CAUSES OF DEATH FOR LAW ENFORCEMENT OFFICERS IN THE LINE OF DUTY: A ONE HEALTH APPROACH TO TRAUMA MORTALITY SURVIVABILITY ASSESSMENT

A Dissertation

by

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ABSTRACT

The development of a comprehensive epidemiological methodology for trauma assessment and mortality classification for law enforcement officers killed in the line of duty, using a 'One Health' interdisciplinary approach provides the foundation for an occupational risk assessment. The "One Health" concept leverages relationships between disciplines by increasing communication and collaboration to tackle complex health issues affecting humans and animals considering environmental in which they occur. The novel application of One Health concepts of interdisciplinary leveraging towards the prevention of traumatic mortality in both human and canine law enforcement populations identifies trends in law enforcement mortality. The central hypothesis that some law enforcement officer line of duty deaths are from injuries that are clinically, potentially survivable. Describing patterns of fatal injuries and identifying risk to develop a framework may reduce the severity and occurrence of fatal injuries in the line of duty. Eighty-four traumatic fatalities sustained by Texas DPS Highway Patrol Officers in the line of duty were reviewed using trauma injury severity scoring to determine potentially survivable injuries. Injuries resulting in twenty-five potentially survivable deaths were evaluated with consideration to established Tactical Combat Casualty Care (TCCC) interventions, such as tourniquets and needle decompression, for their possible impact on survivability for injuries sustained in the line of duty. Truncal hemorrhage was noted to be the most common cause of death with opportunity for future mitigation. Lastly, health hazards impacting officer deaths were evaluated focusing on

environmental and operational risk factors that have the potential to influence survivability. Opportunities for risk mitigation relating to automobile accidents could improve survivability and reduce line of duty deaths. These studies contribute to a more comprehensive understanding of fatal injuries sustained in the line of duty. A long-term goal of this study is to develop an improved public safety morbidity and mortality database in order to prioritize mitigation efforts and recommend risk reduction strategies aiming to reduce the severity and occurrence of injuries sustained in the line of duty.

DEDICATION

This dissertation is dedicated to the Texas Highway Patrol Troopers that bravely and selflessly died in the line of duty, and their family and friends that grieve their loss.

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The data analyzed was conducted by the student independently.

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NOMENCLATURE

AIS	Anatomical Injury Score
ATS	Animal Trauma Triage Score
DPS	Texas Department of Public Safety
FTE	Full Time Equivalent
GSW	Gunshot Wound
ICMM	International Council on Mining and Metals
ISS	Injury Severity Score
MCIS	Military Combat Injury Score
NS	Nonsurvivable
ODMP	Officer Down Memorial Page
PS	Potentially Survivable
TCCC	Tactical Casualty Combat Care
THP	Texas Highway Patrol

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

Purpose

Law enforcement officer line of duty fatalities are noted for occurring in complex, tactical environments resulting in traumatic causes of death, with similar risks of injury observed in a battlefield environment. With little data on anatomical injuries sustained by officers in the line of duty, trauma mitigation and injury incidence are difficult to determine. Battlefield trauma mortality research could apply to law enforcement populations and other populations that incur high incidence of trauma in tactical environments that delay transport to definitive care. This systemic approach to defining injuries and quantifying incidence can reduce the severity and occurrence of fatal injury events.

The purpose of this study was to identify trends in law enforcement mortality to reduce the severity and occurrence of sustained injuries in the line of duty. This methodology will also develop risk assessment considerations specific to the public safety occupational field. The development of a methodology to describe anatomical injuries resulting in occupational 'line of duty' fatalities will allow for the evaluation the potential effectiveness of existing military trauma mitigation interventions to reduce death from potentially survivable injuries. Utilizing approaches from military trauma prevention and intervention, this study contributes towards the identification of factors influencing survivability for law enforcement populations with a significant risk of survivable polytrauma.[1,2] Aiming to identify trends in mortality, identify established

medical interventions such as hemorrhage control and tourniquets that may increase survival from potentially survivable injuries, and identify areas needing future development of pre-hospital medical interventions for increased survivability.

In a systematic review of traumatic fatalities sustained by the Texas DPS Highway Patrol Officers in the line of duty, each fatality was scored using the established Anatomical Injury Score and Injury Severity Score determine potentially survivable injuries.[3,4] In each potentially survivable death, injuries were evaluated with consideration to established Tactical Combat Casualty Care (TCCC) interventions for potential trauma mitigation.[5] Lastly, environmental and operational risk factors that have the ability to influence survivability were reviewed.

Need for department specific data to be reviewed for generalized outcomes to be determined by sound methodology. Policing across America has different operational tempos and requirements - changing the risk profile. The similarities in operational risk suggest this methodology will be of benefit on both a local and national level to further understand and address this risk, but cannot underscore the need for local risk assessment and review of fatalities due to the differences in operations.

Few comprehensive studies addressing injury severity or interventions for law enforcement mortality exist, despite a high trauma burden in this population. Existing studies that review law enforcement officer line of duty mortality examine line of duty deaths are related felonious assault based on the mechanism of injury.[6,7] A detailed review of trauma mortality in law enforcement officer populations could identify

opportunities to select appropriate interventions and improve operational guidelines and response practices to improve officer safety.

Background: Military Trauma Studies

Lessons learned from military injury patterns resulting in fatalities helped shape the identification and implementation of field appropriate medical interventions to be used at the point of wounding. To identify potentially survivable deaths, it is essential to identify the incidence of potentially survivable deaths. In a comprehensive review of fatalities, evidence of wounding patterns and sustained injuries can be reviewed to further mitigation efforts and to prevent future deaths.

Occupational fatalities in law enforcement careers are classified based on the legal mechanism of injury and lack comprehensive injury information or medical cause of death beneficial to address future mitigation efforts. Training and education programs based on military medicine and advances in trauma care have reduced battlefield mortality significantly. Review of law enforcement officer injuries and fatalities should be conducted to determine the potential effectiveness and other needs towards reducing mortality. To test the overall hypothesis that law enforcement officer line of duty deaths are from injuries that are clinically potentially survivable, a retrospective case series will be employed.

Well established military anatomical trauma injury reviews contributed to the identification and implementations of medical interventions that demonstrated reductions in unit mortality rates by mitigating preventable deaths. Sufficient evidence

indicates that law enforcement populations endure similar blunt and penetrating injury patterns to military battlefield trauma, and would stand to benefit from established military medical interventions.

Background: Law Enforcement Occupational Fatalities

Law enforcement occupational fatalities occurring while an officer is serving in their official capacity and enforcement are referred to as line of duty deaths. This phrase is as much colloquial among officers as it is further refinement of an occupational injury. Not all occupational fatalities sustained by law enforcement officers are considered line of duty deaths based on operational definitions set by varying government entities with the authority. One Texas DPS Highway Patrol Trooper died while performing security work at a secondary, non-DPS job, and is not included in this dissertation. While this is, an occupational fatality related to law enforcement, it was not considered a line of duty death by either the department or the FBI Line of Duty Death program.

Although trauma mitigation and management is well established, several gaps in knowledge exist that are critical for comprehensive risk assessment in a tactical and operationally intensive situation have yet to be identified. For instance, the prevalence rates and injury patterns experienced by law enforcement officers in the line of duty resulting in death have not been enumerated to fully characterize the trauma burden. This can be addressed by reviewing fatalities for injury severity and patterns to evaluate options for injury and fatality mitigation.

Trauma scoring systems have produced sufficient evidence to demonstrate that a higher trauma score typically indicates an increased risk of mortality.[4,8] A systematic

risk assessment based on sustained fatal injury patterns has yet to be conducted. The use of Injury Severity Scores to assess trauma mortality and the potential survivability of sustained injuries has been utilized in military medicine resulting in significant improvements towards reductions in unit mortality.[1] Reductions in mortality from potentially survivable trauma in actively engaged military units resulted from epidemiology research identifying needs for education and training in the use of medical interventions including hemostatic dressings and the use of tourniquets.[1,2] It has been well established that military interventions, now known as the Tactical Combat Casualty Care interventions, have demonstrated reductions in unit mortality, particularly when populations are subject to large penetrating trauma burdens, environmental considerations that delay access to definitive medical care and effective training and equipment.[1,2] Sufficient evidence indicates the effectiveness of the use of these interventions in a battlefield environment.[1,9] Further review of law enforcement line of duty deaths is required to demonstrate potential need or opportunity towards mitigation.

Although this methodology is well established in the military battlefield setting, several gaps in knowledge exist that are critical for determining the potential need and effectiveness in a law enforcement population. Using 2014 national data from the Bureau of Labor Statistics, police officers and detectives experience occupational fatalities at a rate of 12.8 occupational fatalities per 100,000 police officers and detectives, exceeding the national occupational fatality rate of 3.4 per 100,000 for all full-time equivalent employees.[10]

Discrepancies in reporting occupational fatalities are noted across four entities that monitor law enforcement occupational fatalities. For 2014, the Officer Down Memorial Page notes 142 law enforcement officer deaths; the FBI reports 95 law enforcement officer deaths and the National Law Enforcement Officers Memorial Fund reports 126 deaths.[6] The BLS data on fatal occupational injuries may not report the total count of law enforcement officer fatalities included by the Officer Down Memorial Page, as ODMP reported 142 police officer fatalities (excluding correctional officers) in 2014. With 142 officers killed in the line of duty in 2014, the occupational fatality rate would be 17.6 per 100,000.[11]

Recent military trauma research has resulted in significant translational improvements in survivability, resulting from the use of prehospital tourniquets and hemostatic dressings.[5] Military mortality has a high burden of penetrating trauma, compared to a non-military population which experiences higher rates of blunt trauma.[9,12] Law enforcement officers experience mortality due to penetrating trauma at higher rates than the general population, suggesting the need for alternate or enhanced methodologies to fully evaluate fatalities to reduce mortality.[13] Employing proven military battlefield trauma severity and survivability assessment methodologies this project can identify the incidence of specific trauma, with the aim to reduce future mortality by implementing risk mitigation with injury interventions and identifying areas of further study. Using established military and trauma mortality classifications, this approach will identify factors that have the potential to influence survivability allowing for improved planning, training, and field operations.[1,14] The overall objective of this

proposed project is to identify the causes of, and incidence of specific fatal injuries sustained by law enforcement officers in the line of duty.

Public safety focused law enforcement officer mortality studies to date, have not utilized interdisciplinary methodologies to identify variables of interest relating to potentially survivable trauma. Despite major advances in trauma care and military medicine, law enforcement mortality has remained at stagnant levels and has not been studied comprehensively to make empirical observations on the cause of death based on injury severity.[1,14] Currently, law enforcement mortality summaries determine deaths to be due to one of only a few categories, little detail to the specific injury and trauma aspects of a fatality.[7] To reduce traumatic deaths in the line of duty, a detailed injury classification will provide a baseline to assist identifying causes and current trends and opportunities to improve survival with field interventions. Identification of potentially survivable deaths is the first step of developing operational response improvements focused on mortality reduction and improvement in survivability of potentially survivable cases.

Comprehensive Dissertation Overview

This dissertation study will be used to characterize and evaluate differences and identify potential risk factors influencing survivability, and identify gaps in knowledge for further review. This methodology will help understand injury patterns and the causes and circumstances of such injuries. This will substantially improve understanding of current law enforcement morbidity and mortality patterns to inform and identify decision makers to implement mitigation strategies.

The overall objective of this project is to identify trends in law enforcement mortality to reduce the severity and occurrence of sustained injuries. Three aims will test the central hypothesis that some law enforcement officer line of duty deaths are from injuries that are clinically, potentially survivable. This hypothesis will be tested with the following specific aims:

The overall aims of this dissertation research are to i) use trauma injury severity scoring to determine potentially survivable injuries; ii) evaluate potential effectiveness of Tactical Combat Casualty Care (TCCC) interventions for potentially survivable injuries; iii) evaluate injury risk considering environmental and operational risk factors. Several critical problems will be addressed in this study to achieve the long-term goal to prioritize mitigation efforts and recommend risk reduction strategies aiming to reduce the severity and occurrence of sustained injuries. This project seeks to demonstrate military battlefield trauma mortality research can be applicable in law enforcement populations in tactical or other environments that delay transport to definitive care, to reduce the severity and occurrence of fatal events. Law enforcement officer line of duty fatalities are noted for occurring in complex or tactical environments resulting in traumatic causes of death, with penetrating injury patterns.[7] Similarities between law enforcement officer line of duty injuries to military battlefield trauma will be examined in this study to better understand the circumstances of potentially survivable death in the law enforcement population. Utilizing approaches from military prevention and control for law enforcement populations with a significant risk of survivable polytrauma, the project will contribute towards identification of factors influencing survivability, aiming

to identify trends in mortality, identify established interventions that may address potentially survivable cases, and identify areas needing future development of pre-hospital medical interventions for increased survivability.

One Health Approach

The application of One Health concepts, including the use of a holistic and interdisciplinary approach to risk assessment and disease prevention to address trauma represents a novel application of the One Health prevention paradigm.[15,16] This project seeks to demonstrate military battlefield trauma mortality research can apply to law enforcement populations, as both populations are at risk for both blunt and penetrating trauma. Evaluation of anatomical injuries sustained by officers of any species in the line of duty will assess the appropriateness of existing military trauma interventions in public safety operational environments. These studies use the One Health paradigm to incorporate all holistic approach to risk management for tactical and operational public safety injuries and fatalities. Also, these studies will identify and assess factors that contribute to the potential survivability of traumatic injuries in tactical public safety operations.

Specific Aims

Three aims will test the central hypothesis that some law enforcement officer line of duty deaths are from injuries that are clinically, potentially survivable (Figure 1). Law enforcement mortality classification requires further assessment and injury severity characterization to address high-risk operational events resulting in occupational

fatalities. Information on the appropriateness of current military trauma interventions towards "potentially survivable" fatalities is widely unknown using trauma scoring methodologies, this study will review what interventions that currently exist may reduce mortality. Mortality assessment and risk factor identification in a complex system with high consequences currently lacks depth in mortality classification based on medical injuries sustained.

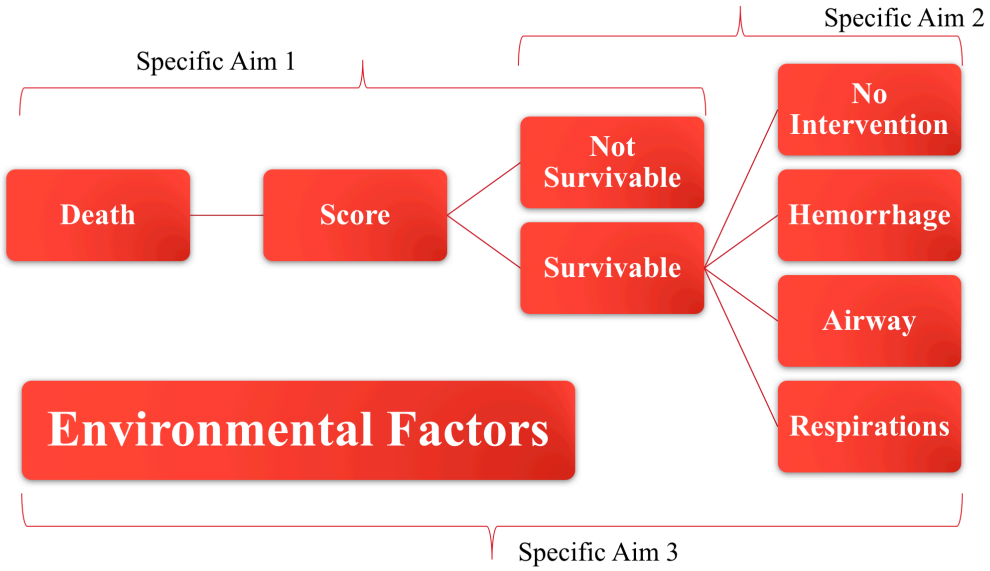

Figure 1: Specific Aims Flow Chart

Trauma remains a leading cause of preventable mortality, and using detailed injury classification methodologies have proven to be useful in mortality reduction efforts. Further research is necessary to develop methods to characterize specific injuries leading to officer line of duty deaths, which will facilitate fatality reduction

efforts in law enforcement officer populations considering complex and dynamic operational needs.

Law enforcement mortality classification requires further assessment and injury severity characterization to address high-risk operational events resulting in occupational fatalities. Prior studies assessing trauma mortality and preventability of trauma deaths in law enforcement populations lack defined criteria for a cause of death classification.[17] The Military methodologies use a trauma severity score in conjunction with incident-specific factors (mechanism of injury, cause of injury, medical intervention performed), to help discern influences to survivability that may be useful in developing mitigation programs.[1,2] The use of this additional, case specific information to assign a "nonsurvivable" or "potentially survivable" designation to an established trauma survivability score affords an improvement in trauma and mortality research, promoting further mortality reduction efforts. Currently, law enforcement line of duty fatalities is tracked on a national level by the Federal Bureau of Investigation. However, this database lacks medical and injury specific data to inform risk mitigation efforts and effectiveness of medical interventions aimed at improving survivability.

Law enforcement officers often work in a high-stress environment with increased occupational risk for penetrating trauma and vehicular incidents.[6,13] Law enforcement officers are subject to direct and or repeated threat of gunfire.[7] Motor vehicle accidents are a significant cause of law enforcement fatalities every year, and along with gunshot injuries are the two primary causes of traumatic officer deaths.[13] Canine death information is limited due to small data set size, but military studies suggest that

occupational ballistic injuries have a high mortality rate and have not been further enumerated by anatomical injury.[18] Military medical training has utilized canines for ballistic wound training for medical personnel, establishing strong relationships of military canines and human injuries from ballistic injuries. Law enforcement officer duty related mortality research has yet to classify traumatic deaths based on the potential survivability of sustained injuries with the aim of reducing mortality. The Texas Department of Public Safety (DPS) is the largest law enforcement agency in the State of Texas, and the DPS Highway Patrol Division has experienced 86 duty fatalities since its inception in 1929.[6]

Classification of death varies across disciplines and often relies on implicit determinations, leaving a study open to potential bias. However, using standardized trauma scoring systems, such as the Abbreviated Injury Scale (AIS), and subsequent score systems such as the Injury Severity Score (ISS) and New Injury Severity Score (NISS), offers researchers a comprehensive and objective tool to quantify trauma based on clinical presentation.[4,19,20] Military methods for quantifying trauma survivability are based on a trauma score and then reviewed by a military panel to determine possibly survivable trauma.[1] Utilizing these established military guidelines to determine possibly survivable trauma to develop an equivalent civilian baseline of trauma injury incidence using an expert medical review board, will allow local entities to better evaluate civilian trauma, allowing for the improvement in trauma outcomes.

The AIS trauma score is an anatomical scoring system that assigns a severity score to traumatic injuries based on the individual injuries "threat to life" rather than a

representation of injury severity. The ISS trauma score uses the AIS severity score to produce a comprehensive survivability score for trauma patients.[4] The use of the Abbreviated Injury Scale (ASI) and Injury Severity Score (ISS) trauma scoring system in and of itself provides a validated score for trauma survivability assessment. This scoring system is known for having a linear correlation to several indicators of trauma severity and survivability including morbidity, mortality and, hospital stay.[4] For canines, the standardized Animal Trauma Triage (ATT) Score will also be assigned. This score represents a standardized way to describe patient status after trauma but is limited in specific anatomical injury information.[21]

Aim 1: Trauma Epidemiology and Injury Survivability

Traumatic injuries sustained by law enforcement officers in the line of duty that results in death will be determined to be potentially survivable or nonsurvivable, and an AIS/ISS trauma score will be assigned to cases with detailed injury information. These measurements will help understand the burden of "potentially survivable" fatalities and help guide further risk assessment. A multidisciplinary trauma team assessed the survivability of each ambiguous case under the assumption of immediately available, ideal trauma care mirroring previously successful military trauma review methodology.[2,9] For autopsy reports received after this committee review, emergency room physicians were sought to offer input on three cases. Potentially survivable or nonsurvivable determinations will be based only on the injuries sustained as if the injuries sustained had occurred with immediately available, ideal Level 1 trauma care and resources including blood product and surgical facilities. Potentially survivable or

nonsurvivable determinations will be based only on the injuries sustained. This inclusion will allow for identification of other factors, including time to definitive care that may impact potential survivability.

Fatalities will be classified as not survivable from either a single wound that is determined to be not survivable, such as decapitation, or several severe injuries that compound each other.

Descriptive epidemiology can provide a historical baseline, trends and risk assessment for mitigating future traumatic mortality in the line of duty or occupational fatalities. An occupational fatality is a death sustained in the execution of one's duties from any cause.

Information on the appropriateness of current military trauma interventions such as tourniquet use or needle decompression to mitigate death from **potentially survivable** fatalities is largely unknown using trauma scoring methodologies. To date, a lack of research exists characterizing fatal injury patterns and specific causes of death officers experience in the line of duty. Further descriptive epidemiology can provide a historical baseline, trends and risk assessment for mitigating future traumatic mortality in the line of duty.

The expected outcomes for Specific Aim 1 will define potentially survivable deaths from traumatic injuries sustained by Texas DPS Highway Patrol Officers in the line of duty with an epidemiological summary identifying the trauma, distributions, and determinants of sustained injuries.

Aim 2: Intervention Effectiveness for Potentially Survivable Injuries

Evaluation of the potential the impact of Tactical Combat Casualty Care (TCCC) interventions for injuries resulting in potentially survivable line of duty deaths and characterization of injury patterns occurring in this law enforcement population will allow for improved trauma management. Epidemiology of these deaths will be described using AIS/ISS trauma scoring. To date, a lack of research exists characterizing fatal injury patterns and specific causes of death officers experience in the line of duty for civilian deaths. In a review of Special Operations Forces deaths completed in 2007 by Dr. John Holcomb, it was found that of 23 deaths related to gunfire, 16 were determined to be not survivable while 7 were determined to be potentially survivable.[2] The TCCC guidelines offer a model for interventions that can be used by non-medical providers in tactical and operationally intensive situations to reduce mortality from traumatic events.

In Aim 2, we will evaluate the potential effectiveness of TCCC interventions including tourniquet control of extremity hemorrhage, needle decompression and cricothyrotomy to sustained injuries; these assessments will help understand the effects of medical interventions that may contribute to increased survivability.

Mortality assessment and risk factor identification in a complex system with high consequences currently lacks depth in mortality classification. Risk factor identification is an essential first step in risk analysis to identify causes to determine future approaches towards developing interventions to reduce the severity and occurrence of traumatic, duty related injury. Herein, we propose to provide a methodology to evaluate and identify risk factors relating to traumatic law enforcement officer mortality in the line of

duty that incorporates a One Health approach. Current methods offer count data from a small number of generalized causes, which fail to account for anatomical injury locations and severity resulting in duty related mortality. Due to lack of research describing law enforcement officer mortality, causes, injury patterns and circumstances analysis on intervention effectiveness have not been fully described. This approach would offer a methodology for reviewing law enforcement related injuries and fatal injuries to better identify areas for mitigation and improvement in officer survivability.

Results from this study share some similarities to military findings for blunt and penetrating trauma injury severity and patterns seen in the military battlefield environment, but have differences that can offer law enforcement leadership considerations for operational decisions to improve officer safety. This research will support the central hypothesis that law enforcement officer line of duty deaths are from injuries that are clinically, potentially survivable. The outcomes for Specific Aim 2 will describe the impact of Tactical Combat Casualty Care (TCCC) interventions for sustained injuries, and identify other injury patterns that may benefit from other interventions, resulting in potentially survivable line of duty deaths. This evaluation will provide information for law enforcement departments to determine needs for medical interventions, equipment and training to reduce mortality from line of duty injuries – especially those sustaining injuries with ISS scores over 15 representing major trauma.

Aim 3: Occupational and Environmental Risk Factors and Survivability

Evaluation of environmental and operational risk factors influencing survivability can support injury prevention efforts rather than injury mitigation once the

injury has occurred. Effective trauma management for law enforcement populations requires epidemiology of traumatic mortality to be considered using an interdisciplinary approach incorporating risk assessment, with consideration of environmental factors and law enforcement operational needs. In Aim 3, we will describe current states of occupational and environmental risk factors in a way that will help understand factors that may increase the risk of injury and identify potentially modifiable factors.

The TCCC guidelines offer a model for interventions that can be used by non-medical providers in tactical and operationally intensive situations to reduce mortality from traumatic events. However, the most significant reductions in line of duty deaths would result from injury prevention.

Results will include identification of risk factors and trends and will support the central hypothesis that law enforcement officer line of duty deaths are from injuries that are clinically, potentially survivable. The outcomes for Specific Aim 3 include identification of environmental and operational risk factors influencing survivability and will use One Health and epidemiologic risk assessment of traumatic mortality to identify possible prevention efforts. This assessment will identify areas of further consideration or research to reduce risk and identify opportunities to improve operational responses.

This comprehensive risk assessment is fundamental to identify needs for education and policies for operational responses to reduce mortality. Identification of risk factors, causes of injuries and mortality will help develop interventions to mitigate the severity and occurrence of events. Incorporation of demographics, temporal factors as well as consideration of both the circumstances in which the event occurred as well as

law enforcement operational considerations will produce a comprehensive One Health approach to identify risk factors and consider control measures.

Considerations to occupational health assessment and system theory complement the One Health approach to addressing the complex interactions that lead to occupational fatalities. To most adequately address vehicle accidents, which represent the most common mechanism of injury for officer fatalities, a review of the theoretical framework of accident causation and prevention will support a holistic perspective on fatal occupational crashes.[22] Extensive work addressing identification of hazards resulting automobile accidents has led to the development of external safety measures aiming to reduce the risk of accidents including guard rails, jersey barriers, and traffic signs. The Heinrich risk triangle offers a proportion focused representation of automobile accidents suggesting that frequency and severity are related.[23] In this risk triangle, the resulting fatalities would only represent a small quantification of risk for such events. For every fatal accident, there would be more accidents that sustain an injury, and still, more accidents that produce no injuries; and still more near-miss events. The base of the triangle would be composed of all drivers in which no events, or near events occur.

One Health Methodologies: Human and Canine Risk Assessment

One Health methodologies represent a paradigm of integrated thought and collaboration to transcend disciplines and develop comprehensive perspectives towards addressing complex issues. Using this holistic approach to review traumatic injury can reduce morbidity and mortality. Traumatic injury remains a leading cause of mortality in America, despite recent advances in engineering and safety initiatives.[24] Trauma

mortality studies have been utilized in military medicine and trauma surgery to assess, describe and recommend operationally appropriate actions/interventions to reduce mortality from traumatic events. The use of an interdisciplinary One Health methodology can benefit any population subject to trauma and better assess risks and identify potentially survivable mortality. Efforts to then implement mitigations efforts may reduce the severity of trauma. This study of law enforcement line of duty mortality aims to identify potentially survivable injuries and identify factors that may influence survivability and reduce mortality. This study will also provide a trauma mortality risk assessment method for other populations subject to difficulties with immediate access to trauma systems, and to enhance further research. This method could also be used to reduce preventable traumatic mortality from other causes. While any retrospective case series provides a generalization of the data used, the aim of this study is to provide a reliable and practical risk assessment methodology to reduce mortality and improve the identification of factors influencing survivability in trauma. This research will also address occupational canine considerations, and expand the knowledge while identifying future gaps for research opportunities.

Preliminary fatality information was obtained from "The Officer Down Memorial Page," and Texas Department of Public Safety online records. Detailed fatality information including autopsy records will be obtained from the Texas Department of Public Safety. Over 28% (n = 24) of the fatalities in the study were due to penetrating trauma, with the remaining fatalities due to blunt trauma or complications

from trauma. This evidence supports the central hypothesis that some officer line of duty deaths are from injuries that are clinically, potentially survivable.

Texas DPS Highway Patrol did not sustain any canine deaths during the study period. Anecdotal data from the Officer Down Memorial Page suggests that dogs are killed most frequently from heat exhaustion and gunfire for the reported fatalities for 2014 through September 30, 2016. Previous military studies used canines for ballistics testing and wound pattern identification, supporting the assumption that canines and humans would be susceptible to similar injury patterns for gunshot wounds. This methodology would be suitable for use in law enforcement canine populations and would have expected results comparable to those in humans relating to survivability. The Animal Trauma Triage score would be used in place of the AIS/ISS score for survivability determinations and further risk mitigation efforts.

CHAPTER II

TRAUMATIC MORTALITY EPIDEMIOLOGY

Trauma management in tactical and austere environments need a firm understanding of the epidemiology of surrounding these deaths mitigate future occurrences. The epidemiology of deaths for all Texas Department of Public Safety Highway Patrol Troopers/Highway Patrolman that died of traumatic causes in the line of duty between January 1, 1932, through December 31, 2016, were included for review. Identifying and recognizing injury mechanisms, injury patterns, and potential mitigation can improve officer safety and survivability. The risk of death from traumatic causes is increasing for a police officer, and the mechanism of injury has changed over time with the risk of death from gunshot wound decreasing while risk of death from motor vehicle collision increases.[25] While the length of time included in this study presents some limitations in obtaining some information, this demonstrates the strength of this methodology in reviewing deaths attributed to varying causes and assessing risk. The risks to Troopers over time has changed, in part to operational practices and increased safety efforts including motorcycle helmets, bulletproof vests, and vehicle safety to include patrol vehicle upgrades.

Trauma scoring systems including the AIS and ISS, have produced sufficient evidence to demonstrate that a higher trauma score typically indicates an increased risk of mortality.[20] A systematic risk assessment based on sustained fatal injury patterns has yet to be conducted for occupational trauma in law enforcement. The use of Injury Severity Scores to assess trauma mortality and the potential survivability of sustained

injuries has been utilized in military medicine resulting in significant improvements towards reductions in unit mortality.[1,2] Reductions in mortality from potentially survivable trauma in actively engaged military units resulted from epidemiology research identifying needs for education and training in the use of medical interventions including hemostatic dressings and the use of tourniquets.[1]

Methodology

A multidisciplinary disciplinary panel reviewed autopsy reports and incident details for cases with autopsy reports or incident details sufficient to determine potential survivability in ambiguous cases for Texas Department of Public Safety Highway Patrol Troopers/Highway Patrolman that died of traumatic causes in the line of duty between 1970 through 2016. Cases prior to 1970 were not considered for review by the multidisciplinary panel due to lack of quality information on injuries including autopsy reports. All cases with adequate information were determined to be potentially survivable or not survivable. Cases were considered **potentially survivable** if the casualty may have survived the sustained injuries had immediately available trauma center care, including blood products and surgical capabilities, been available. Location, medical trends over time and other situational factors were not considered influential in this initial determination of potentially survivable or not survivable. Consensus rule was used following the Holcomb methodology for case review.[2] Fatal wound survivability classification followed prior studies to notate injuries in which the death may have been preventable through circumstance or intervention as nonsurvivable and potentially

survivable rather than to use conventional civilian terminology of preventable or not preventable (Table 1). [1,2]

Table 1: Comparison of Trauma Terminology and Study Definition

Civilian Trauma Terminology	Military Terminology	Study Definition
Non-preventable death (NP)	Not survivable (NS)	Result from either a single wound that is determined to be not survivable, such as decapitation, or several injuries that compound each other.
Possible preventable death (PP)	Potentially survivable (PS)	May have survived the sustained injuries had immediately available trauma center care, including blood products and surgical capabilities, been available.
Definitely preventable death (DP)		

Survivability will be determined by reviewing each case with consideration to the mechanism of injury, the cause of injury, any medical interventions performed and existing interventions that may have improved survivability. The military terms "nonsurvivable" and "potentially survivable" would be utilized as opposed to civilian terms including "preventable" to encourage improvement of practices over identification of fault or blame.[1,26]

Each case will be reviewed and injury information will be scored using AIS and ISS severity scores. From sustained injuries noted, the potential survivability will be assessed. The cases will initially be reviewed to determine if the sustained injuries would

be potentially survivable with immediately available, ideal trauma care. Epidemiology of these deaths will be described using AIS/ISS and MCIS trauma scoring. Autopsy reports, death certificates, and incident information were used for an a priori determination of survivability. Demographic information, cause of death and injury information were collected. Case specific information including age, years of service, cause of death, geographic information and time of day were collected. Cause of death is categorized using the following categories; Automobile accident, Gunfire, Gunfire (Accidental), Motorcycle accident, Struck by train, Struck by vehicle, Training accident, Vehicle pursuit, Vehicular assault, and Weather/Natural disaster.

In cases in which an autopsy report or detailed injury information was available, injuries were coded using the Anatomical Injury Severity Score. The injury is coded using the standardized Anatomical Injury Severity score system. Each case is scored twice to ensure intra-rater reliability. Injuries are noted on a standardized data form with six body regions. From the injuries scored, the three body regions with the highest score have that injury score squared and the three scores summed to calculate the Injury Severity Score.

The mechanism of injury resulting in death was considered with the resulting injuries when known, to make a survivability determination. Injuries resulting in death such as 3rd and 4th-degree total body burns or massive destruction of the skull, brain and intracranial contents were determined to be not survivable. Cases that succumb to their injuries after a period of time exceeding two days were determined to be potentially survivable. Further review of incident information determined survivability where

information on sustained injuries was sufficient to make such a decision. In some cases, the information was severely limited or insufficient for coding with death certificates noting "injuries - severe" as a sole cause of death. Survivability group composition is presented visually for clarity in Figure 2, where all 86 deaths of Texas DPS Troopers killed in the line of duty are accounted for based on survivability, trauma type and case AIS/ISS score.

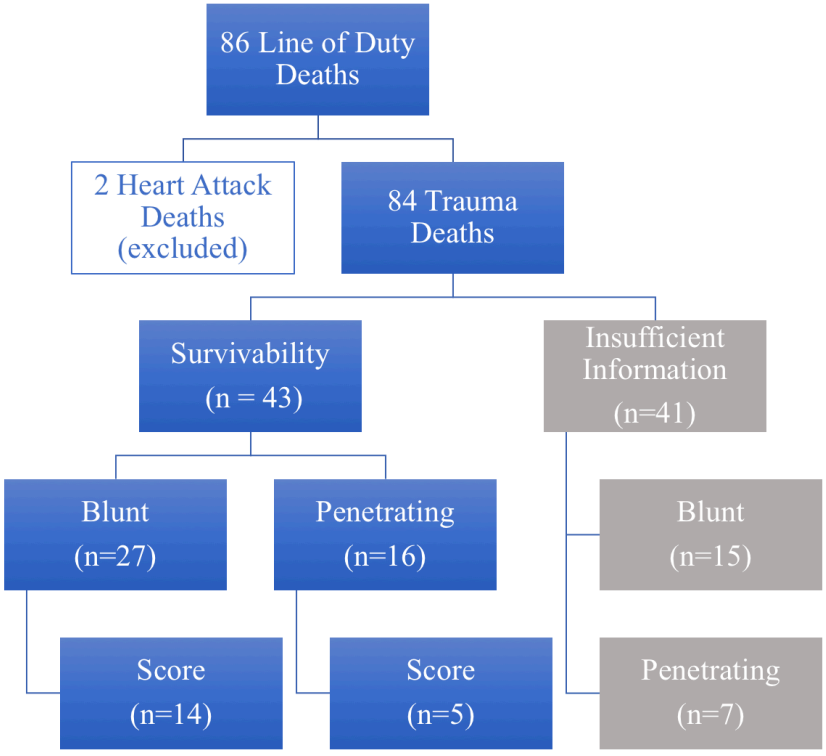

Figure 2: Line of Duty Death Survivability Group Composition

This defined and structured analysis will use injury information to create a framework for further study and develop useable information for stakeholders to review "equipment, training, research requirements to improve future outcomes."[2] The use of autopsy reports is the gold-standard measure for trauma mortality review and is essential for the prevention and mitigation of future injuries.[2,27] The primary purpose of this effort was to describe traumatic law enforcement deaths in the line of duty based on sustained injuries to assess future prevention and mitigation efforts.

Results

Of the eighty-four deaths reviewed in this study, the leading cause of death was related to motor vehicular collisions. Automobile accident causes 37 (44%) deaths, gunfire caused 27 (32%) deaths, casualties struck by a vehicle caused 10 (12%) deaths, motorcycle accidents were responsible for six (7%) deaths and other trauma including stuck by lighting and a boxing accident caused four (5%) deaths. Of these deaths, more traumatic injuries were sustained from blunt force trauma rather than penetrating trauma. Of the 84 deaths, survivability was determined for 43 cases. Of the 43 cases with sufficient information to determine survivability, 19 cases had detailed injury information in which a score could be coded from injury details (Figure 3).

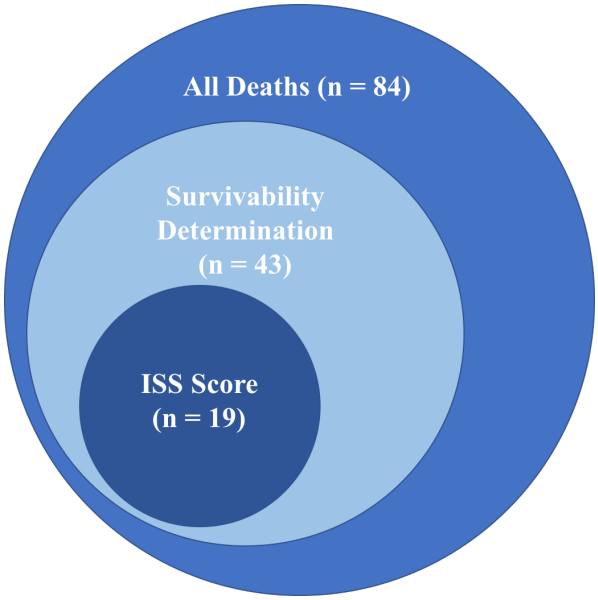

Figure 3: Venn Diagram of Study Deaths, Survivability Determination and ISS Score

Fourteen of the 84 cases were selected for review by the interdisciplinary panel. Each of the cases was presented with the AIS/ISS scoring for sustained injuries with the cause of death, date and time of the incident, weather information, geographical information including county designation for rural/urban and border/non-border. From the review, 21% (n = 3) of the fourteen cases were determined to be non-survivable. 36% (n = 5) of the cases reviewed were determined to be potentially survivable.

Of all 84 cases, 47.6% (n = 40) of the cases insufficient information on the case, the cause of death and injuries sustained resulted in no survivability determination made. Of the remaining 44 cases, 52.4% (44/84), 29.7% (25/84) of the cases were determined to be potentially survivable, and 22.6% (19/84) of the cases were determined to be not survivable. MCIS severity scores did not offer further insight to deaths where all cases

that could be scored with MCIS (n = 78) had a mean of 4.47 (s = 0.618). Observed causes of death in the Texas DPS Highway Patrol Line of Duty Deaths were more likely to be due to an automobile accident than gunfire, though trends varied over the decades. The causes of these deaths were similar and related to military trauma and FBI Police death data. However, Texas DPS Highway Patrol Troopers sustained more deaths from automobile accidents than either military trauma or the FBI Police death data (Table 2).[2,13,28–35]

Table 2: Primary Cause of Death by Entity

Entity	Primary Cause of Death
Texas DPS Highway Patrol (1932 - 2016)	1. Automobile Accident (44.0%) 2. Gunshot Wound (32.1%)
SOF Military (2001 - 2004)[2]	1. Explosion (43.8%) 2. Gunshot Wound (28%)
FBI Police Data (2012 - 2015)[28–35]	1. Firearms (45.9%) 2. Automobile Accident (28.9%)

Twenty-five of the 84 cases were determined to be potentially survivable. Fourteen potentially survivable deaths resulted from penetrating trauma due to a gunshot wound, and eleven of the deaths resulted from blunt force trauma due to motor vehicle collision (Table 3). Nineteen of the 84 cases were determined to be not survivable from the injuries sustained. Of the not survivable deaths, fourteen were due to automobile accidents. Of the 40 cases in which survivability could not be determined, fourteen were due to automobile accidents and twelve deaths were due to gunfire. In each of the cases

where no survivability could be determined, injury information was sought from numerous sources including historical interview accounts, without sufficient reliable information available for determination.

Table 3: Mechanism of Injury: 84 Texas Highway Patrol Deaths - Total and By Survivability

Mechanism	Total (n= 84)	Not Survivable (n = 19)	Potentially Survivable (n = 25)	Survivability Unknown (n = 40)
Automobile Accident	37 (44%)	14 (78%)	9 (36%)	14 (37%)
Gunfire	27 (32%)	1 (6%)	14 (56%)	12 (29%)
Struck by vehicle	10 (12%)	1 (6%)	0	9 (22%)
Motorcycle Accident	6 (7%)	0	1 (4%)	5 (12%)
Other	4 (5%)	3 (17%)	1 (4%)	0
Total	84	19	25	40

Military studies suggest that 85% of fatalities sustained in battle are not survivable.[1,2,9,36] The cases with sufficient data to review in this study indicate that of 44 cases, 25 are potentially survivable based on anatomical injuries sustained in the line of duty. Potentially survivable cases are offered a generous leaning towards survivability to include cases that may even have injuries that are clinically survivable, even if unlikely,

suggest 29.7% of the 84 Texas Department of Public Safety Line of Duty Deaths are potentially survivable. Compared to military findings for blunt and penetrating trauma injury severity and patterns seen in the military battlefield environment, Texas DPS Highway Patrol line of duty deaths resulted in a higher percentage of potentially survivable injuries and a higher burden of deaths due to blunt trauma.

Injury wounding patterns noted little extremity injury, and no deaths due to extremity hemorrhage. Injury information sustained by body region was available for 79.8% (n = 67) of the cases. Thirty-eight percent (n = 32) of the cases sustained injuries exclusive to the head/neck area, 21.4% (n = 18) of the cases sustained injuries isolated to the torso, no cases sustained injuries isolated to the extremities resulting in death. Cases with multiple body regions impacted by sustained injuries represented 16.7% (n = 14) of the cases, while 20.2% (n = 17) of the cases had insufficient information to identify a body region based on injuries.

Table 4: Body Region of Sustained Injuries for 84 Line of Duty Deaths

Body Region of Sustained Injuries for All Deaths (n = 84)	
Body Region	**Count**
Indeterminate	17
Head and Neck	32
Face	0
Thorax	18
Abdomen	1
Extremities	0
External and Other	2
Head and Neck + Thorax	8
Head and Neck + Abdomen + Extremities	1
Thorax + Abdomen	3
Thorax + Extremities	2

Injuries sustained were noted to primarily occur in the head and neck region or thorax region more than any other body region areas used in the ISS scoring, or the combination of body regions in cases of multisystem trauma (Table 4). From all cases with a survivability determination (n=43), the head/neck region and thorax region were the most affected body regions (Figure 4). Not survivable cases sustained more head/neck injuries, while potentially survivable injuries were more commonly seen in the thorax region.

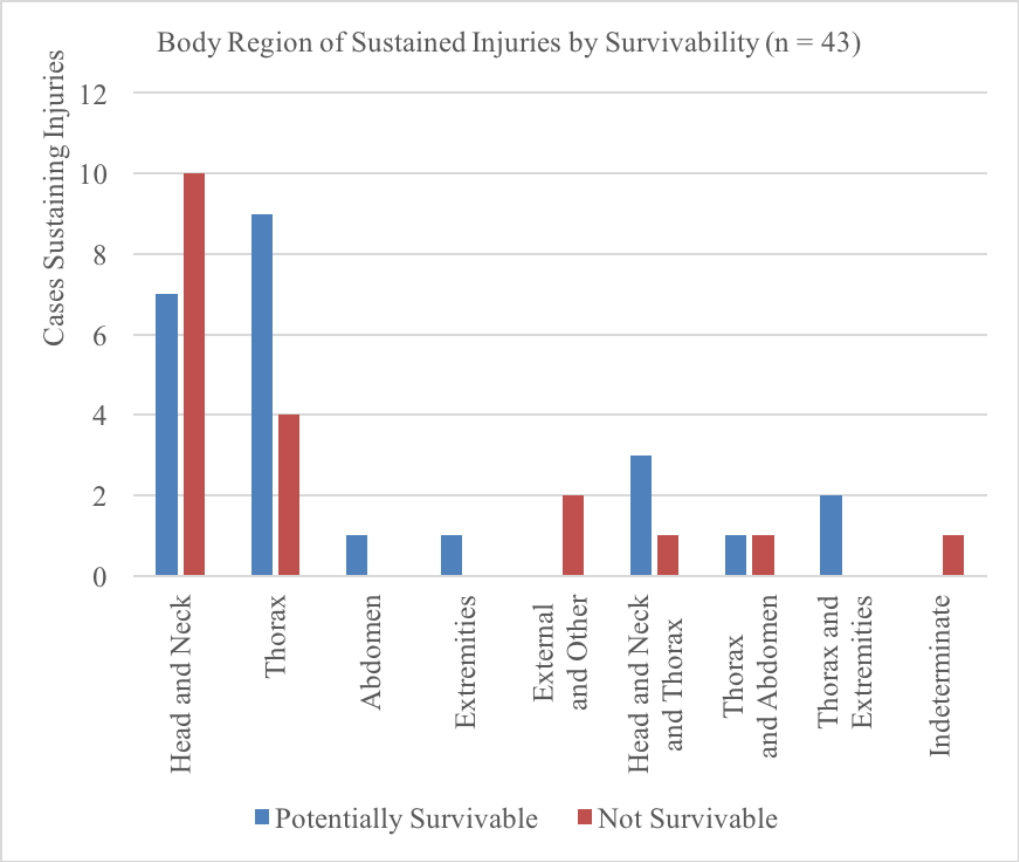

Figure 4: Body Region of Injuries Sustained (n = 43)

In nineteen cases, an ISS was determined from available injury information. Of the 19 cases with an ISS score, eleven deaths were determined to be not survivable and eight were potentially survivable. Using Fisher's exact test, potentially survivable deaths had lower ISS scores (30.56) than not survivable cases (71.6), with a p-value < 0.001. This is consistent with other studies on trauma prevention.[2,9,12] Confidence intervals are not computed with Fisher's Exact Test as would be with a Chi Square test as R is not squared, and there is no formal test statistic. While all injury severity scores would

represent *major trauma* using civilian trauma paradigm as an ISS score over 15, six of eight potentially survivable cases had injury severity scores below 50 (Figure 5).

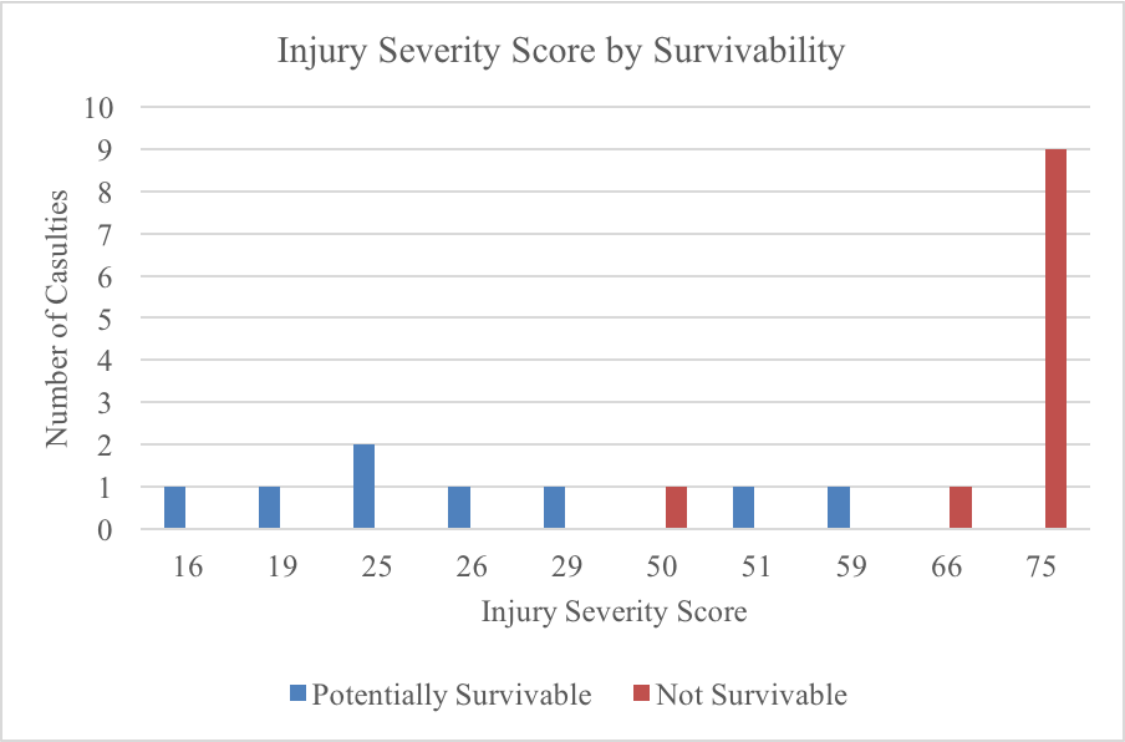

Figure 5: Injury Severity Score – Survivability

Gunshot wound injuries more frequently resulted in lower ISS scores, because they impacted one body region greatly rather that several body regions. The scoring methodology increases scores for multi-system or multi-body area injuries. For deaths resulting from gunshot wound injuries (n = 5), the mean Injury Severity Score was 29.2 (s = 12.498). For deaths resulting from blunt force trauma injuries (n = 14), the mean Injury Severity Score was 63.93 (s = 19.3011). Injury Severity Scores were analyzed

using an unpaired t-test to compare means. The Injury Severity Score was lower in deaths determined to be potentially survivable (mean 30.6) than those determined to be not survivable (mean 71.9), the difference in the severity of sustained injuries was statistically significant to potential survivability ($p < 0.0001$, -51.9 5 to -30.65). The Injury Severity Score was lower in resulting from penetrating trauma (mean 29.2) than those resulting from blunt trauma (mean 63.93), the difference in the severity of sustained injuries was statistically significant to potential survivability ($p = 0.0017$, 15.017071 to 54.442929). The Injury Severity Score for potentially survivable deaths from penetrating trauma (mean 29.2) does not have a statistically significant difference from those deaths resulting from blunt trauma (mean 32.25), the difference in the severity of sustained injuries was not statistically significant to potential survivability ($p = 0.78$, -21.43 to 27.53).

The significance of difference of means presents difficulty due to data set size. While the difference in injury severity between sustained blunt force injuries and penetrating injuries for Troopers killed in the line of duty is significant, data set size limitations may inhibit generalizability. Considerations for interventions from this difference could be reducing the risk of blunt force trauma before the injury is sustained, and incorporating TCCC interventions for Troopers in routine operations.

Of the 84 cases, autopsies were performed on 29 cases. For 28 cases, no autopsy was ordered. It is unknown in 27 cases if autopsies were ordered. Eighteen autopsy reports were obtained from across the State. The autopsy reports were sought from the local justice of the peace, County Judge and the Medical Examiner's Office known or

suspected of performing the autopsy. Open records requests and formal inquiry procedures were used to obtain records. Texas DPS Highway Patrol had autopsy reports for the most recent deaths available as a component of the crash report. From each of the entities with responsibility for maintaining records, indications that records were lost, not kept or otherwise unavailable were offered. One unidentified Justice of the Peace Office indicated that they "don't keep records like that" when presented with an open records request.

Nineteen cases sustained injuries determined to be non-survivable, of those two were from penetrating injuries and 17 resulted from blunt injuries. Twenty-five cases sustained injuries determined to be potentially survivable, of those 14 were caused by penetrating injuries and 11 from blunt injuries. In 40 cases, information was not available, not sufficient or complete in which a determination on survivability could be reasonably assessed. Of these cases, fatal injuries resulted from penetrating injuries for 12 cases, and 28 blunt cases (Table 5).

Table 5: Survivability Based on Trauma Type

Survivability Based on Trauma Type (n=84)

	Potentially Survivable	Not Survivable	Indeterminate	
Penetrating	14	2	12	28
Blunt	11	17	28	56
Total	25	19	40	84

In some cases, death certificates for automobile accidents noted: “injuries, multiple severe” with no other enumeration. In other cases, review of historical eyewitness interviews from court documents or newspapers could not produce effective information to determine anatomical injury severity, for example, “his head looked bad,” and lack of medical knowledge of the interviewed party precluded the ability to decipher subjective assessment terms.

CHAPTER III

CAUSES OF DEATH BY ANATOMICAL INJURY

Identification of injury information to address the appropriateness of current military trauma interventions towards "potentially survivable" officer line of duty deaths is largely unknown using trauma scoring methodologies such as the AIS or ISS score. To date, a lack of research exists characterizing fatal injury patterns and anatomical causes of death law enforcement officers experience in the line of duty. An understanding of injuries sustained in the line of duty will allow for the first steps of a comprehensive risk assessment. The TCCC guidelines offer a model for interventions that can be used by non-medical providers in a tactical and operationally intensive situation to reduce mortality from traumatic events. To date, a lack of research exists characterizing fatal injury patterns and specific causes of death officers experience in the line of duty. Identification of specific injuries will help address the potential effectiveness of the three primary TCCC interventions including tourniquet control of extremity hemorrhage, airway control, needle decompression and cricothyrotomy to sustained injuries; these assessments will help understand the effects of medical interventions that may contribute to increased survivability.

Evaluation of the potential impact of using Tactical Combat Casualty Care (TCCC) interventions for injuries sustained by law enforcement officers in the line of duty will offer insight on the need and potential effectiveness of interventions to mitigate traumatic line of duty deaths.

Evaluation of the potential effectiveness of TCCC interventions for injuries sustained in the line of duty that results in death, as well as general injury patterns occurring in this population will allow for improved trauma management. To date, a lack of research exists characterizing fatal injury patterns and specific causes of death officers experience in the line of duty. The TCCC guidelines offer a model for interventions that can be used by non-medical providers in a tactical and operationally intensive situation to reduce mortality from traumatic events.

Tactical Combat Casualty Care interventions were selected for use in this study from their proven effectiveness to improve survivability when implemented by non-medical professionals in a tactical operational environment. It has been well established that military interventions, now known as the Tactical Combat Casualty Care interventions, have demonstrated reductions in unit mortality particularly when populations are subject to large penetrating trauma burdens, environmental considerations that delay access to definitive medical care and effective training and equipment.[1,2,14] Sufficient evidence indicates the effectiveness of the use of these interventions in a battlefield environment. Further review of law enforcement line of duty deaths is required to demonstrate potential need or opportunity towards mitigation.

Methodology

The methodology used in this study is well established in the military battlefield setting and addresses several critical gaps in knowledge to address the opportunity for trauma mitigation in a law enforcement population.[2,25,36] A retrospective review of autopsy reports and case information addressed the potential effectiveness of TCCC

interventions for fatal injuries sustained in the line of duty for Texas DPS Highway Patrol Troopers that were potentially survivable. Autopsy reports were requested through open records requests, or department established protocols from Justice of the Peace offices or Medical Examiner offices for each case. Once received, autopsy reports were scored using a data abstraction form based on established trauma review formats.[37] Data verification and validity was ensured through double data entry. Each case was scored twice to ensure consistency and intra-rater reliability. Should a deviation in scores occur, a second rater was sought. Deaths resulting from potentially survivable injuries were reviewed to determine interventions that may mitigate the injury severity or improved survivability. In cases where an autopsy was not ordered or available, survivability determinations were made based on available incident information, crash reports, court proceedings and some first-hand account from persons associated with the incident. In cases where a death certificate noted no autopsy was ordered and interval from injury to death exceeded six hours, cases were determined to be potentially survivable. Of 84 Texas DPS Highway Patrol line of duty deaths resulting from trauma, 25 died from injuries that were potentially survivable and were included in this review.

There is no risk to the subjects in this study. All subjects were over the age of 18. Sources of material will include publically available data from autopsy reports, court reports and newspapers. Overall, there is no risk to the subjects associated with participation in this study. References to the deceased will be maintained in a locked office, only accessible to project researchers.

Cases will be reviewed to determine if the TCCC interventions including tourniquet control of extremity hemorrhage, needle decompression, and cricothyrotomy, would have influenced the survivability. Other TCCC intervention areas assessed included sepsis/infection, compressible hemorrhage, TBI, airway and truncal hemorrhage.

Autopsy-based review of aorta trauma suggested that patients with traumatic aorta or aortic arch branches that resulted from motor vehicle collisions were more likely to reach the hospital alive, compared to those with injuries resulting from other forms of trauma.[27] Injury information suggests that Texas DPS Highway Patrol Troopers have sustained injuries to the aorta and aortic branches; rapid transport and truncal hemorrhage control would be considerations for improved survivability in these circumstances.

Results

Data collected from review of autopsy reports and supporting material is presented in the following tables and figures. Data collected from cases included in this detailed review is summarized in Tables 7-8 and Figures 7.

Using incident information, death certificate and autopsy reports, the interval of time between injury and death were determined. Using an MCIS Severity score and guidelines presented by Eastman for assessing nonsurvivable injuries, injuries were assigned a time interval for injury to death of immediate or acute unless otherwise noted in an hours or days period.[1] In some cases, the injury noted on the death certificate may suggest a different interval based on MCIS reference for immediate death classification,

but the death certificate was used as the official documentation when available. For example, a basilar skull fracture was noted on one death certificate as the only injury resulting in immediate death. Based on AIS scoring, this injury would be scored with a severity of 3, and would be a 3 (serious) on the MCIS scoring. Cases transported by EMS and declared dead upon arrival at the hospital were noted to be acute deaths under the presumption that EMS teams would not transport a patient with "obvious signs of death" even if the patient was pulseless and apneic upon EMS arrival. Thirty-Five Troopers died immediately or within minutes of sustaining the injury. The longest interval of an injury resulting in death was 700 days. Injuries that died instantly were noted to be related to catastrophic brain injury and catastrophic great vessel injury, which were similar findings to Dr. Eastridge's military trauma study.[1]

The most common potentially survivable injuries resulted from non-compressible hemorrhage, hemorrhage not amenable to tourniquet yet compressible, obstructed airway, pneumothorax and sepsis/infection (Figure 6).[1,2]

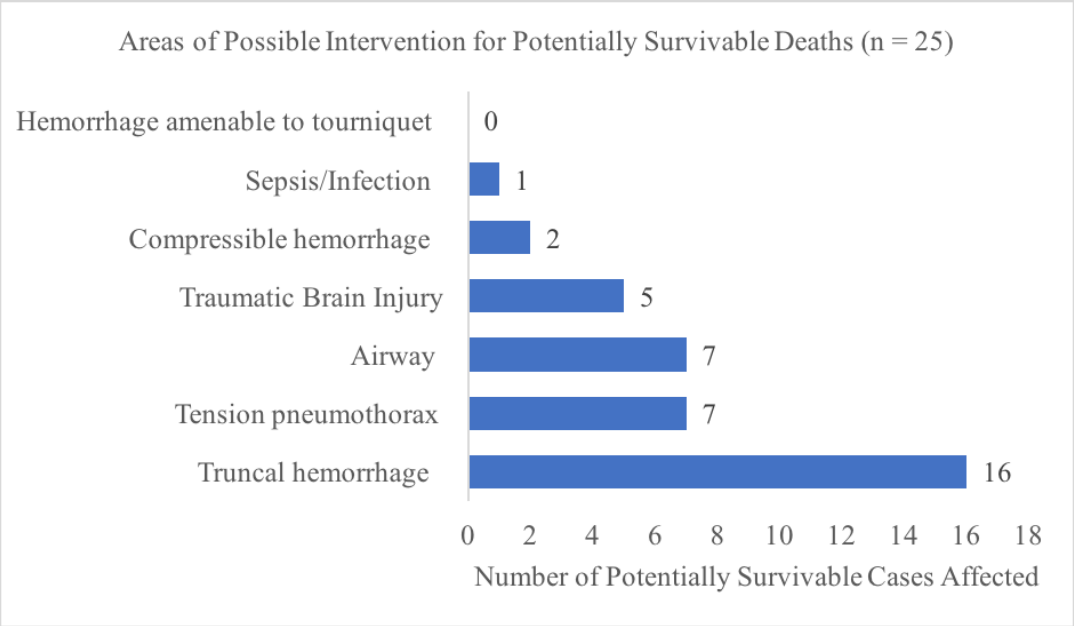

Figure 6: Areas of Possible Intervention for Potentially Survivable Deaths (n = 25)

Among the potentially survivable injuries, non-compressible hemorrhage was the most common cause of death. No deaths resulting from extremity hemorrhage were noted in this study. Cases that may have benefited from an identified intervention does not indicate that a case would have survived from a single intervention alone. The availability of resources and training to implement these interventions warrant further consideration.

Of the nine potentially survivable deaths reviewed for anatomical injury, gunfire was the most common mechanism of injury (n = 5). In potentially survivable cases, injury severity scores were lower than nonsurvivable injury severity scores due to lower AIS scores, and fewer body regions sustaining injuries. In the potentially survivable

cases, there were eight AIS scores of 5, and nine AIS scores of 5 (Table 6). These injuries are most related to organ disruption.

Table 6: Potentially Survivable AIS Scores of 4 and 5

AIS Code	Potentially Survivable AIS Scores = 5	Frequency
116004.5	Major penetrating injury to skull	1
140692.5	Cerebrum - penetrating injury > 2 cm deep	1
440110.5	Bronchus, main stem - complex; avulsion; rupture; transection; with separation	1
441012.5	Heart Injury - Laceration, perforation, ventricular or atrial	2
542832.5	Pancreas - Massive; avulsion; complex; tissue loss; massive disruption of pancreatic head	1
544228.5	Spleen - Laceration, hilar disruption	1
640440.5	Cord laceration, NSF (T9)	1

AIS Code	Potentially Survivable AIS Scores = 4	Frequency
140608.4	Cerebrum - Contusion, large, deep	1
150206.4	Basilar skull fracture - Complex; open, torn exposed or loss of brain tissue; comminuted; ring; hinge	1
420606.4	Brachiocephalic vein - Major; rupture; transection	1
441450.4	Lung - Laceration, bilateral NSF	2
442201.4	Hemothorax	2
442202.2	Pneumothorax	1
440610.4	Diaphragm, rupture with herniation	1

In nonsurvivable cases, injury severity scores were higher due to higher AIS scores, as well as multiple body regions sustaining injuries. In the nonsurvivable cases, there were twelve AIS scores of 6, and five AIS scores of 5 (Table 7). These injuries are

most related to destructive brain injuries and aorta transection. Of the eleven nonsurvivable deaths reviewed for anatomical injury, automobile accidents were the most common mechanism of injury (n = 9).

Table 7: Not Survivable AIS Scores of 5 and 6

AIS Code	**Not Survivable AIS Scores = 6**	Frequency
113000.6	Crush Injury - Massive destruction of the skull, brain and intracranial contents	4
140212.6	Laceration of brainstem	1
140218.6	Brain stem, medulla - Transection	1
140214.6	Brain stem, pons - Massive destruction (crush type injury)	1
419208.6	Mucosal sloughing, endoluminal obliteration	1
420218.6	Aorta, transection with hemorrhage not confined to the mediastinum	2
640269.6	Cervical Spine, C-3 or above but NSF on fracture/dislocation	1
912032.6	3rd and 4th degree total body burns	1

AIS Code	**Not Survivable AIS Scores = 5**	Frequency
420210.5	Aorta Transection, NFS	2
420216.5	Aorta Transection, with hemorrhage confined to mediastinum	1
640468.5	Cord transection at T1/T2 with fracture and dislocation	1
541628.5	Kidney, Total destruction of organ and its vascular system	1

Identification of specific injuries resulting in death allows for further efforts and increased effectiveness in risk mitigation. Blunt force trauma produces more injuries with higher injury severity than penetrating trauma. Efforts to address bulletproof vest

compliance and tourniquet use stand to reduce injury severity and save lives. Addressing a holistic approach to risk assessment and mitigation identifies prevention of blunt force trauma would produce the greatest increase in survivability. Further review of occupational and environmental factors relating to law enforcement line of duty deaths is warranted.

CHAPTER IV

INJURY MITIGATION AND RISK IDENTIFICATION

Risk assessment and injury prevention are foundations of occupational epidemiology. Risk factor assessment is often represented in a Haddon Matrix, developed by William Haddon to identify risk factors for motor vehicle crashes prior to the event, for the event and after the event.[38,39] The use of the Haddon Matrix has been used to assess risk relating to situations causing injury or death from automobile accidents to violence prevention and rape.[40–42] The One Health concept integrates health of animals and humans in relation to their environments. Assessing risk of injury incorporating both One Health concepts and occupational and injury epidemiology represents a novel approach to high consequence trauma mitigation.

Methodology

Descriptive epidemiological variables were assessed to further define the population. Age, years of service, geographical location and temporal variables were reviewed. A review of these factors will help identify opportunities mitigate risk.

Automobile accidents and gunfire resulted in 64 of the 84 deaths in this dissertation. A review of the occupational health risks was conducted and a Haddon Matrix was developed for risk prevention for each mechanism of injury.

Fully assessing risk for Texas DPS Troopers or other law enforcement agencies would require review of all injuries sustained as opposed only including fatal injuries. This further effort could be implemented in partnership with academic and agency or

department support. Identification of those at risk is further identified through a risk hierarchy.

Results

Measures of central tendency were used to summarize data for age. Measures of dispersion were calculated to understand the variability of scores for the age of Texas Highway Patrol Troopers killed in the line of duty as a result of trauma. The median age of Texas Highway Patrol Troopers killed in the line of duty as a result of trauma (n = 84) since 1932, was 31.5 years of age, while the mean age at the time of death was 33.5 years. The middle 50% of deaths were of Troopers aged 26 to 38 on the date of death. The age range of all Troopers included in this study was 21 - 57 years.

To represent experience, the years of service with Texas DPS as a commissioned officer was used as a proxy value, as some Troopers have prior law enforcement experience from other municipalities or military service. Measures of central tendency were used to summarize data for years of service with Texas DPS. Measures of dispersion were calculated to understand the variability of scores for the years of service of Texas Highway Patrol Troopers killed in the line of duty as a result of trauma.

The Troopers killed in the line of duty as a result of trauma have an average of five years of service (mode 2, median 8.1). The middle 50% of deaths were of Troopers with 2 to 10.25 years of service. The range of years of service of Troopers in this study was 0 - 36 years of service.

County of death or county of assigned service area was classified as rural or urban using currently utilized Texas Department of State Health Services designation

which is based on the 2013 classifications from the U.S. Office of Budget and Management (OMB). Texas Department of State Health Services has determined the terms "Non-metropolitan and Metropolitan" are interchangeable with "Rural and Urban."[43,44]

Of the 84 deaths in this study, 54.8% (n = 46) occurred in an urban county. Over the decades of this study, several counties that were previously rural have been designated as urban, possibly influencing this observation. Deaths occurring in rural counties represented 45.2% (n = 38) of the cases in this study.

County of death or county of assigned service area was classified as a border or non-border county. The Texas Department of State Health Services uses Article 4 of the La Paz Agreement of 1983, to determine county classification as a border or non-border county.[43,45] Under this agreement, a border county is defined as a county that is within 100 kilometers of the U.S./Mexico Border.[43,45]

As population growth across Texas has changed at various speeds over time and geographical location, the Texas-Mexico border has long been an area with increased policing presence compared to similarly populated counties across Texas. Texas DPS Trooper line of duty deaths resulting from trauma primarily occurred in non-border counties, with 94.05% (n = 79) of cases resulting in death from injuries sustained in non-border counties. Five deaths (5.95%) occurred in border counties. The first Texas DPS death in this study sustained in a border county occurred in 1981, when a Trooper was shot in Cameron County.

Texas Department of Public Safety Region associated with a case was assigned using Texas DPS Region map based on determined county of death. Region boundaries have changed over the years, and current Texas DPS Region designations are used for consistency. Region 7 is the Texas Capitol complex and is functionally, but not geographically distinct from Region 6; this region is new and was condensed into Region 6 for this study. No deaths occurred in Region 7. Region 1, which is the most populated region is composed of 42 counties in the Dallas-Ft. Worth metropolitan area and much of East Texas, including Tyler. While Region 1 sustained the highest occurrence of Texas DPS Line of Duty deaths (n = 21), the adjusted rate per million population is below the average rate for the state. Region 4, with headquarters in El Paso, is the least densely populated region. Region 4 is composed of 71 counties yet has the smallest population of all six regions. Regional differences could represent significant risk profile differences due to geography, weather, and the average miles that may be driven per Trooper. Current Trooper allocations per Region are influenced by county/region population in addition to functionally distinct operations including Capitol programs and border security initiatives. These functional/operational influxes of Troopers will influence the historical observed versus expected mortality ratio across regions. This consideration is important for future studies to address functional and operational differences that may influence risk profiles of a specific location. Region 3 (Rio Grande Valley/Corpus Christi/Laredo) would appear to have a protective observed versus expected mortality ratio using historical deaths and current Trooper allocations (Table 8). This ratio may be influenced by recent increases in staffing to this region for a

border security initiative. Further review of differences between regions may offer increased insight to risk mitigation strategies that would be effective with regional contribution and support.

Table 8: Texas Highway Patrol Death by Region

THP Deaths by Region (n= 84)

DPS Region	Number of Deaths (%)	Observed Deaths /Expected Deaths
Region 1	21 (25%)	1.27
Region 2	16 (19%)	1.09
Region 3	8 (9%)	0.40
Region 4	7 (8%)	0.88
Region 5	12 (14%)	1.30
Region 6/7	20 (24%)	1.29
Total	84	

At the inception of the Texas Highway Patrol, there were 50 Patrolmen in 1930 using motorcycles to patrol highways across Texas. Since that time, approximately 15,000 men and women have served as Highway Patrolmen or as they are now referred to as Highway Patrol Troopers. As the State of Texas population has grown, the Texas DPS Highway Patrol has increased its ranks.

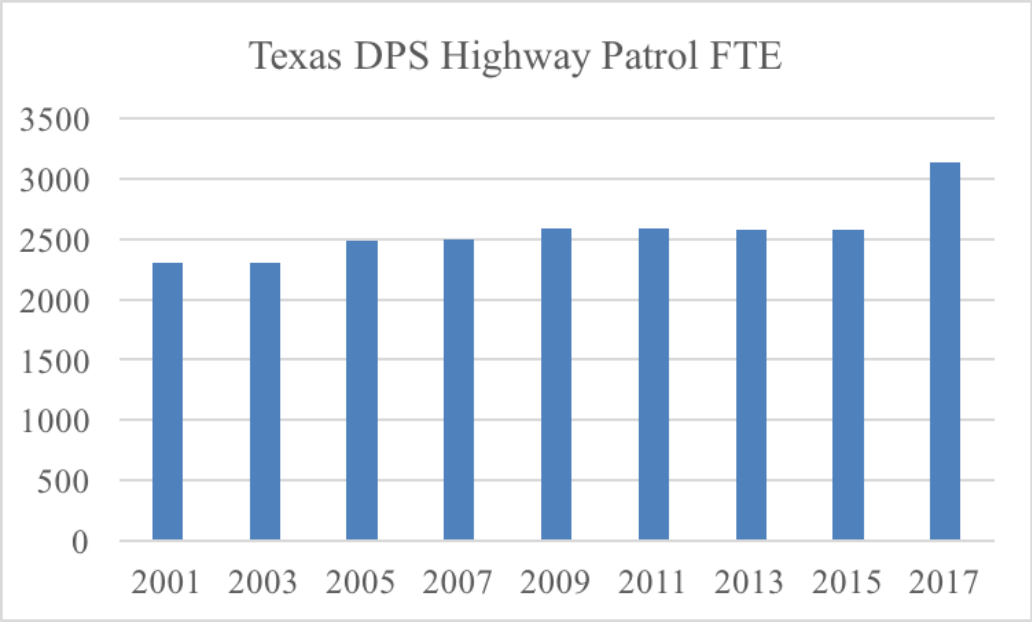

Figure 7: Texas DPS Highway Patrol FTE

Currently, there are 3193 FTE Highway Patrol Troopers with increases in the past couple of years attributed to border security initiatives (Figure 7). With recent border security initiatives, Region 3 boasts the most assigned Troopers with 740 FTE. Texas DPS Highway Patrol reports the Troopers per citizen in legislative reports to address coverage across the State. Not accounting for regional population differences, current coverage is at approximately one Trooper FTE per 9,143 citizens.

Texas DPS Troopers and other commissioned officers often work over 40 hours per week, and are currently under legislative mandate to work 50 hours per week. An hours-based occupational fatality rate was determined from 2001 through 2017. Total Highway Patrol FTE were reported in odd numbered years only. The average of the odd numbered years was used to estimate the FTE staffing for even numbered years in this

time period. Using standard hours-based occupational fatality rate calculations, occupation fields can be compared to each other. The average worker fatality rate for all U.S. workers for 2015 was 3.38 deaths per 100,000 FTE, as reported by the U.S. Bureau for Labor Statistics.[46] The occupation with the most occupational deaths in 2015 was observed in logging workers, with 132.7 deaths per 100,000 FTE.[46] Texas DPS Highway Patrol experienced 38.87 deaths per 100,000 FTE in 2015. This occupational fatality rate is more than ten times the national average for occupational fatalities.

Table 9: Hours-Based Fatality Rates for Texas DPS Highway Patrol 2001 - 2017

Year	THP FTE's	Deaths per year	Hours per year	FTE Annual Hours (estimated)	Death Rate per 100,000 FTE
2001	2305	1	2500	5762500	43.38
2002	2305.5	0	2500	5763750	0.00
2003	2306	0	2500	5765000	0.00
2004	2396.5	1	2500	5991250	41.73
2005	2487	1	2500	6217500	40.21
2006	2493.5	3	2500	6233750	120.31
2007	2500	1	2500	6250000	40.00
2008	2541.5	1	2500	6353750	39.35
2009	2583	0	2500	6457500	0.00
2010	2585	2	2500	6462500	77.37
2011	2587	0	2500	6467500	0.00
2012	2582	1	2500	6455000	38.73
2013	2577	0	2500	6442500	0.00
2014	2575	0	2500	6437500	0.00
2015	2573	1	2500	6432500	38.87
2016	2854.5	1	2500	7136250	35.03
2017	3136	0	2500	7840000	0.00

The occupational fatality rate for Texas Highway Patrol Troopers for the time period 2001 – 2017 was 30.29 deaths per 100,000 FTE, with a range of 35.03 deaths per 100,000 FTE to 120.31 deaths per 100,000 FTE for years in which deaths occurred (Table 9). When compared to occupational fields as opposed to occupations with high occupational fatality rates, Texas Highway Patrol experiences a higher than anticipated burden of deaths. Construction jobs experience an occupational fatality rate of 10.1 deaths per 100,000 FTE while agriculture, forestry, fishing and hunting jobs experience an occupational fatality rate of 22.8 deaths per 100,000 FTE.[46]

Identifying a comprehensive occupational fatality rate for police occupational fields using the U.S. Bureau for Labor Statistics occupational population for 2014 is challenging due to the ambiguity of available death information, and the use of part-time staff by some departments. The use of part-time staff without detailed information on the true hours worked can contribute to an artificially low fatality rate. To estimate a national police occupational fatality rate, death information from the Officer Down Memorial page and the U.S. Bureau for Labor Statistics was used. For 2014, the U.S. Bureau for Labor Statistics reported 106 deaths of law enforcement officers sustained in the line of duty; using a 50-hour work week, the occupational fatality rate would be 16.43 deaths per 100,000 FTE.[47] For 2014, the ODMP reported 150 deaths of officers sustained in the line of duty; using a 50-hour work week, the occupational fatality rate would be 23.25 deaths per 100,000 FTE.[11] Differences in these numbers result from reporting definitions. The Officer Down Memorial Page includes deaths from heart attacks sustained in the line of duty, for 2014 this included 20 such deaths. Assessing

occupational risk from a global perspective may not help a department identify and mitigate risk as much as a local approach. Further standardization of definitions may help develop a more reliable occupational fatality rate for this field.

Using current Texas DPS day and night shift hours, of 6 a.m. – 6 p.m. as day shift and 6 p.m. – 6 a.m. as night shift, the shift of death was determined in 75 cases (Figure 8). More deaths occurred during the night shift (n = 51) than during the day shift (n = 24). Traumatic injuries sustained at night have shown an increased correlation to adverse outcomes including death. In some, but not all cases an exact time of injury was available. Time of injury was determined from death certificates and supplemental reports on each case. For eleven cases, a time of injury could not be ascertained to assign a DPS Shift for this measure. Future studies should consider time as an important factor for trauma risk assessment. Fatigue may be a confounding factor relating to night shift injuries and deaths and warrants further review.

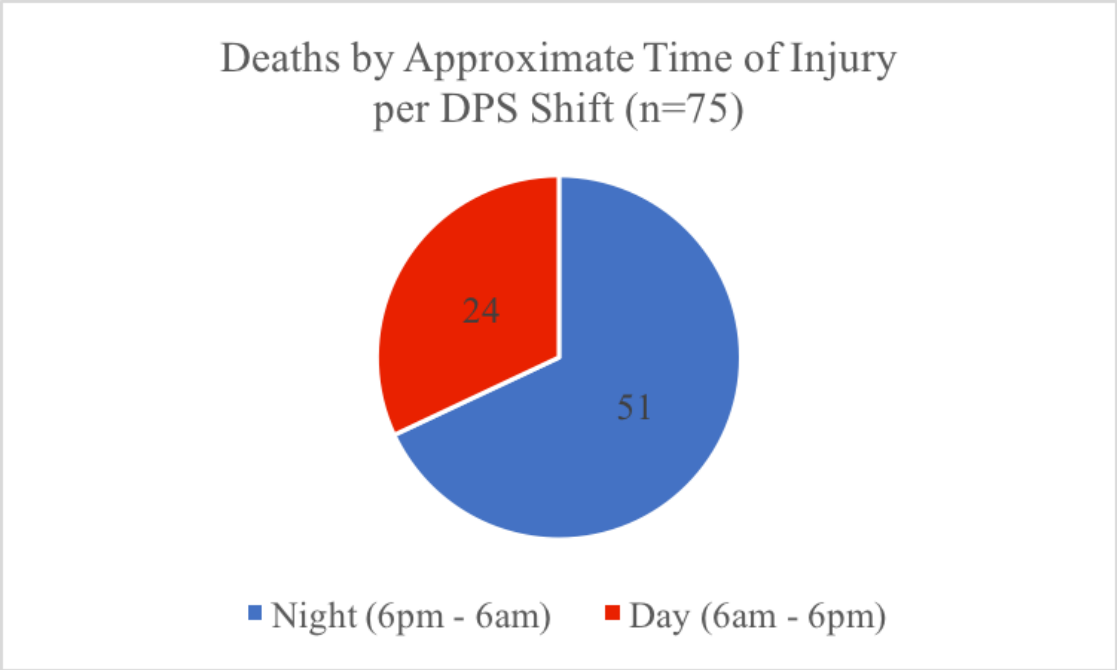

Figure 8: Death Occurrence by Approximate Time of Injury per DPS Shift

The frequency of death by day of the week does not show significant variation (Figure 9). Trends to have increased deaths occur on Friday, Saturday and Sunday would correlate to increased highway traffic and enforcement activities to due increases use of roadways and travel. As operational tempos have changed over time, this measure may have more value if repeated in a larger population. A fluctuating schedule to look at the day number in a series of a shift, for example shift number three in a series of 7 shifts may be more helpful for risk assessment and mitigation.

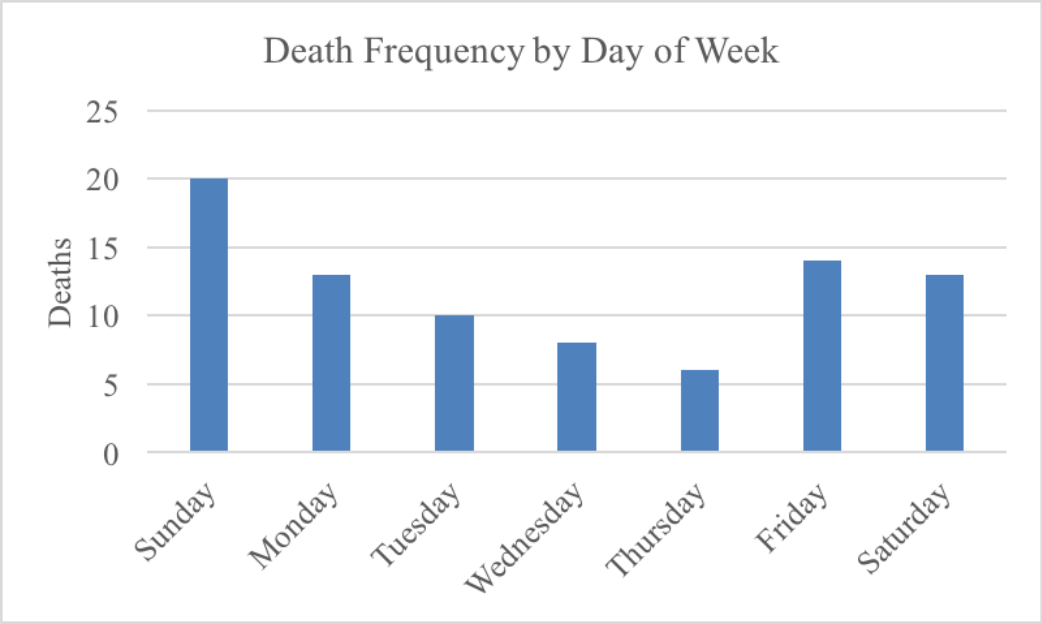

Figure 9: Death Frequency by Day of Week

April was the deadliest month (n = 17) for Texas Highway Patrol Troopers killed in the line of duty from traumatic injuries. April is a moderate traffic month with highly variable weather across Texas, but further consideration to this seasonality may be used by stakeholders to support mitigation planning. February (n = 2) and August (n = 2) were noted for the having the fewest deaths (Figure 10).

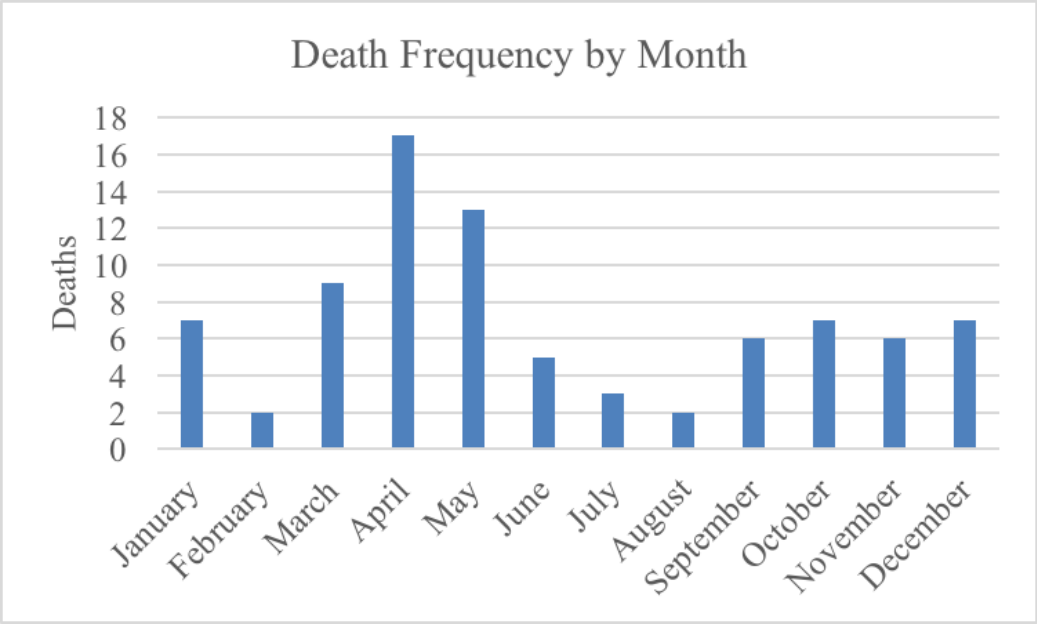

Figure 10: Death Frequency by Month

Deaths reviewed by decade indicate changing trends for the mechanism of injury (Figure 11). The primary mechanism of injury has changed over the years, and changes to reduce line of duty deaths and improve safety can be observed through these trends. Current trends indicate higher risk of death from automobile accident as opposed to death from gunfire. Using death as the only outcome measure will not fully address the risk of any adverse event.

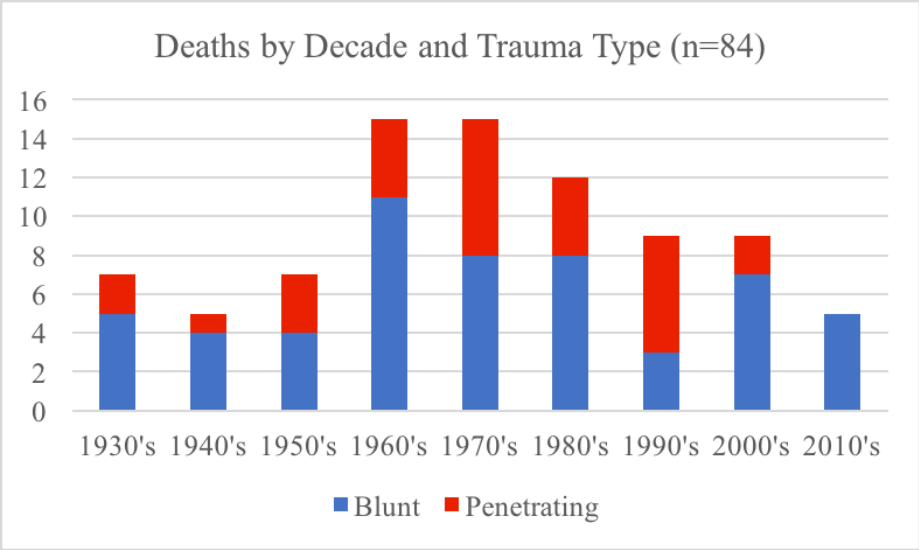

Figure 11: Deaths by Decade and Trauma Type

With the inception of the Highway Patrol as the primary law enforcement agency for Texas and the expanding highway system in 1929, the future Texas Department of Public Safety was created. In the 1930's, the leading mechanism of injury resulting in death was due to a motorcycle accident (n = 5). As motorcycles were phased out of operation, and then brought back in a different enforcement role, accounts for the decline of death resulting from motorcycle accidents. The use of additional equipment to perform expanded responsibilities caused a shift away from the heavy reliance on motorcycles towards automobiles, which could have contributed to the last death caused by a motorcycle accident in 1942. During the 1940's, the leading mechanism of injury resulting in death was due to automobile accidents (n = 3). During the 1950's, the leading mechanism of injury resulting in death was due to gunfire (n = 3), while struck by vehicle and automobile accidents resulted in two deaths each. During the 1960's the

leading mechanism of injury resulting in death was due to automobile accidents (n = 9) with two deaths resulting from being struck by a train. The development of railroad crossing guards in the 1960's may have contributed to reduced deaths from train accidents, as the last death caused by a train was in 1969.[48] During the 1970's the leading mechanism of injury resulting in death was due to gunfire (n = 9) with four deaths resulting from being struck by vehicle. During the 1980's the leading mechanism of injury resulting in death was due to automobile accidents (n = 5). During the 1990's the leading mechanism of injury resulting in death was due to gunfire (n = 6). The expanded use of bulletproof vests, including using vests that have both chest and back coverage may have contributed future decreases in death due to gunfire. In the 2000's, the primary mechanism of fatal injury resulting was due to automobile accidents (n = 5).

Epidemiology of traumatic deaths sustained in the line of duty for Texas DPS Highway Patrol Troopers can help assess risk, and identify opportunities for mitigation. Quantification of the injuries sustained provides an objective way to assess, score and prevent future deaths in an occupational environment. The use of the One Health paradigm to consider traumatic injuries in a holistic way will serve to develop an effective methodology for future review of law enforcement occupational fatalities in both human and canine populations.

In the last seven years, five line of duty deaths were sustained, and all resulted from automobile accidents in Crown Victoria vehicles. In the last 25 years, twelve deaths were due to automobile accidents. Of these deaths, ten involved Crown Victoria vehicles which are noted for poor lateral impact and rear-impact crash test ratings.[49] As

vehicle safety continually improves, vehicle use over time suggests the need for further analysis to address risk with consideration to operational priorities.

The use of a Haddon Matrix can help identify and address factors in three phases of a event to mitigate risk. The Haddon Matrix, was first developed in 1970 to address the complex risk of automobile accidents.[38,39] The Haddon Matrix is applied to high risk situations and events to allow identification and mitigation. Consideration to risk and mitigating factors before the event, during the event and following the event allow for a holistic risk mitigation effort.

		Factors			
Phase		**Human/Canine**	**Vehicles and Equiptment**	**Enviroment**	
				Physical	**Socio-Cultural**
Pre-Crash	Crash Prevention	Weather Fatigue	Vehicle Maintenance Speed Safety Rating	Road Design	Mindset/ Complacency Mitigation
Crash	Injury Mitigation at time of crash	Use of restraints	Crash Protection Safety Features	Road side crash protection	Focus
Post-Crash	Life Sustaining	Medical Self-Intervention (training and equipment) Care Follow Up	Fire Risk	Access for EMS Long Term Follow Up	Heroism and Culture of Safety

Figure 12: Haddon Matrix for Line of Duty Automobile Accident Risk[38,39]

This is complimentary to a One Health approach and address both physical and socio-cultural environmental factors. Through the identification of risk factors relating to the two primary mechanisms of injury resulting in Texas DPS Highway Patrol Trooper

deaths, a Haddon Matrix was created for automobile accidents (Figure 12) and risk of gunfire (Figure 13). In both cases, socio-cultural factors including complacently, and heroism could be risk factors. Lack of awareness of surroundings and impeded judgement should be heavily considered by a department to address risk; this consideration is not addressed in this dissertation other than to identify a police operation focused discussion should be considered by departments when addressing occupational fatalities and line of duty deaths.

		Factors			
Phase		**Human/Canine**	**Weapon and Assailant**	**Enviroment**	
				Physical	**Socio-Cultural**
Pre-Event	Event Prevention	Training Vest Compliance	Vehicle Positioning Wait for Return on Violator Request for another unit Situational Awareness	Bullet-proof windows and vehicle body	Mindset/ Complacency Mitigation
Event	Injury Mitigation during the event	Medical Self-Intervention (training and equipment)	Appropriate action Securing weapons Terry Frisk	Access for Backup	Focus
Post-Event	Life Sustaining	Care Follow Up	Suspect Control and Apprehension	Access for EMS Long Term Follow Up	Heroism and Culture of Safety

Figure 13: Haddon Matrix for Line of Duty Gunfire Risk[38,39]

The Heinrich risk triangle - representation of automobile accidents suggesting that frequency and severity are related.[23] How to address risk levels and data collection

for law enforcement in a prospective way. To further assess risk, a comprehensive denominator must be determined for rate assessment and monitoring over time. The total risk assessment would include all drivers with a quantification to miles driven per time unit. Texas DPS Troopers have a responsibility to patrol the highways of Texas and encourage voluntary compliance with both state and federal laws. All driving poses a risk, and can be described using a risk hierarchy to include the total population of consideration (Figure 14). Efforts to reduce the frequency of high-risk events will reduce the occurrence of adverse outcomes from these events.

Figure 14: Risk Hierarchy for Texas DPS Line of Duty Automobile Accidents

Occupational Health Risk Assessment has been largely driven by high risk, high consequence occupations. The International Council on Mining and Metals has developed the *Good Practice Guidance on Occupational Health Risk Assessment* to assist in quantifying risk and the adequacy of available or currently implemented control measures.[50] This assessment assigns a risk rating score by finding the product of four scores – consequence, probability of exposure, period of exposure and uncertainty (Figure 15).

Figure 15: Risk Rating for Occupational Risk[50]

Using the ICMM assessment of existing control measures for identified risk, a risk rating was determined for both risk of injury from Texas DPS Line of Duty automobile accidents and gunfire. Injury resulting from automobile accident resulted in a risk rating of 3000. This risk rating suggests the risk rating is intolerable per the ICMM guidelines. While the risk categories were developed for the mining industry to assess and reduce occupational risk, this is an important future consideration. In using the same formula to assess the risk of injury resulting from gunfire, the risk rating was 150. This

risk rating suggests this is a high risk and mitigation should be addressed without delay. These two scores suggest risk quantification that complements the injury severity score pattern between blunt and penetrating trauma in that risk mitigation and injury prevention of automobile accidents should be a priority.

CHAPTER V

DISCUSSION AND CONCLUSION

Risk assessment, risk mitigation, and hazard reduction should be addressed in a comprehensive method to incorporate low frequency and high consequence events in the law enforcement population. Further risk assessment and analysis is warranted and can be addressed in a follow-up study and department partnership through the identification of gaps in knowledge this study revealed.

Discussion – Mechanism of Injury: Automobile Accident

This study suggests that efforts to reduce the risk of automobile accidents may be more difficult to achieve – but would have the greatest impact towards improving survivability and reducing line of duty deaths. Pre-event risk mitigation should be addressed at a department level for automobile accidents. Considerations for future vehicle choice should review historical crash impacts with analysis of fatal events, injury events and near-miss events. This extended review would identify location of impact and allow for improved knowledge operational risk for fleet purchasing. While Texas DPS Highway Patrol is expanding their fleet with an increasing FTE commissioned force, some high-mileage, older Crown Victoria's remain operational in this fleet. With disappointing lateral impact crash ratings in the Crown Victoria, a lateral impact risk would be a key focus of future studies to mitigate risk from automobile accidents. Review of recent, average hours worked prior to a fatal, injury or near-miss automobile event would be one consideration to review fatigued driving. While this study did not

have the information available to address fatigue on systematic level, a couple of cases were highly suspect that fatigue may have been a contributing factor to the event. The hour of a shift, for example, eight hours into a ten-hour shift, in which the accident occurs may be just as important a consideration as time of day in further risk studies.

Age and years of service are lower for Troopers that died in the line of duty from blunt trauma, with a majority of deaths due to automobile accidents. Departmental consideration to Trooper risk aversion, driving experience and eagerness to contact violators may help identify opportunities to improve driver safety compliance even in extreme tactical driving situations.

Vehicle selection may include automatic sensor information for seatbelt use, and routine compliance awareness at a local DPS level. Seatbelt information was sought, but not available. Based on some sustained injuries and historical cases in which seatbelts were not available, some injuries may have been mitigated or prevented with the use of a seatbelt. Automatic crash notification to departmental communications could aid in more prompt initiation of emergency medical service activation, response and arrival on scene. This automatic notification would be most helpful in incapacitating crashes where a driver may not be able to make a request for assistance. Texas DPS Highway Patrol has a significant response responsibility in rural and remote areas, and may not have an accident noticed for a significant time. In earlier cases, some were noted to have been found by passerby's well after last radio contact. Research has shown an increased mortality in trauma sustained in rural counties possibly due to distance from care and

efforts to address rural trauma care from an occupational health perspective may offer one avenue for improved survivability.[51]

Forward thinking considerations to autonomously driven vehicles should be acknowledged as for occupational injury and death prevention, not only for law enforcement occupations. Due to the complex, high-risk and dynamic driving that law enforcement officers are required to engage in on a routine basis, routine driving algorithms may not apply as easily for this kind of tactical driving. As autonomous driving becomes commonplace, considerations for to promote voluntary or managed compliance with the law for routine drivers may reduce some need for law enforcement officers to engage in high-risk operational driving as frequently.

Discussion – Mechanism of Injury: Gunfire

Medical intervention training would offer the greatest impact for improved survivability for penetrating trauma injuries. Troopers that died from penetrating injuries were more likely to be older and have more experience than those dying from blunt injuries. A comprehensive review of bulletproof vest compliance may identify opportunities for risk mitigation. Bulletproof vests are known to be uncomfortable, hot and often not worn. Texas DPS policy indicates that bulletproof vests must be worn during any enforcement action unless the situation does not allow for the vest to be worn. Despite vest compliance, severe injuries may be sustained from gunfire a bulletproof vest may not mitigate. In these cases, longitudinal monitoring should be initiated at a department and national level for fatal, injury and near-miss events. Gunfire

injury pattern analysis can improve training opportunities and post-event intervention efforts.

In many line of duty deaths or severe injury events, an officer is heralded a hero. This sentiment should not be forgotten, but further effort to post-event review and training could benefit departments not engaging in this type of review. Critical competencies and compliance for weapon check on violators and situational awareness must be addressed as learning points.

Strengths

The primary strength of this study is to identify knowledge gaps in addressing risk and burden of line of duty deaths for law enforcement officers. Identification of occupational hazards resulting in potentially fatal injuries with respect to the environment allows for a department focused assessment accounting for operational, geographical and temporal trends. Texas DPS Highway Patrol serves a large population over a diverse and spacious geography.

The use of the One Health perspective and holistic approach to risk identification incorporates a variety of perspectives and disciplines to more fully assess the risks to officers and the opportunities for risk mitigation pre-event and post-event. Using injury severity scores to assess sustained trauma can allow for improved injury prevention efforts and operational decision making to be more informed of historical risk.

It is essential to review officer line of duty deaths and occupational fatalities to identify opportunities to minimize injury severity or prevent future deaths. This study starts a conversation for law enforcement departments to further review department risk,

and calls for larger review of law enforcement fatalities in an injury prevention perspective. Compliance and complacency may have been contributing factors in some of the reviewed deaths; department operational review and longitudinal monitoring would be essential to addressing potential compliance and complacency concerns early.

Limitations

The most significant limitation of this study is the lack of broad generalizability of the findings beyond the highly-specified population studied. Alternatively, a review of each of the interventions that may demonstrate a benefit to each case could be developed and then summarized to demonstrate the type of interventions that could mitigate law enforcement officer line of duty deaths.

Despite limitations in working with rare-event data sets, this methodology can be expanded to a larger law enforcement population once the systematic approach is established. The potential for inconsistent data due to the large study period and the variety of reporting quality could represent a limitation, but efforts to reduce this limitation can be address through consistency in chart review and addressing missing data in the analysis. While the Texas Department of Public Safety has not experienced any line of duty canine fatalities, limiting an anatomical injury review of this species, considerations will be made for inclusion, as canines are law enforcement officers subject to similar risks as their human counterparts.

Working dog fatality information are limited by rare-event data sets and jurisdictional procedures relating to death. Future studies should consider a canine line

of duty death in any officer safety risk assessment and planning using the same methodologies for human officers due to same exposure profile.

While risk assessment studies are limited by confounding factors and lack of quantified extrapolation, this is an essential first step towards later research to quantify risk and expand methods to a larger population.

Conclusion

Overall, this methodology incorporates epidemiology, trauma, occupational health and risk mitigation to identify opportunities for system improvement to keep officers going home. Improving survivability for officers in the line of duty must consider the primary injuries sustained for each risk. Improved vehicle safety, operational engagement and providing medical training and equipment could together mitigate risk for officers in the line of duty. It is concerning that the occupational fatality rates exceed national averages for all occupational fields as well as exceed national average for all police. However, the changing trends in death rate are a testament to the work done by the Texas Department of Public safety to adapt to an ever-changing risk profile. The implementation of side of the road commercial vehicle enforcement stations has likely helped to reduce deaths from officers struck by vehicles, especially by commercial vehicles and tractor trailers.

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Case Number	Cause	Blunt/ Penetrating	Autopsy Ordered	PS/NS	Major or Most Significant Body Region	ISS Score
7*	Automobile accident	Blunt	YES	PS	Thorax	59
45	Automobile accident	Blunt	NO	PS	Head and Neck Thorax	
46	Automobile accident	Blunt	NO	PS	Head and Neck Thorax	
55	Automobile accident	Blunt	NO	PS	Head and Neck	
73	Automobile accident	Blunt	NO	PS	Indeterminate	
75	Automobile accident	Blunt	Unknown	PS	Thorax	
1	Automobile accident	Blunt	YES	NS	Head and Neck	75
2	Automobile accident	Blunt	YES	NS	Head and Neck	75
3	Automobile accident	Blunt	YES	NS	External and Other	75
4*	Automobile accident	Blunt	YES	NS	Thorax	50
5*	Automobile accident	Blunt	YES	NS	Thorax	66
9	Automobile accident	Blunt	Unknown	NS	Head and Neck	
12	Automobile accident	Blunt	YES	NS	Thorax	75
13*	Automobile accident	Blunt	YES	NS	Head and Neck	75
16	Automobile accident	Blunt	Unknown	NS	Head and Neck	75
59	Automobile accident	Blunt	NO	NS	Head and Neck	
61	Automobile accident	Blunt	YES	NS	Head and Neck	75
8	Automobile accident	Blunt	Unknown	Indeterminate	Indeterminate	
17*	Automobile accident	Blunt	Unknown	Indeterminate	Thorax	
23	Automobile accident	Blunt	Unknown	Indeterminate	Indeterminate	
36	Automobile accident	Blunt	YES	Indeterminate	Head and Neck Thorax	
56	Automobile accident	Blunt	NO	Indeterminate	Head and Neck	
58	Automobile accident	Blunt	NO	Indeterminate	Head and Neck	
60	Automobile accident	Blunt	NO	Indeterminate	Indeterminate	
65	Automobile accident	Blunt	NO	Indeterminate	Head and Neck	
74	Automobile accident	Blunt	NO	Indeterminate	Indeterminate	

Case Number	Cause	Blunt/ Penetrating	Autopsy Ordered	PS/NS	Major or Most Significant Body Region	ISS Score
14*	Gunfire	Penetrating	YES	PS	Head and Neck	25
20*	Gunfire	Penetrating	YES	PS	Head and Neck	19
21*	Gunfire	Penetrating	YES	PS	Thorax	25
39	Gunfire	Penetrating	YES	PS	Thorax	
52	Gunfire	Penetrating	YES	PS	Thorax	
53	Gunfire	Penetrating	YES	PS	Thorax	
62	Gunfire	Penetrating	YES	PS	Thorax	
66	Gunfire	Penetrating	NO	PS	Abdomen	
70	Gunfire	Penetrating	NO	PS	Head and Neck Thorax	
72	Gunfire	Penetrating	NO	PS	Thorax	
81	Gunfire	Penetrating	Unknown	PS	Thorax Extremities	
82	Gunfire	Penetrating	Unknown	PS	Thorax External and Other	
15	Gunfire	Penetrating	YES	NS	Head and Neck	
6*	Gunfire	Penetrating	Unknown	Indeterminate	Head and Neck	
18	Gunfire	Penetrating	Unknown	Indeterminate	Head and Neck	
19	Gunfire	Penetrating	Unknown	Indeterminate	Indeterminate	
22*	Gunfire	Penetrating	Unknown	Indeterminate	Head and Neck	
27*	Gunfire	Penetrating	Unknown	Indeterminate	Thorax	
32	Gunfire	Penetrating	YES	Indeterminate	Head and Neck	
35	Gunfire	Penetrating	YES	Indeterminate	Head and Neck	
37	Gunfire	Penetrating	YES	Indeterminate	Thorax	
41	Gunfire	Penetrating	Unknown	Indeterminate	Thorax Abdomen	
42	Gunfire	Penetrating	YES	Indeterminate	Head and Neck Thorax	

Case Number	Cause	Blunt/ Penetrating	Autopsy Ordered	PS/NS	Major or Most Significant Body Region	ISS Score
48	Gunfire	Penetrating	NO	Indeterminate	Thorax	
57	Gunfire	Penetrating	YES	Indeterminate	Indeterminate	
28*	Gunfire (Accidental)	Penetrating	Unknown	PS	Thorax	26
47	Gunfire (Accidental)	Penetrating	YES	PS	Thorax Abdomen	51
76	Motorcycle accident	Blunt	Unknown	PS	Head and Neck	
78	Motorcycle accident	Blunt	Unknown	Indeterminate	Indeterminate	
79	Motorcycle accident	Blunt	Unknown	Indeterminate	Head and Neck	
80	Motorcycle accident	Blunt	Unknown	Indeterminate	Indeterminate	
83	Motorcycle accident	Blunt	NO	Indeterminate	Thorax	
84	Motorcycle accident	Blunt	Unknown	Indeterminate	Head and Neck	
54	Struck by train	Blunt	Unknown	NS	Thorax	
64	Struck by train	Blunt	NO	NS	Head and Neck	
10	Struck by vehicle	Blunt	YES	NS	Head and Neck	75
26	Struck by vehicle	Blunt	Unknown	Indeterminate	Indeterminate	
30	Struck by vehicle	Blunt	Unknown	Indeterminate	Indeterminate	
33	Struck by vehicle	Blunt	NO	Indeterminate	Head and Neck	
40	Struck by vehicle	Blunt	NO	Indeterminate	Indeterminate	
43	Struck by vehicle	Blunt	NO	Indeterminate	Head and Neck Thorax	
44	Struck by vehicle	Blunt	NO	Indeterminate	Head and Neck	
50	Struck by vehicle	Blunt	NO	Indeterminate	Head and Neck Abdomen Extremities	
67	Struck by vehicle	Blunt	NO	Indeterminate	Head and Neck	
71	Struck by vehicle	Blunt	NO	Indeterminate	Indeterminate	
11*	Training accident	Blunt	YES	PS	Head and Neck	16

Case Number	Cause	Blunt/ Penetrating	Autopsy Ordered	PS/NS	Major or Most Significant Body Region	ISS Score
38	Vehicle pursuit	Blunt	YES	PS	Head and Neck	
63	Vehicle pursuit	Blunt	NO	NS	Indeterminate	
34	Vehicle pursuit	Blunt	NO	Indeterminate	Indeterminate	
68	Vehicle pursuit	Blunt	Unknown	Indeterminate	Indeterminate	
69	Vehicle pursuit	Blunt	NO	Indeterminate	Head and Neck	
24*	Vehicular assault	Blunt	YES	PS	Head and Neck	29
25	Vehicular assault	Blunt	YES	NS	Thorax	75
51	Vehicular assault	Blunt	NO	NS	Head and Neck	
29	Vehicular assault	Blunt	Unknown	Indeterminate	Head and Neck Thorax	
31	Vehicular assault	Blunt	Unknown	Indeterminate	Indeterminate	
49	Vehicular assault	Blunt	NO	Indeterminate	Head and Neck	
77	Weather/Natural disaster	Penetrating	Unknown	NS	External and Other	

Cases numbers notated with an asterisk * were reviewed by UT Health Committee Consensus.