	0.56270487
Suicide	1	0	0	1	0	1	0	3.50783837
Suicide	0	1	0	0	1	0	1	0.6200222
Suicide	0	1	1	0	1	0	1	0.6200222
Suicide	0	1	0	0	1	0	1	0.6200222
Suicide	0	1	0	1	0	1	1	3.8651481
Suicide	0	1	1	0	1	0	1	0.6200222
Suicide	0	1	1	0	1	0	1	0.6200222
Suicide	0	1	0	0	1	0	1	0.6200222
Suicide	0	1	1	0	0	0	1	3.8651481
Suicide	0	1	1	0	1	0	1	0.6200222
Suicide	0	1	1	0	1	0	1	0.6200222
Suicide	0	1	1	0	1	0	1	0.6200222
Suicide	0	1	1	0	1	0	1	0.6200222
Suicide	0	1	0	0	1	0	0	0.09255058
Suicide	0	1	0	1	1	0	0	0.09255058

CHAPTER 4

DISCUSSION

This sample of Tennessee homicides and suicides follows patterns that were described in Chapter 1. The focus of this study was entry site and bullet trajectory, however when all factors are taken into account certain trends appear. Below are descriptions of characteristics indicative of suicide and homicide.

Suicide Characteristics

As illustrated by this sample, age, sex, ancestry, gun type, distance of gunshot, entry site and bullet trajectory are variable in their usefulness as indicators of suicide. Older individuals are more likely to be suicide victims, especially when age at death is greater than 60 years. Male victims are more likely to be suicide victims, but this means little in itself. Males are also more likely than females to be homicide victims. Information on both ancestry and sex can indicate which manner of death is more likely. A White male is more likely to be a victim of suicide while a Black male is more likely to be a victim of homicide.

After personal descriptors are considered (age, sex, ancestry), characteristics of the GSW itself assist in determination of manner of death. This sample suggests that suicide deaths are more likely to be the result of handgun use rather than that of a two-handed weapon. Suicides will also exhibit soft tissue evidence of a contact GSW. Entry site in the right temple is

also more indicative of suicide rather than homicide. Finally, bullet trajectory from right to left has greater probability of being found in suicidal GSWs.

Homicide Characteristics

Homicides are less easy to identify, if suicides lay claim to the characteristics above. Mean age for homicide victims is less than that of suicides. Despite this, homicide victim ages fall within the range of suicide ages. Age alone is not enough to suggest homicide as manner of death. When sex and ancestry are considered, however, a stronger case can be made for determination of manner of death. Black males are more likely to be homicide rather than suicide victims.

There can be no statements made about gun type use in homicides based on this sample, as over half of the cases did not report gun type. Soft tissue evidence of a distant GSW indicates homicide as manner of death. Evidence of a close range shot is less strongly linked to homicide as close range shots also appear in suicides. However, close range shots are more rare in suicides than in homicides. As statistical analysis of this sample revealed, GSWs are more likely to be indicative of homicide when the entry site is in the torso and when the bullet path moves from the dorsal to the ventral surface.

As a final note of caution, this study suggests that trends exist that allow investigators to determine manner of death based on both personal characteristics (age, sex, ancestry) and information on bullet entry (site,

distance) and bullet trajectory. Despite the fact that these trends do exist and can be documented there will be variation in cases of violent death. An investigator should recognize when anomalies occur, and attempt to understand the processes that created them. This research, resulting in the formation of an equation that can be used in determination of manner of death, is not a perfect tool, and the equation is approximately 75% accurate.

CHAPTER 5

CONCLUSION

This study of bullet entry area and trajectory is based on assumptions that human behavior during firearm suicides follows discernable patterns that differ significantly from that of homicide. The first pattern is the appearance of suicide areas. In this sample, a majority of suicidal GSWs entered at the right temple, followed in frequency by entry wounds in the left chest area. While homicidal GSWs are not prevented from appearing at suicide areas, neither are they limited to suicide areas. In a similar correspondence between manner of death and bullet entry area, GSWs that enter the dorsal surface of the body are more likely to be homicides rather than suicides.

Understanding the differences between entry site rates of homicides and suicides is one step towards defining manner of death based on findings during autopsy. This study also attempted to analyze how bullet trajectory might affect manner of death determination. Due to the small number of GSWs studied combined with the desire to break the data down into refined divisions the ideal analysis of the information was not possible. However, flexibility in analysis allowed certain facts to be recognized. According to the logistic regression from this study, bullets that travel from back to front are almost six times more likely to be homicides rather than suicides. Suicidal GSWs to the right or left temple offer the only opportunity for bullets to travel from back to front. In this study's sample of suicides, 11 of the 36 GSWs to the right temple (30.6%) and none of the 6 GSWs to the left temple traveled in a back

to front direction. Because GSWs entry area was not taken into account, the analysis compared 11 (14.9%) of 74 suicidal GSWs to 23 (34.3%) of 67 homicidal GSWs that traveled from back to front.

A second characteristic that has potential to separate homicidal GSWs from suicidal GSWs is bullet entry in the torso. Over half of the homicidal GSWs had entry in the chest, back or abdomen: (46 (68.7%) out of 67) while the remaining 21 (31.3%) occurred in the head or neck. Conversely, a majority of suicidal GSWs entered the head or neck (48 (64.9%) out of 74). The remaining 26 (35.1%) had bullet entry in the chest.

Finally, logistic regression also showed that a bullet that traveled from the right to the left had a greater chance of being suicides rather than homicides.

This study is only a preliminary step in the investigation of the usefulness of bullet entry and trajectory in the differentiation between homicide and suicide GSWs. There are certain trends that have appeared. In entry area analysis, a GSW to the right temple is more likely to be the result of suicide, while torso entry is more indicative of homicide. In bullet trajectory analysis, back to front bullet trajectory is more indicative of homicide, while right to left bullet trajectory is slightly more indicative of suicide.

With a larger sample, generalizations about bullet trajectory will be more satisfactorily linked to entry area. It is after such an analysis is complete that this method of identifying manner of death can be added to law

enforcement's repertoire. This method has potential usefulness, but further analysis is necessary prior to widespread use.

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APPENDICES

Appendix A

Table 1: Tennessee Autopsy Report Samples
(including manner of death, entry site, coordinate data and bullet trajectory.)

Manner of Death	Sex	Entrance	Entrance	Exit	Trajectory
Homicide	Female	Left Chest	(5.4, 51.25)	(0, 46)	BDR
Homicide	Female	Left Abdomen	(0.9, 43)	(-2.3, 47)	BUR
Homicide	Female	Left Chest	(3.5, 50)	(2.8, 48)	BDR
Homicide	Female	Left Chest	(2.8, 48)	(6, 50)	BUL
Homicide	Female	Left Temple	(2.7, 62.5)	(-2.5, 62.5)	FPR
Homicide	Female	Left Back	(3.2, 45.5)	(3,6, 41.5)	FDP
Homicide	Female	Right Back	(24, -36)	(-10.5, -48)	FDR
Homicide	Female	Right Back	(9.5, -46)	(-3.5, -47)	FDR
Homicide	Female	Right Back	(-23.5, 28)	(-25.5, -26)	FUL
Homicide	Female	Left Back	(18.5, -30)	(18.5, -27)	FUP
Homicide	Female	Left Chest	(14.5, -27.5)	(2, -38)	BDR
Homicide	Female	Left Back	(9.2, -55)	(3, 51)	FUR
Homicide	Female	Midface	(.25, 4.25)	(-2, 4)	BPR
Homicide	Female	Left Chest	(7, 14)	(-5, 18)	BDR
Homicide	Female	Left Temple	(1.5, .75)	(-2.25, 2.5)	BDR
Homicide	Male	Right Temple	(-2.5, 67.25)	(0, 63)	BDL
Homicide	Male	Right Temple	(-2.4, 67.5)	(2.4, 64.25)	BDL
Homicide	Male	Mid-Face	(0, 67.26)	(0, 64)	BDP
Homicide	Male	Right Face	(-3.5, 68)	(-.75, 68.5)	BUL
Homicide	Male	Right Dorsal Head	(-1.35, 67.5)	(-1.5, 69)	FUP
Homicide	Male	Left Back	(6.5, 54)	(-6, 56.5)	PUR
Homicide	Male	Left Back	(4.5, 32.5)	(-4.8, 33)	PUR
Homicide	Male	Left Temple	(2.9, 62)	(-1.5, 52)	BDR
Homicide	Male	Left Dorsal Head	(-2.9, 63)	(2, 62.5)	FDL
Homicide	Male	Left Chest	(1.6, 54)	(5.75, 47)	BDL
Homicide	Male	Left Abdomen	(7.75, 46.25)	(-8, 47.5)	PPR
Homicide	Male	Right Chest	(-2.7, 51.5)	(4.9, 41.5)	BDL
Homicide	Male	Left Chest	(3.6, 55)	(-3.0, 48.5)	BDR
Homicide	Male	Right Chest	(-4.2, 53)	(-9.8, 53.5)	BPR
Homicide	Male	Left Back	(9.3, 56)	(-10, 55)	PPR
Homicide	Male	Right Temple	(-2.5, 67.5)	(3.0, 68.5)	BUL

Appendix A
Table 1 Continued

Manner of Death	Sex	Entrance	Entrance	Exit	Trajectory
Homicide	Male	Left Chest	(4.2, 51)	(.5, 50)	BDR
Homicide	Male	Right Chest	(7.5, 49)	(-6, 48.5)	BDL
Homicide	Male	Left Back	(1.6, 51.5)	(5.5, 52)	FPL
Homicide	Male	Mid-Back	(0, 46)	(3.3, 58)	FUL
Homicide	Male	Left Chest	(6.95, 58.5)	(-3.6, 44)	BDR
Homicide	Male	Left Chest	(6.5, 52)	(-5.6, 45)	PDR
Homicide	Male	Right Back	(-8.0, 54.5)	(2.7, 51)	FDL
Homicide	Male	Left Back	(7.6, 56)	(.25, 56)	PPR
Homicide	Male	Left Chest	(8.4, 59.5)	(3.4, 60)	PPR
Homicide	Male	Mid-Neck	(0, 60.5)	(-1.7, 56.5)	BDR
Homicide	Male	Mid-Back	(1.8, -42.5)	(15, -36.6)	FUL
Homicide	Male	Mid-Dorsal Head	(0, -12.6)	(0, 0)	FUP
Homicide	Male	Right Neck	(-1.5, -27)	(-5, -23)	BUR
Homicide	Male	Right Neck	(-3, -31)	(20, -42)	BDL
Homicide	Male	Left Neck	(17.6, -17.5)	(-12.8, -17.6)	FPR
Homicide	Male	Right Chest	(-13.5, -33)	(-3, -39)	BDL
Homicide	Male	Left Back	(3, -39)	(-11, 32)	FDR
Homicide	Male	Right Temple	(-7.8, -10.3)	(3, -20)	FDL
Homicide	Male	Left Face	(-7.6, -17.5)	(-7.6, -17)	BPP
Homicide	Male	Left Neck	(11.5, -22)	(14, -26)	BDL
Homicide	Male	Left Chest	(16.2, -31)	(2, -37)	BDR
Homicide	Male	Left Chest	(2.5, -45.5)	(31, -45)	BPL
Homicide	Male	Left Temple	(13, -8)	(2, -2.6)	BUR
Homicide	Male	Left Neck	(3.2, -21.5)	(2.5, -33)	BDP
Homicide	Male	Mid-Chest	(-.5, -38.25)	(8.2, -48.5)	BDL
Homicide	Male	Right Chest	(-8, -55.2)	(3.4, -60)	BDL
Homicide	Male	Right Abdomen	(-5.5, 22.5)	(7, 17)	BUL
Homicide	Male	Left Back	(1, 17.5)	(-5.5, 16)	FUR
Homicide	Male	Left Chest	(4, 15.5)	(-7, 19.5)	BDR
Homicide	Male	Left Chest	(1.25, 18)	(-3.25, 18)	BPR
Homicide	Male	Left Back	(4.25, 7.25)	(4.5, 5.5)	FUP
Homicide	Male	Right Back	(-9, 14.5)	(4, 21.5)	FDL
Homicide	Male	Left Chest	(8, 7.5)	(-2.25, 8.5)	PPR
Homicide	Male	Mid-Back	(4.5, 10.5)	(2.5, 9.5)	FUR

Appendix A
Table 1 Continued

Manner of Death	Sex	Entrance	Entrance	Exit	Trajectory
Homicide	Male	Right Back	(-3.25, 20.5)	(-1.25, 28)	FDL
Suicide	Male	Right Temple	(-2.8, 69)	(3.1, 70)	BUL
Suicide	Male	Right Temple	(-2.7, 67.5)	(1.5, 71)	BUL
Suicide	Male	Mid-Chest	(0, -53)	(0, 71)	BDP
Suicide	Male	Right Temple	(-12.5, -8)	(10.5, -3)	BUL
Suicide	Male	Left Chest	(4, -52)	(25, -53.5)	BPL
Suicide	Male	Left Chest	(6.5, -58.5)	(15, -55)	BUL
Suicide	Male	Right Temple	(-9.5, -9)	(2, -2)	FUL
Suicide	Male	Right Temple	(-14, -11)	(13.5, -7)	PUL
Suicide	Male	Right Temple	(-12, -6.5)	(13.2, -6)	BUL
Suicide	Male	Right Temple	(-12, -9)	(3, 0)	BUL
Suicide	Male	Right Temple	(-14, -7.8)	(6, -7.5)	BPL
Suicide	Male	Left Chest	(9.5, -46.8)	(-4, -39)	BUR
Suicide	Male	Right Temple	(-13, -9.5)	(-12.5, -10)	PPL
Suicide	Male	Mid-Neck	(0, -25)	(2, -18)	BUL
Suicide	Male	Left Temple	(11, -5.6)	(-16.2, -8)	BUR
Suicide	Male	Mid-Chest	(1, -56)	(9, -58)	BDL
Suicide	Male	Right Temple	(-13.5, -9)	(21.5, -11)	BDL
Suicide	Male	Left Chest	(1.4, -49.7)	(18, -45)	BUL
Suicide	Male	Right Temple	(-16.8, -5)	(11.5, -3)	FUL
Suicide	Male	Right Temple	(-11.5, -6)	(19.5, -2.5)	BUL
Suicide	Male	Left Chest	(6.5, -53)	(8, -52)	BDL
Suicide	Male	Mid-Chest	(0, -45)	(4, -46)	BDL
Suicide	Male	Right Temple	(-11.5, -8)	(15.5, -2.5)	BUL
Suicide	Male	Mid-Chest	(0, -45)	(-1.5, -58)	BDP
Suicide	Male	Mid-Chest	(2.4, -46)	(0, -41)	BUR
Suicide	Male	Right Temple	(-12.5, -11)	(17.5, -11)	BPL
Suicide	Male	Left Temple	(8.5, -9.8)	(-14, -6)	BUR
Suicide	Male	Right Temple	(-9.5, -10)	(15.2, -3)	BUL
Suicide	Male	Left Chest	(8.5, -50)	(-2, -75)	BDR
Suicide	Male	Mid-Chest	(1, -42)	(5, -53)	BDL
Suicide	Male	Mid-Chest	(-1, -46)	(11, -53)	BDL
Suicide	Male	Right Temple	(-14, -9.4)	(25.8, -2.4)	BUL
Suicide	Male	Right Temple	(-11.5, 2.5)	(8, 4)	FUL

Appendix A
Table 1 Continued

Manner of Death	Sex	Entrance	Entrance	Exit	Trajectory
Suicide	Male	Right Temple	(-15, 4)	(9.5, 4)	FPL
Suicide	Male	Right Temple	(-12.5, 8)	(19, 3)	BUL
Suicide	Male	Right Temple	(-12, -10.5)	(11, -6)	FUL
Suicide	Male	Left Temple	(12, -9)	(-12, -9.4)	PDR
Suicide	Male	Chin	(0, -25)	(0, 0)	BUP
Suicide	Male	Right Temple	(-7, -11)	(8.5, -5.6)	BUL
Suicide	Male	Mouth	(0, -17)	(-2, 0)	BUP
Suicide	Male	Left Temple	(13.5, -4)	(-13.5, -4.5)	PPR
Suicide	Male	Left Chest	(3, -20)	(9, -51.1)	BDL
Suicide	Male	Right Temple	(-14.5, -7.5)	(11, -7)	FPL
Suicide	Male	Right Temple	(-10, -8.4)	(5, -2)	FUL
Suicide	Male	Left Chest	(2.5, -48)	(4.4, -58)	BDL
Suicide	Male	Right Temple	(-12.7, -9.3)	(14.6, -4.6)	BUL
Suicide	Male	Left Chest	(1, -50.2)	(3.5, -47.9)	BUL
Suicide	Male	Right Temple	(-12.5, -7)	(16.5, -3.6)	BUL
Suicide	Male	Left Temple	(17.2, -5.6)	(-19.5, -7.3)	BDR
Suicide	Male	Right Temple	(-9.5, -11)	(13.5, -10)	BUL
Suicide	Male	Left Chest	(1.75, 55)	(3, 48.5)	BDL
Suicide	Male	Left Chest	(1, 35.5)	(11, 18.5)	BUL
Suicide	Male	Right Temple	(-12, 4)	(13, 8)	BDL
Suicide	Male	Mouth	(-.125, 6)	(-1, 2)	BUR
Suicide	Male	Right Temple	(-4.75, 3.5)	(5.5, 2.5)	BUL
Suicide	Male	Right Temple	(-3.5, 3.25)	(5.5, 3)	BPL
Suicide	Male	Right Temple	(-2.75, 4)	(2.75, 4)	PPL
Suicide	Male	Right Temple	(-7, 2.5)	(6.25, 3)	FDL
Suicide	Male	Right Temple	(-5, 5)	(6, 2)	BUL
Suicide	Female	Right Face	(-2.5, 57.5)	(2.5, 55.5)	PDL
Suicide	Female	Left Chest	(8.5, -50)	(0, -55)	BDR
Suicide	Female	Mid-Chest	(1.3, -35)	(14.5, -42)	BDL
Suicide	Female	Right Temple	(-12, -7)	(9.5, -5)	FUL
Suicide	Female	Left Chest	(2.5, 27)	(9.5, 32)	BDL
Suicide	Female	Left Chest	(8, 43)	(6, 45)	BDR
Suicide	Female	Mid-Chest	(.07, -38)	(4, -52)	BDL
Suicide	Female	Left Chest	(4.2, -38.5)	(12, -50.5)	BDL

Appendix A
Table 1 Continued

Manner of Death	Sex	Entrance	Entrance	Exit	Trajectory
Suicide	Female	Left Chest	(9, -46)	(2.7, -70)	BDR
Suicide	Female	Left Temple	(8.5, -19)	(-3.5, -15.5)	BUR
Suicide	Female	Left Chest	(8, -22.7)	(15, -25)	BDL
Suicide	Female	Right Temple	(-9, -9)	(5, -6)	FUL
Suicide	Female	Right Temple	(-13, -7)	(16.5, -6.5)	BPL
Suicide	Female	Mouth	(0, 6.5)	(2, 1)	BUL
Suicide	Female	Right Temple	(-5.5, 3.25)	(2.75, 2)	FUL

Appendix B

Table 1: Tennessee Sample Logistic Regression Data

Manner of Death	Entry Site	Direction	B-F	F-B	U-D	D-U	R-L	L-R	Torso
Homicide	Left Chest	BDR	0	1	1	0	0	1	1
Homicide	Left Abdomen	BUR	0	1	0	1	0	1	1
Homicide	Left Chest	BDR	0	1	1	0	0	1	1
Homicide	Left Chest	BUL	0	1	0	1	1	0	1
Homicide	Left Temple	FPR	1	0	0	0	0	1	0
Homicide	Left Back	FDP	1	0	1	0	0	0	1
Homicide	Right Back	FDR	1	0	1	0	0	1	1
Homicide	Right Back	FDR	1	0	1	0	0	1	1
Homicide	Right Back	FUL	1	0	0	1	1	0	1
Homicide	Left Back	FUP	1	0	0	1	0	0	1
Homicide	Left Chest	BDR	0	1	1	0	0	1	1
Homicide	Left Back	FUR	1	0	0	1	0	1	1
Homicide	Midface	BPR	0	1	0	0	0	1	0
Homicide	Left Chest	BDR	0	1	1	0	0	1	1
Homicide	Left Temple	BDR	0	1	1	0	0	1	0
Homicide	Right Temple	BDL	0	1	1	0	1	0	0
Homicide	Right Temple	BDL	0	1	1	0	1	0	0
Homicide	Mid-Face	BDP	0	1	1	0	0	0	0
Homicide	Right Face	BUL	0	1	0	1	1	0	0
Homicide	Right Dorsal Head	FUP	1	0	0	1	0	0	0
Homicide	Left Back	PUR	0	0	0	1	0	1	1
Homicide	Left Back	PUR	0	0	0	1	0	1	1
Homicide	Left Temple	BDR	0	1	1	0	0	1	0
Homicide	Left Dorsal Head	FDL	1	0	1	0	1	0	0
Homicide	Left Chest	BDL	0	1	1	0	1	0	1
Homicide	Left Abdomen	PPR	0	0	0	0	0	1	1
Homicide	Right Chest	BDL	0	1	1	0	1	0	1

Appendix B

Table 1 Continued

Manner of Death	Entry Position	Direction	B-F	F-B	U-D	D-U	R-L	L-R	Torso
Homicide	Left Chest	BDR	0	1	1	0	0	1	1
Homicide	Right Chest	BPR	0	1	0	0	0	1	1
Homicide	Left Back	PPR	0	0	0	0	0	1	1
Homicide	Right Temple	BUL	0	1	0	1	1	0	0
Homicide	Left Chest	BDR	0	1	1	0	0	1	1
Homicide	Right Chest	BDL	0	1	1	0	1	0	1
Homicide	Left Back	FPL	1	0	0	0	1	0	1
Homicide	Mid-Back	FUL	1	0	0	1	1	0	1
Homicide	Left Chest	BDR	0	1	1	0	0	1	1
Homicide	Left Chest	PDR	0	0	1	0	0	1	1
Homicide	Right Back	FDL	1	0	1	0	1	0	1
Homicide	Left Back	PPR	0	0	0	0	0	1	1
Homicide	Left Chest	PPR	0	0	0	0	0	1	1
Homicide	Mid-Neck	BDR	0	1	1	0	0	1	0
Homicide	Mid-Back	FUL	1	0	0	1	1	0	1
Homicide	Mid-Dorsal Head	FUP	1	0	0	1	0	0	0
Homicide	Right Neck	BUR	0	1	0	1	0	1	0
Homicide	Right Neck	BDL	0	1	1	0	1	0	0
Homicide	Left Neck	FPR	1	0	0	0	0	1	0
Homicide	Right Chest	BDL	0	1	1	0	1	0	1
Homicide	Left Back	FDR	1	0	1	0	0	1	1
Homicide	Right Temple	FDL	1	0	1	0	1	0	0
Homicide	Left Face	BPP	0	1	0	0	0	0	0
Homicide	Left Neck	BDL	0	1	1	0	1	0	0
Homicide	Left Chest	BDR	0	1	1	0	0	1	1
Homicide	Left Chest	BPL	0	1	0	0	1	0	1
Homicide	Left Temple	BUR	0	1	0	1	0	1	0

Appendix B

Table 1 Continued

Manner of Death	Entry Position	Direction	B-F	F-B	U-D	D-U	R-L	L-R	Torso
Homicide	Left Neck	BDP	0	1	1	0	0	0	0
Homicide	Mid-Chest	BDL	0	1	1	0	1	0	1
Homicide	Right Chest	BDL	0	1	1	0	1	0	1
Homicide	Right Abdomen	BUL	0	1	0	1	1	0	1
Homicide	Left Back	FUR	1	0	0	1	0	1	1
Homicide	Left Chest	BDR	0	1	1	0	0	1	1
Homicide	Left Chest	BPR	0	1	0	0	0	1	1
Homicide	Left Back	FUP	1	0	0	1	0	0	1
Homicide	Right Back	FDL	1	0	1	0	1	0	1
Homicide	Left Chest	PPR	0	0	0	0	0	1	1
Homicide	Mid-Back	FUR	1	0	0	1	0	1	1
Homicide	Right Back	FDL	1	0	1	0	1	0	1
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Mid-Chest	BDP	0	1	1	0	0	0	1
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Left Chest	BPL	0	1	0	0	1	0	1
Suicide	Left Chest	BUL	0	1	0	1	1	0	1
Suicide	Right Temple	FUL	1	0	0	1	1	0	0
Suicide	Right Temple	PUL	0	0	0	1	1	0	0
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Right Temple	BPL	0	1	0	0	1	0	0
Suicide	Left Chest	BUR	0	1	0	1	0	1	1
Suicide	Right Temple	PPL	0	0	0	0	1	0	0
Suicide	Mid-Neck	BUL	0	1	0	1	1	0	0
Suicide	Left Temple	BUR	0	1	0	1	0	1	0

Appendix B

Table 1 Continued

Manner of Death	Entry Position	Direction	B-F	F-B	U-D	D-U	R-L	L-R	Torso
Suicide	Mid-Chest	BDL	0	1	1	0	1	0	1
Suicide	Right Temple	BDL	0	1	1	0	1	0	0
Suicide	Left Chest	BUL	0	1	0	1	1	0	1
Suicide	Right Temple	FUL	1	0	0	1	1	0	0
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Left Chest	BDL	0	1	1	0	1	0	1
Suicide	Mid-Chest	BDL	0	1	1	0	1	0	1
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Mid-Chest	BDP	0	1	1	0	0	0	1
Suicide	Mid-Chest	BUR	0	1	0	1	0	1	1
Suicide	Right Temple	BPL	0	1	0	0	1	0	0
Suicide	Left Temple	BUR	0	1	0	1	0	1	0
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Left Chest	BDR	0	1	1	0	0	1	1
Suicide	Mid-Chest	BDL	0	1	1	0	1	0	1
Suicide	Mid-Chest	BDL	0	1	1	0	1	0	1
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Right Temple	FUL	1	0	0	1	1	0	0
Suicide	Right Temple	FPL	1	0	0	0	1	0	0
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Right Temple	FUL	1	0	0	1	1	0	0
Suicide	Left Temple	PDR	0	0	1	0	0	1	0
Suicide	Chin	BUP	0	1	0	1	0	0	0
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Mouth	BUP	0	1	0	1	0	0	0
Suicide	Left Temple	PPR	0	0	0	0	0	1	0
Suicide	Left Chest	BDL	0	1	1	0	1	0	1

Appendix B

Table 1 Continued

Manner of Death	Entry Position	Direction	B-F	F-B	U-D	D-U	R-L	L-R	Torso
Suicide	Right Temple	FPL	1	0	0	0	1	0	0
Suicide	Right Temple	FUL	1	0	0	1	1	0	0
Suicide	Left Chest	BDL	0	1	1	0	1	0	1
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Left Chest	BUL	0	1	0	1	1	0	1
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Left Temple	BDR	0	1	1	0	0	1	0
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Left Chest	BDL	0	1	1	0	1	0	1
Suicide	Left Chest	BUL	0	1	0	1	1	0	1
Suicide	Right Temple	BDL	0	1	1	0	1	0	0
Suicide	Mouth	BUR	0	1	0	1	0	1	0
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Right Temple	BPL	0	1	0	0	1	0	0
Suicide	Right Temple	PPL	0	0	0	0	1	0	0
Suicide	Right Temple	FDL	1	0	1	0	1	0	0
Suicide	Right Temple	BUL	0	1	0	1	1	0	0
Suicide	Right Face	PDL	0	0	1	0	1	0	0
Suicide	Left Chest	BDR	0	1	1	0	0	1	1
Suicide	Mid-Chest	BDL	0	1	1	0	1	0	1
Suicide	Right Temple	FUL	1	0	0	1	1	0	0
Suicide	Left Chest	BDL	0	1	1	0	1	0	1
Suicide	Left Chest	BDR	0	1	1	0	0	1	1
Suicide	Mid-Chest	BDL	0	1	1	0	1	0	1
Suicide	Left Chest	BDL	0	1	1	0	1	0	1
Suicide	Left Chest	BDR	0	1	1	0	0	1	1
Suicide	Left Temple	BUR	0	1	0	1	0	1	0

Appendix B

Table 1 Continued

Manner of Death	Entry Position	Direction	B-F	F-B	U-D	D-U	R-L	L-R	Torso
Suicide	Left Chest	BDL	0	1	1	0	1	0	1
Suicide	Right Temple	FUL	1	0	0	1	1	0	0
Suicide	Right Temple	BPL	0	1	0	0	1	0	0
Suicide	Mouth	BUL	0	1	0	1	1	0	0
Suicide	Right Temple	FUL	1	0	0	1	1	0	0

Appendix C

Table 1: Tennessee Logistic Regression Equation Results
exp(-.550+(1.805*B_F)+(1.902*torso)-(1.853*R_L)

Manner of Death	Entry	Direction	Prediction
Homicide	Right Dorsal Head	FUP	3.51
Homicide	Mid Dorsal Head	FUP	3.51
Homicide	Left Dorsal Head	FDL	0.55
Homicide	Right Temple	FDL	0.55
Homicide	Right Temple	BUL	0.09
Homicide	Right Temple	BDL	0.09
Homicide	Left Temple	FPR	3.51
Homicide	Left Temple	BUR	0.58
Homicide	Left Temple	BDR	0.58
Homicide	Right Face	BUL	0.09
Homicide	Mid Face	BPR	0.58
Homicide	Mid Face	BDP	0.58
Homicide	Left Face	BPP	0.58
Homicide	Right Neck	BUR	3.87
Homicide	Right Neck	BDL	0.61
Homicide	Mid Neck	BDR	3.87
Homicide	Left Neck	FPR	23.5
Homicide	Left Neck	BDP	3.87
Homicide	Left Neck	BDL	0.61
Homicide	Right Chest	BPR	3.87
Homicide	Right Chest	BDL	0.61
Homicide	Mid Chest	BDL	0.61
Homicide	Left Chest	PPR	3.87
Homicide	Left Chest	PDR	3.87
Homicide	Left Chest	BPR	3.87
Homicide	Left Chest	BPL	0.61
Homicide	Left Chest	BUL	0.61
Homicide	Left Chest	BDR	3.87
Homicide	Left Chest	BDL	0.61
Homicide	Right Abdomen	BUL	0.61
Homicide	Left Abdomen	PPR	3.87
Homicide	Left Abdomen	BUR	3.87
Homicide	Right Back	FUL	3.68
Homicide	Right Back	FDR	23.5
Homicide	Right Back	FDL	3.68
Homicide	Mid Back	FUR	23.5
Homicide	Mid Back	FUL	3.68
Homicide	Left Back	PPR	3.87
Homicide	Left Back	PUR	3.87
Homicide	Left Back	FPL	3.68
Homicide	Left Back	FUP	23.5
Homicide	Left Back	FUR	23.5

	Appendix C		
	Table 1 Continued		
Manner of Death	**Entry**	**Direction**	**Prediction**
Homicide	Left Back	FDP	23.5
Homicide	Left Back	FDR	23.5
Suicide	Mouth	BUP	0.58
Suicide	Mouth	BUR	0.58
Suicide	Mouth	BUL	0.09
Suicide	Right Temple	PPL	0.09
Suicide	Right Temple	PUL	0.09
Suicide	Right Temple	FPL	0.55
Suicide	Right Temple	FUL	0.55
Suicide	Right Temple	FDL	0.55
Suicide	Right Temple	BPL	0.09
Suicide	Right Temple	BUL	0.09
Suicide	Right Temple	BDL	0.09
Suicide	Left Temple	PPR	0.58
Suicide	Left Temple	PDR	0.58
Suicide	Left Temple	BUR	0.58
Suicide	Left Temple	BDR	0.58
Suicide	Right Face	PDL	0.09
Suicide	Chin	BUP	0.58
Suicide	Mid Neck	BUL	0.61
Suicide	Mid Chest	BUR	3.87
Suicide	Mid Chest	BDP	3.87
Suicide	Mid Chest	BDL	0.61
Suicide	Left Chest	BPL	0.61
Suicide	Left Chest	BUR	3.87
Suicide	Left Chest	BUL	0.61
Suicide	Left Chest	BDR	3.87
Suicide	Left Chest	BDL	0.61

Vita

Rosemary Leigh Pennefeather was born in Burlington, Wisconsin on September 9, 1976. She was raised in Burlington, Wisconsin and attended grade school and junior high school at St. Charles School in Burlington. She graduated from Burlington Senior High School in 1995. From there, she went on to the University of Wisconsin, La Crosse and received a B.A. in archaeology in 2000. After earning her B.A., she attended the University of Tennessee, Knoxville and earned her M.A. in anthropology in 2003.

Rosemary is currently pursuing a career in physical and forensic anthropology.