The Burden of Traumatic Injury: Evidence from a Trauma Hospital in Port-au-Prince, Haiti

Ph.D. Thesis Written by Christopher Zuraik

Supervisor: Dr. John S. Sampalis

Department of Experimental Surgery, Faculty of Medicine
McGill University
Montreal, Canada

Submitted: December 2017

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree Ph.D. Experimental Surgery

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Abstract (English)

Introduction: Haiti is currently facing a public health crisis, exacerbated by the lack of pre- and in-hospital care, as well as a spike in injuries due to trauma. The Bernard Mevs Hospital Project Medishare (HBMPM) is the only critical and trauma care hospital in the entire nation; thus significantly limiting access to critical care for the injured. Little is known about the epidemiology and growing burden of trauma-related disease in Haiti, as there is no formal injury surveillance system or trauma registry. The objectives of this thesis are four-fold: To describe the epidemiology of traumatic injuries; to determine the economic and social burden of disease; to conduct a cost-effective analysis of implementing better traffic enforcement; and to conduct a cost-effective analysis of trauma care.

Methods: This retrospective, hospital-based, cross sectional chart review study was conducted for the period December 1, 2015 to January 31, 2016, at HBMPM, located in the capital city of Port-au-Prince, Haiti. All patients presenting for evaluation and treatment of traumatic injuries during the study period were eligible for inclusion. Data were obtained through review of the hospital's main patient logbook, patient medical charts, and trauma registry forms. Costs were calculated using the human capital approach, measured from the patient's perspective. Costs were divided into three sections: direct medical costs, indirect costs, and intangible costs. Direct medical costs were retrieved from patient hospital bills. Indirect costs consist of each individual's lost productivity and ability to work. For the loss of productivity for a fatal injury, the sum of each future year's lost output was estimated. Intangible costs were estimated as 28% of total lost income. In order to model the cost-effectiveness of improved traffic enforcement, the Bishai and Hyder model was used, adapted to the Haitian setting with a government perspective. In order to model the cost-effectiveness of a trauma center in Port-au-Prince, Haiti, the McCord and Chowdhury method was used, with simplified estimates of risk of death or permanent disability, and effectiveness of treatment.

Results: A total of 410 patients were evaluated for treatment of traumatic injuries during the 2-month study. The mean age in years was 30, with 66.3% male and 78.4% less than 41 years of age. There were 6.6 injuries per day and no correlation between frequency of injury and day of the week. Road traffic accidents accounted for 43.0% of trauma modes. The mean (median) length of stay 6.6 (3.0) days. 9.0% of patients suffered severe trauma and 21.0% suffered severe traumatic brain injury. 22.7% of patients were admitted, and 15.1% patients underwent at least one surgical procedure. Total costs for all patients were $501,706 with a mean cost of $1,224. Direct medical costs represented 19% of all costs, indirect costs 63%, and intangible costs 18%. Surgical costs accounted for the majority of direct medical costs (29%). Patients involved in road traffic accidents accounted for the largest percentage of total costs (51%). Patients with gunshot wounds had the highest mean costs ($1,556). Mean costs by injury severity ranged from $62 for minor injuries, $1,269 for serious injuries, and $13,675 for critical injuries. Assuming an intervention of increased traffic enforcement reduces mortality and permanent disability by 25% at a 1:1 ratio, an estimated 3,313 DALY's are saved per million persons per year. Given an estimated total cost of $32,316 for traffic enforcement for this intervention, the cost per death averted is $539. The cost per DALY saved ranges from $10 to $39 per DALY saved. With regards to the cost-effectiveness of a trauma center, during the study period, an estimated 1,605 DALYs were incurred by trauma patients. An estimated 565 DALYs were averted due to care provided by HBMPM. Variable and fixed cost totaled $135,897 during the 2-month period. Cost per DALY averted calculations indicate that $241 are spent per DALY averted. Based on the WHO threshold, both traffic enforcement and trauma care interventions are highly cost-effective.

Conclusion: Injuries lead to a significant economic burden to individuals in Haiti. Medical record documentation was variable, and trauma registry forms were seldom used. Interventions aimed at improving documentation and trauma surveillance to better define the burden of trauma are needed. Programs aimed at reducing injuries, particularly road traffic accidents, would likely reduce the economic burden to the nation. Interventions aimed at providing critical and trauma care are highly cost-effective.

Abstract (French)

Introduction: Haïti est actuellement confronté à une crise de santé publique, exacerbée par le manque de soins pré-hospitaliers et hospitaliers, ainsi que par une hausse de traumatismes. L'hôpital *Bernard Mevs Hospital Project Medishare* (HBMPM) est le seul hôpital de soins critiques et de traumatologie de toute la nation, limitant ainsi considérablement l'accès aux soins critiques pour les blessés. On en sait peu sur l'épidémiologie et le fardeau croissant des maladies liées aux traumatismes en Haïti, car il n'existe pas de système officiel de surveillance des traumatismes ni de registre des traumatismes. Les objectifs de cette thèse sont de quatre ordres: décrire l'épidémiologie des traumatismes; déterminer le fardeau économique et social des maladies; effectuer une évaluation médico-économique de la mise en œuvre d'une meilleure surveillance routière; et effectuer une évaluation médico-économique des soins de traumatologie.

Méthodes: Cette étude rétrospective, transversale, en milieu hospitalier, a été réalisée du 1er décembre 2015 au 31 janvier 2016, à la HBMPM, située dans la capitale, Port-au-Prince, en Haïti. Tous les patients se présentant pour l'évaluation et le traitement des blessures traumatiques pendant la période d'étude étaient admissibles à l'inclusion. Les données ont été obtenues grâce à l'examen du principal registre des patients de l'hôpital, des dossiers médicaux des patients et des formulaires de registre des traumatismes. Les coûts ont été calculés en utilisant la méthode du capital humain, mesurés du point de vue du patient. Les coûts ont été répartis en trois sections: les coûts médicaux directs, les coûts indirects et les coûts intangibles. Les coûts médicaux directs ont été récupérés à partir des factures d'hospitalisation des patients. Les coûts indirects comprenaient la perte de productivité et la capacité de travailler de chaque individu. Pour la perte de productivité pour une blessure mortelle, la somme de la production perdue de chaque année future a été estimée. Les coûts intangibles ont été estimés à 28% du total des pertes de revenus. Afin de modéliser le rapport coût-efficacité de l'amélioration de la surveillance routière, le modèle de *Bishai and Hyder* a été utilisé, adapté au contexte haïtien, et ayant une perspective gouvernementale. Afin de modéliser le rapport coût-efficacité d'un centre de traumatologie à Port-au-Prince, Haïti, la méthode McCord et Chowdhury a été utilisée, en appliquant des estimations simplifiées du risque de décès ou d'invalidité permanente, et de l'efficacité du traitement.

Résultats: Un total de 410 patients ont été évalués pour le traitement des blessures traumatiques au cours de l'étude de 2 mois. L'âge moyen était de 30 ans ; la majorité des patients identifiés étaient mâle (66,3%) et moins de 41 ans (78.4%). Cet étude a identifié 6,6 blessures par jour et aucune corrélation entre la fréquence des blessures et le jour de la semaine. Les accidents de la route représentaient 43,0% des traumatismes. La durée moyenne (médiane) d'hospitalisation était de 6,6 (3,0) jours. 9,0% des patients ont subi un traumatisme grave et 21,0% ont subi une lésion cérébrale traumatique sévère. 22,7% des patients ont été admis en hôpital, et 15,1% des patients ont subi au moins une intervention chirurgicale. Les coûts totaux pour tous les patients étaient de 501 706 $ avec un coût moyen par patient de 1 224 $. Les coûts médicaux directs représentaient 19% de tous les coûts, les coûts indirects 63% et les coûts intangibles 18%. Les coûts chirurgicaux représentaient la majorité des coûts médicaux directs (29%). Les patients impliqués dans les accidents de la route représentaient le pourcentage le plus élevé des coûts totaux (51%). Les patients avec des blessures par balle ont eu les coûts moyens les plus élevés (1 556 $). Les coûts moyens selon la gravité des blessures variaient de 62 $ pour les blessures mineures, de 1 269 $ pour les blessures graves et de 13 675 $ pour les blessures critiques. En supposant que l'augmentation de la surveillance routière réduira la mortalité et l'incapacité permanente de 25% à un ratio de 1:1, on estime que 3 313 *disability-adjusted life years* (DALY) sont épargnées par million de personnes par année. Compte tenu du coût total associé au renforcement de cette augmentation de surveillance routière, estimé à 32 316 $, le coût par décès évité serais de 539 $. Le coût par DALY épargné variera de 10 $ à 39 $ par DALY épargné. En ce qui concerne la rentabilité d'un centre de traumatologie, au cours de la période d'étude, environ 1 605 DALY ont été encourues par des patients admis. On estime que 565 DALYs ont été évitées grâce aux soins prodigués par le HBMPM. Les coûts variables et fixes ont totalisé 135 897 $ au cours de la période de deux mois. Le coût

par DALY évité calculs indique que 241 $ sont dépensés par DALY évitée. Sur la base du seuil du WHO, les interventions en surveillance routière, et les interventions en centre de traumatologie, sont tous deux très rentables.

Conclusion: Les blessures entraînent un fardeau économique important pour les personnes traitées dans un hôpital semi-privé à Port-au-Prince, en Haïti. La qualité de l'information au dossier médical était variable et les formulaires du registre des traumatismes étaient rarement utilisés. Des interventions visant à améliorer la documentation et la surveillance des traumatismes afin de mieux définir le fardeau des traumatismes sont nécessaires. Les programmes visant à réduire les blessures, en particulier les accidents de la circulation, réduiraient probablement le fardeau économique de la nation. Les interventions visant à fournir des soins critiques et de traumatologie sont très rentables.

Acknowledgements

Dr. John S. Sampalis: As a supervisor and mentor, has provided continued support at every stage of the project. Dr. Sampalis has provided guidance for the study design, analysis of the data, and the preparation of the thesis.

Dr. Lisbet Haglund: As a chairperson, has provided support in the organizational aspects of the project as well as invaluable feedback and direction.

Dr. Tarek Razek: As a research advisory committee member, has provided expertise in trauma care and invaluable feedback on research direction.

Dr. Dan Deckelbaum: As a research advisory committee member, has provided expertise in trauma care and invaluable feedback on research direction.

Dr. Moishe Lieberman: As a research advisory committee member, has provided expertise in trauma care and invaluable feedback on research direction.

Dr. Jacques Lapointe: As a member of the comprehensive examination committee, has provided expertise and invaluable feedback and direction.

Dr. Jerry Bitar: As Director and Lead Surgeon at Hospital Bernard Mevs Project Medishare, has allowed this research possible by providing access to hospital staff and documents.

Dr. Marlon Bitar: As Director and Lead Surgeon at Hospital Bernard Mevs Project Medishare, has allowed this research possible by providing access to hospital staff and documents.

Dr. Joanne Cherry: As Chief Medical Officer at Hospital Bernard Mevs Project Medishare, has allowed this research possible by providing access to hospital staff and documents.

Dr. Patrick Chatelain: As a Medical Resident at Hospital Bernard Mevs Project Medishare, has contributed significantly in data collection.

Alexa Brierre: As Administrator at Hospital Bernard Mevs Project Medishare, has contributed significantly in data collection.

Roselaine Carre: As Chief Medical Records Officer at Hospital Bernard Mevs Project Medishare, has contributed in the organization of the collection of data.

Preface

I, Christopher Zuraik, have solely authored the chapters of this thesis, under the supervision and guidance of the thesis supervisor, Dr. John Sampalis.

There are numerous elements of the thesis that are considered original scholarship and that contribute to the advancement of knowledge. The following points are a summary of key advancements:

- First study conducted on traumatic injuries in an urban setting in Haiti
- First study assessing the outcomes of injured patients, particularly injury severity scores in Haiti
- First cost of illness study conducted on traumatic injuries in Haiti
- First cost-effectiveness study for traffic enforcement conducted in Haiti
- First cost-effectiveness study of a semi-private, premier trauma center in Haiti

This study provides much needed epidemiological data that can help determine and prioritize possible health interventions. This study also provides insight on conducting health economic assessments in trauma care in a developing country that is currently in crisis. This thesis is highly significant in guiding Haiti towards implementation of a feasible and optimal reform for trauma care.

1. Introduction

1.1 Background

The 2010 Haitian Earthquake dealt the final blow to already deteriorating state institutions. The Haitian public health system, which was already in abysmal state before the earthquake, was left in complete turmoil following the collapse of most major hospitals and the death of countless trained health professionals. It is estimated that over 250,000 people died from the earthquake due to various injuries, as the lack of any organized emergency trauma care system exacerbated the situation. Although Haiti is transitioning from the emergency stage to the reconstruction stage, it is imperative that reforms of the health care system are identified as a priority. With competing priorities for reconstruction, it is crucial to address the growing burden of trauma-related morbidity and mortality in Haiti and the developing world.

1.2 Implications

Injuries due to trauma continue to rise due to poor road infrastructure, the lack of road safety enforcement, interpersonal violence, and inadequate pre- and in-hospital trauma care. Currently, the Bernard Mevs Hospital Project Medishare (HBMPM) is the only trauma critical care and rehabilitation hospital in the entire nation; thus significantly limiting access to critical care for the injured. HBMPM currently operates as a level II trauma center, as Haiti does not have a level I center on the island. At the present time, trauma care in Haiti is not organized at any level. In addition, given the paucity of resources it is unlikely that a regionalized trauma care system will be established within the short term. However, injuries, and in particular motor vehicle accidents, continue to present a major cause of burden of illness and remains a disease that is not well understood from the epidemiological, preventive, and health services perspective. In addition, there are no indicators to determine the cost-effectiveness of and hence priority ranking of possible interventions that can reduce the burden of illness due to traumatic injuries in Haiti. The current study will address this knowledge gap. This study will be the first study assessing the epidemiology and outcomes of patients injured in traumatic accidents in Port-au-Prince, Haiti that also assesses the potential impact of possible interventions, while considering regional factors that can affect feasibility. The impact of the study will be highly significant in guiding Haiti towards

implementation of a feasible and optimal reform for trauma care in this country. Health-economic assessment of trauma care remains controversial and the current study will provide insight on conducting these types of studies in trauma and in a developing country that is currently in crisis. The use of health-economic models to define achievable interventions in a society with minimal resources is also unique about the current study. This thesis has four primary objectives: To describe the epidemiology of traumatic injuries, to determine the economic and social burden of disease of traumatic injuries, to conduct a cost-effective analysis of implementing better traffic enforcement, and to conduct a cost-effective analysis of a trauma center in Port-au-Prince, Haiti.

1.3 Study Rationale

Haiti, the poorest country in the western hemisphere, has been marred with political instability and a host of environmental disasters since gaining independence in 1804 from France. What has become clear is that the Haitian people have long been neglected by their leaders and by the international community. Far too often, the politics of prevention and safety measures have lagged behind, and the state has been unable to respond to emerging crises such as the earthquake in 2010, the following cholera epidemic in 2011, the threat of Zika Virus in 2015, and more recently, a devastating hurricane Matthew that claimed more than 10,000 lives. With competing interests, trauma-care is seldom identified as a priority.

In the immediate aftermath of the 2010 Haitian earthquake, it became quite clear that the health system was unable to accompany tens of thousands of injured people. With the majority of hospitals damaged and scores of health professionals missing or deceased, victims of the earthquake had no hope for quality care. I spent two months volunteering at the Haitian Community Hospital in the capital city of Port-au-Prince following the earthquake. From the hospital gates all the way to the hospital doors (about one kilometer of distance), patients had set up their makeshift tents and mattresses in order to receive care. The sheer number of patients was overwhelming. Inside the hospital, matters were worse. At a minimum, a dozen or more patients shared a room intended to host two patients. The halls of the hospitals were lined up with patients, and navigating these halls became increasingly difficult with each passing day.

The Haitian Community Hospital was divided into two sections. The ground floor was the basis for care for the injured, and the top floor served as the administration, where personnel would regroup and sleep (barely), and where medical supplies were kept. I was originally tasked with assisting foreign personnel in navigating the hospital grounds, but my role grew significantly to include the following: acting as the liaison between patients and foreign doctors who did not speak the local language, identifying patients who needed immediate medical attention, assisting surgeons in the operating rooms, transporting patients from the operating rooms to post-operative care to beds (if available), providing care to post-surgical patients by replacing and renewing wound bandages and replacing intravenous fluids, collecting consent forms from patients undergoing amputations, and carrying the deceased outside the hospital to be claimed by family members. The most common injuries seen were undoubtedly orthopedic injuries. Amputations were frequent. Most who arrived days or weeks late and had severe injuries, especially head, spinal, and thoracic trauma, did not survive. Below are a few observations that are worth sharing:

An eager surgeon. Various personnel from various backgrounds worked tirelessly, day and night, with one goal in mind: providing the best available care in an attempt to save lives and improve outcomes. The hospital was flooded with all sorts of responders, from qualified local and foreign medical doctors and surgeons to volunteers tasked with filling out paperwork. There was no shortage of willing bodies and no task was deemed too great. A general surgeon from the United States had landed in Port-au-Prince. I had met with him at a private American high school in the city, which was coordinating medical teams from the States, and accompanied him to the Haitian Community Hospital. It was clear that Haiti needed all of the medical help available. However, it became evident that nurses and emergency medical technicians (EMTs) were more valuable than ever. Although there were surgeons operating around the clock, there was little to no post-operative care. Surgeons, and in particular this American surgeon, had to take on responsibilities that are often delegated to other staff in a normal hospital environment. The willingness to provide basic care and to do what it takes, no matter how small, speaks volumes about the character of the individuals providing in care in the aftermath of the earthquake. This revelation also highlights the need for and emphasis on the training of nurses and EMTs for the future of Haiti. This can also be a lesson learnt in responses to disasters around the world. It was only about three weeks later did a team of nurses from the University of Miami make it to the hospital in order to care for the

injured. I found myself, often alone, caring for the injured after they had received initial care or surgery.

Generation of amputees. The most challenging task was to inform patients that an amputation was needed in order to save their lives. I remember, in particular, a young lady in her mid 20s, who required an amputation to her right arm. She had suffered a broken arm and had only been able to come a week or so later for treatment. As I prepared the consent form, she had broken into tears and told me that she would not be able to sign it. She was alone and there were no family members with her that I could approach to help convince them that this procedure was needed to save her life. I sat with her, hand in hand, and told her that we would do what it takes to save it, but that she had to be strong if that wasn't possible. Her response was heartbreaking. What future is there for a young woman who is unable to work due to a loss of an arm? The reality is that there is no future for the handicap in Haiti. We both understood that. There are no words that can describe the sorrow that was felt that day. She signed the consent form. The procedure was done. A generation of amputees had been created.

Hope and politics. I remember another face, one young man amongst thousands, just like myself, yet so unfortunate. A face I won't ever forget, but a name I'll never know. A victim, but not just a victim, no, he had something more, something bigger to say. Despite two separate amputations below the knees, an immeasurable amount of optimism and hope poured out of his body. Each day I arrived, I found more and more hope but less and less body. This young man was losing a part of his legs day by day yet he remained unfazed. There are two very clear lessons to be learned. The first, and most important, is the resilience of the Haitian people time, despite disaster after disaster. The second is more complex and more political. This young man had been waiting on clearance in order to be flown out to the United States for further treatment at a tertiary hospital. The response time was slow, but expectedly so in times of chaos. As a result, the quality of life and prognosis of this patient diminished in proportion with the response time. There is a real need for advanced and critical care for the injured in Haiti. We simply cannot afford to rely on the aid workers that come and go, but must develop systems that are able to cater to the needs of the population immediately.

A hidden truth. With hundreds of thousands of victims presenting themselves for various injuries in the remaining health facilities in Haiti after the earthquake, a phenomenon occurred. Those who had never had access to healthcare flocked to various hospitals for care unrelated to the earthquake. With free healthcare being provided country-wide, Haitians previously deprived of care took advantage. This unexpected phenomenon proved particularly daunting in the triage stage at the Haitian Community Hospital. While best efforts were made to cater to the critically injured, individuals who had obtained various diseases or injuries previous to the earthquake presented themselves for care, making triage a nightmare. This phenomenon speaks volumes about the state of healthcare in Haiti prior to the earthquake. Healthcare was, and is, simply unaffordable to the majority of the Haitian people. Haitians have been deprived of basic care for far too long, and no one can deny that.

2. An Overview of Traumatic Injuries and Trauma Care in Haiti

2.1 A Brief Overview of Haiti's Health Care System

Following the fall of the Duvalier regime and the establishment of the country's 1987 Constitution, health was recognized as a human right. Articles 19 and 23 of the Haitian Constitution state that the Haitian state has the obligation to guarantee the right to life, health, and respect of the human person for all citizens without distinction and in conformity with the Universal Declaration of the Rights of Man (1948 United Nations Universal Declaration of Human Rights) [1]. These articles also stipulate that the State has an obligation to provide all citizens in all territorial divisions appropriate means to ensure protection, maintenance, and restoration of their health [2]. Haiti's health policy framework is contained in the 2004 Strategic Plan for Health Sector Reform. In this framework, health is considered to be an "essential condition for human development" [3]. The framework revolves around three major strategic lines:

1. Development of primary health care
2. Decentralization and reorganization of the national health system
3. Strengthening and development of public health facilities

Furthermore, ten priorities of intervention are established:

1. Primary health care
2. Reorganization of the health system
3. Development of an effective and efficient financing method
4. Strengthening of community participation
5. Development of multi-sectoral coordination
6. Coordination and linkage with different participants
7. Development of a policy on suitable human resources
8. Development of research
9. Introduction of legislation defending the population's interests
10. Integration of traditional medicine

Note that while this strategy outlines action areas for meeting these priorities, there is little information on how these goals will be assessed and which indicators will be used. More recently, a new health policy initiative has been presented in July 2012, by the Ministere de la Sante Publique et de la Population (MSPP), Haiti's health ministry [4]. In this more recent national plan of action, morbidity and mortality due to accidents and violence are described as a growing burden in Haiti. Despite this, the document does not specify further how it plans on tackling issues due to traumatic injuries in Haiti. There is no mention of the establishment of a regional trauma system or specific interventions aimed at curbing road traffic accidents, for example. However, at the international level, there are preliminary talks from donor nations and the Ministry of Health for a national plan for a trauma critical care network to be implemented in the future [5].

2.2 Health Care System Infrastructure and Key Indicators

Haiti's current health care system and infrastructure consists of various competing sectors:

1. Public Sector:
    a. Ministry of Public Health and Population (MSPP)
    b. Ministry of Social Affairs
2. Private for Profit Sector
3. Non-Profit Sector
4. Private Non-Profit Sector
5. Traditional Health System

Further, health care is organized around three main levels:

1st level: approximately 700 primary health care facilities distributed country-wide, which are supported by community hospitals
2nd level: 10 departmental hospitals constitute the secondary level of care
3rd level: 4 university hospitals (tertiary)

Although the exact number of health care facilities are unknown, one estimation before the 2010 earthquake by the Pan American Health Organization (PAHO) revealed that there were 371 health

posts, 217 health centers, and 49 hospitals. These formal services reached an estimated 60% of the total population, whereas the remaining portion of the population relied on traditional medicine, mostly in rural areas due to costs. It is also estimated that nearly half of all health facilities are concentrated in the Port-au-Prince metropolitan area, and are estimated to supply 30-40% of the Haitian market [6]. The World Health Organization (WHO) estimated that there were about 1,949 physicians (a density of 3 per 10,000 people) and 834 nurses (a density of 1 per 10,000 people) in 2009 [7]. Key demographic, health, and socioeconomic development indicators are presented in Table 1.

Table 1. Key demographic, health, and socioeconomic development indicators.

Total Population (2015) [8]	10,711,000
Population in Urban Areas (%, 2015) [8]	59
Population Growth Rate (%, 2015) [8]	1.3
GDP Per Capita (Current US$, 2015) [8]	828.8
GDP Growth Rate (Annual %, 2015) [8]	1.7
Human Development Index (Rank, 2015) [9]	163
Poverty Headcount Ratio at National Poverty Lines (% of pop., 2012) [8]	58.5
Physicians/1,000 of the Population (1998) [7]	0.25
Under 5 Mortality Rate per 1000 Live Births [8]	69
Total Expenditure on Health per Capita (International $, 2014) [7]	131
Total Expenditure on Health as % of GDP (2014) [7]	7.6
Life Expectancy at Birth m/f (years, 2015) [8]	62/66

(Sources: multiple, as indicated)

The Haitian healthcare system is primarily based on out-of-pocket payments, and Haitians from the worst poverty and health outcomes in the western hemisphere. Internationals organizations, foreign government agencies and non-governmental organizations (NGOs) play a central and key role in the delivery of health services in Haiti, due to the limited capacity and financing of the public health sector. The 2016-2017 budget adopted currently allocates a meagre 4.5% of the total budget, representing approximately $92,000,000 [10]. These resources are allocated to the Ministry of Health on a historic basis, and not by a programmatic basis, of which 70% are focused on programs related to HIV and cholera, even though the proportion of the burden of disease in these two areas is relatively low [11]. However, the recent national plan of action does identify the need to increase the budget to reflect up to 15% of the national budget.

Haiti's health supply system is operated entirely by external actors and PAHO. Haitian authorities seldom have a say in the operations and activities of the numerous foreign actors operating in the health sector and yield very little regulatory power. Additionally, a vast number of medical professionals and Haitian-trained physicians leave the country in order to pursue a more lucrative career outside [12].

2.3 Burden of Trauma Injury in Low- and Middle-Income Countries (LMICs)

The burden of disease due to traumatic injuries in low- and middle-income countries (LMICs) have received tremendous attention and support over the last few years by the international community and has been categorized as a matter needing urgent attention and action [13-15]. According to the 2004 Global Burden of Disease study, an estimated 5.8 million lives are lost each year worldwide due to traumatic injuries, accounting for more than 10% of the world's deaths, and representing 32% more lives lost than tuberculosis, malaria, and HIV/AIDS combined [16,17]. Approximately 90% percent of the burden of disease due to traumatic injuries falls on LMICs, which contributes to immense socioeconomic consequences for these developing countries [18-21]. Although trauma systems in high-income countries (HICs) have been shown to dramatically reduce morbidity and mortality resulting from traumatic injuries, these systems are rarely implemented in developing countries due to financial, infrastructural, and human resource barriers [22-26]. Several international organizations have developed tools and guidelines in an attempt to assess and improve trauma care in developing countries [27-29]. The WHO and the International Association for the Surgery of Trauma and Surgical Intensive Care (IATSIC) have developed the Guidelines for Essential Trauma Care (Guidelines for EsTC), which provide a minimum standard of care that should be available to every injured person regardless of setting [26].

The financial burden on developing countries is estimated to be around $500 billion annually, which may serve to justify the implementation of trauma care systems in low-resource settings [30]. Trauma continues to be among the greatest global public health challenges of our time, contributing to millions of deaths and injuring more than 100 million individuals, often permanently [17,31-33]. Along with this great challenge is great opportunity, as implementation of injury control and effective trauma care in LMICs has the potential to not only save millions of lives every year, but to reduce the major financial and societal burden on society [17,24,32-38].

Despite the enormous economic and social burden due to traumatic injuries in LMICs, injury prevention and trauma care have not been prioritized [39]. For example, larger efforts and attention has been given to disease such as HIV/AIDS, TB, and Malaria over injury prevention. To date, data on injury morbidity and mortality have failed to convince policy-makers to invest in injury prevention, thus one approach advocated by Wesson et al. [39] is to consider the costs associated with injury and the cost effectiveness of injury-prevention programs and optimal trauma care.

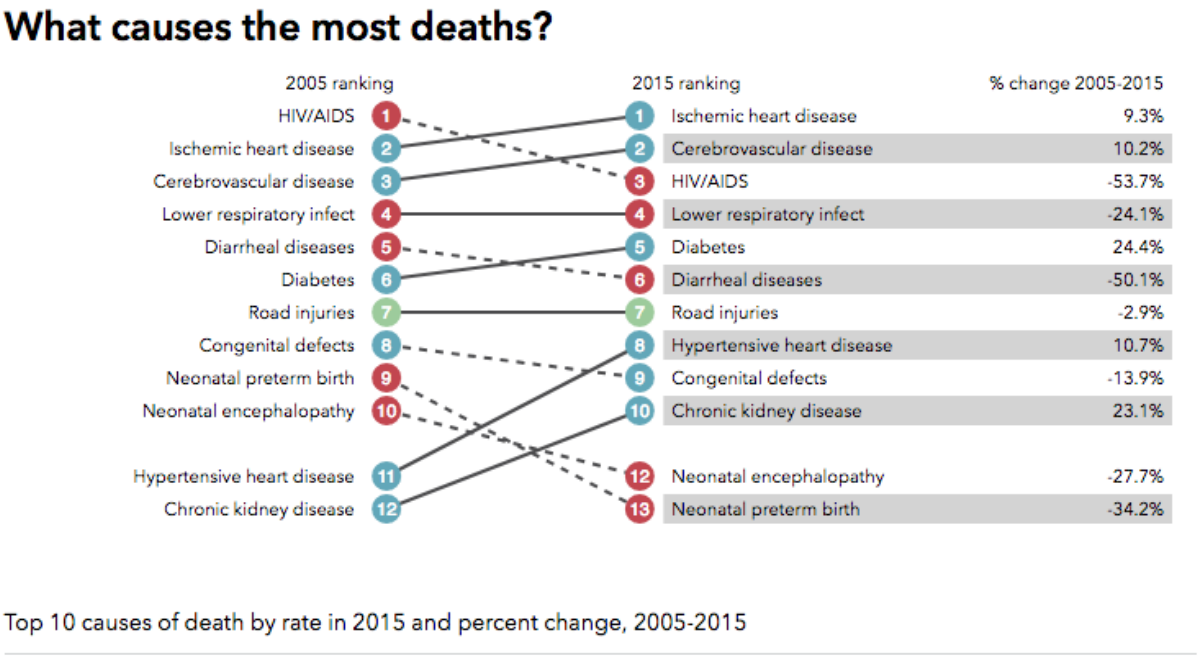
Approximately half of all mortalities due to traumatic injury occur in individuals under the age of 44, during economically productive years [40]. This development is important as the financial burden of injuries far exceed the direct medical costs associated with treatment of an injury. Thus, comprehensive injury-related studies on the cost of traumatic injuries are needed in order to quantify not only direct medical costs, but costs related to productivity and costs incurred by family members of victims. Cost-effectiveness studies are also needed in order to compare competing interventions. Wesson et al. argue that a key first step in injury prevention requires obtaining evidence on the costs and effectiveness of interventions in order to present decision makers with options. With limited resources and competing health needs in the majority of LMICs, costs of various interventions in relation to their benefits must be taken into account. Cost studies have been on the rise and is encouraged heavily by the WHO and other world organizations [39,41,42]. Despite an increase in the number of cost studies worldwide, the majority of studies and systematic reviews that have explored costs and cost-effectiveness of injury prevention are conducted in HICs, which represent less than 10% of the global burden of injury due to trauma [39,43-45].

2.4 Burden of Disease: Haiti

The Institute for Health Metrics and Evaluation (IHME) country profiles provides estimates from the Global Burden of Disease (GBD) [46]. These estimates may differ from national statistics, as different methodologies and data sources are used. Road injuries in Haiti accounted for the 7th most deaths in 2005, and remained at number 7 in 2015 (Figure 1). In terms of premature death, measured in years of life lost (YLL), road injuries ranked 9th in 2005, but has risen to number 7 in 2015, surpassing neonatal preterm birth and neonatal encephalopathy. In 2005, natural disasters ranked 56 in health problems causing disability, but rose sharply to number 4 in 2015, due to

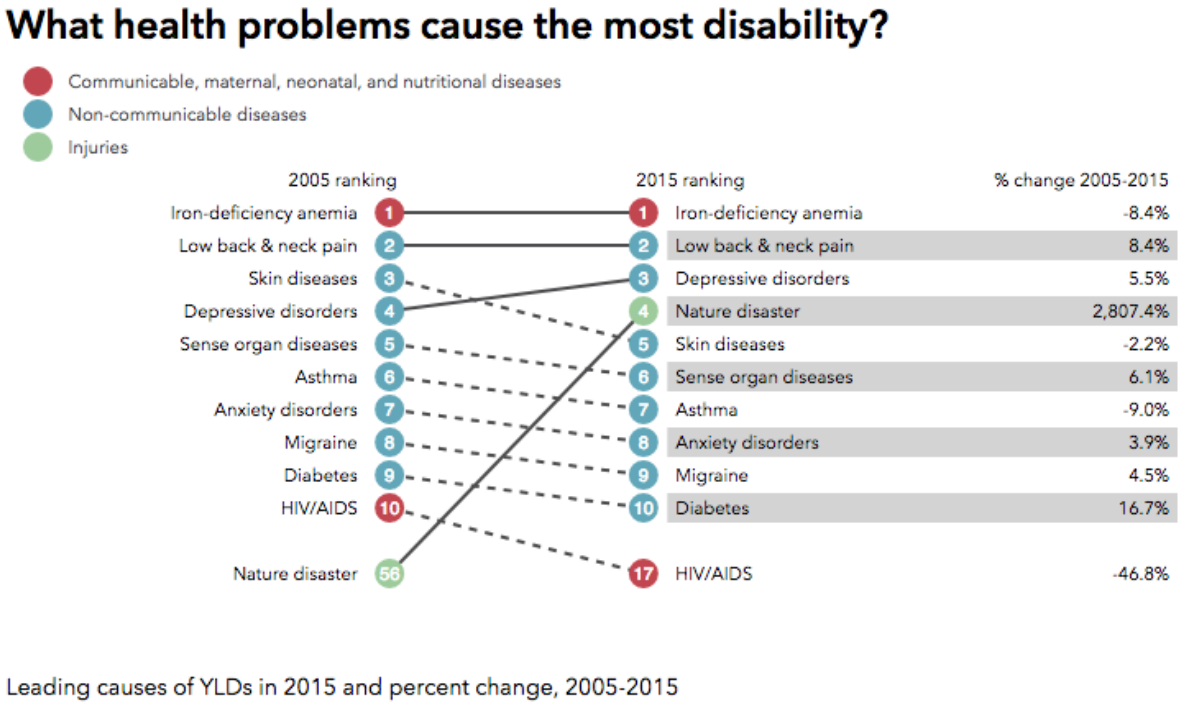
numerous natural disasters in the past decade (Figure 2). In terms of both death and disability combined, the GBD study ranked injuries as number 7. It is clear from the GBD study that injuries are a top-10 leading cause of morbidity and mortality, and is exacerbated by the host of natural disasters in the past decade. When compared to all countries in the region, Haiti had an estimated premature deaths caused by road injuries of 1,229 YLL in 2015, more than doubling the comparison group average of 577 YLL.

Figure 1. Top 10 causes of death by rate in 2015 and percent change, 2005-2015 (source: IHME).



Top 10 causes of death by rate in 2015 and percent change, 2005-2015

Figure 2. Leading cases of YLDs in 2015 and percent change, 2005-2015 (source: IHME).



Leading causes of YLDs in 2015 and percent change, 2005-2015

2.5 Transportation Issues and Increasing Medical Liabilities

While it is true that the country is no longer in the emergency phase, trauma care seems to have been pushed to the back of the agenda. The evidence on the ground is clear: Haiti's fragile medical system is being strained by an overwhelming number of traumas presenting for treatment. Trauma due to road vehicle accidents are on the rise and are expected to increase. Haiti is experiencing an explosion in the use of motorcycles. Accidents on the road have spiked due to the lack of safety that is being practiced by drivers and passengers. Coupled with this is the absence of any sort of police enforcement and traffic laws. This combination creates a unique problem: injuries are proving to be a major strain on Haiti's already fragile medical system. On the side of prevention, there are fixes that have already been proven to be cost-effective such as the enforcement of traffic laws and requiring seatbelt and helmet use. On the side of trauma care, research has proven that injury surveillance coupled with the regionalization of trauma care has led to major improvement in morbidity and mortality outcomes. Haiti clearly has to improve their policies on both injury prevention and trauma care.

It is evident that Haiti does not have the infrastructure necessary for a working public transportation system. With damaged roads, increasing traffic, and an explosion of motorcycles, travel has become increasingly chaotic and treacherous. There is no doubt that the introduction of motorcycles has provided both employment and a means for faster transportation that is affordable. However, regulations have not caught up and passengers are not afforded the luxury of being able to wear protective gear or helmets. Something needs to be done to make wearing a helmet "cool" again, or simply, government needs to take responsibility and strictly enforce these rules. As of the current state, none of these initiatives are being implemented. One eye witness account from a medical team providing care best describes the situation at hand:

"I did not realize the gravity of the issue until we got on ground at our medical clinic and started treating patients. One after another, patients arrived with multiple injuries from motorcycle accidents. Some accidents resulted in minor lacerations while others ended with extensive orthopedic injuries and death. After leaving the country, I thought extensively on how this one problem, which greatly impacted the Haitian medical system, could be improved…but anecdotally any health care provider who has spent time in Haiti will tell you that this is a major issue."[47]

Haiti's transportation issues and the resulting burden on the medical system are not to solely blame on the introduction of motorcycles. It is known that a host of issues, such as speeding, drunk driving, and wreckless driving have taken many lives. Vehicles are often poorly maintained and prone to failure on treacherous and mountains roads. A quick search online of road traffic accidents in Haiti yields countless articles, some appearing on major news outlets such as CNN. Below are a few titles extracted from newspapers and online news agencies in the past three years alone.

"Au moins 11 morts dan un accident cavaillon" (11 June 2017) [48]

"Bus plows into parade crowd in Haiti, killing 38" (13 March 2017) [49]

"18 morts dan un accident sur le trajet Port-de-Paix-Port-Au-Prince" (8 January 2017) [50]

"Un accident de la circulation fait 18 morts et 28 blessés dans le Nord" (17 August 2015) [51]

"Haiti: au moins 15 morts dans un accident lors du carnival de Port-au-Prince" (17 February 2015) [52]

2.6 Pre-Hospital Care

Centre Ambulancier National (CAN)

After the 2010 earthquake, a national emergency number, 116, was implemented in order to respond to emergency requests. Haiti's ambulance system, referred to as the Centre Ambulancier National (CAN), currently operates the phones and dispatches help when called. Upon conception, CAN received dozens of equipped ambulances from foreign donors. As per an investigation into CAN by the Minister of Health in 2017, there were only 6 remaining functioning ambulances in the capital city of Port-au-Prince, and none fully-equipped [53]. The CAN currently employs 443 employees for 6 functioning ambulances, including 80 drivers, 47 call-center operators, 84 EMTs, and 92 nurses. As of July 2017, the newly appointed Minister of Health had closed the CAN for restructuring purposes with no re-opening date in sight, pointing out, for example, that 80 drivers for 6 ambulances was unreasonable and a waste of valuable state resources. Other research has estimated that in 2015, there were approximately 200 EMTs trained in basic EMT skills, including Basic Life Support in the entire country [54].

Helicopter Air Ambulance

Haiti is currently the first developing country that offers a publicly-available helicopter ambulance service, at a cost of $3.5 million per year, with US aviation and aeromedical care standards adopted [54]. As there are only a handful of tertiary care centers that offer high-quality intensive care spread across the country, the utility of a hospital is greatly increased. During the first year of operation, 76 patients were transferred, including 13 children and 3 pregnant women. The most common reason for transfer was traumatic injury, primarily due to road traffic accidents. This service was primarily used by six hospitals, and was limited by weather, lack of radar and visual flight recognition, and the inability to operate at night. The helicopter service is publicly available and offers to services to all individuals, regardless of ability to pay. The aim of this program is to increase pre-hospital care capability, including possible intervention for on-scene calls. A complete and comprehensive pre-hospital system must be established. For example, the Haitian National Police (PNH) and fire-fighters must be trained in pre-hospital care and scene management, as they are often the first responders on site.

2.7 Organization of Trauma Care and Epidemiology of Traumatic Injuries in Haiti

To date, trauma care in Haiti is not organized at any level. There is a lack of data on the state of trauma care in Haiti, and there is a lack of contemporary statistics on the epidemiology of traumatic injuries, as there is no organized system for injury surveillance. There are no published studies that have investigated the cost of traumatic injuries in Haiti. A few studies have been conducted post-earthquake on the state of trauma care, yet it is not enough to describe the epidemiology of traumatic injuries. Haiti is divided into 10 geographic and administrative regions (Figure 3). Below is a summary of all published literature on trauma by region, as well as a description of basic trauma care capabilities of the main facilities in each department, as well as any trauma-related statistics available.

Figure 3. Map of Haiti by geographic department.

2.7.1 Central Department

The Central department has an estimated population of 746,000 [55]. For the Central region of Haiti, three published studies confirm a high burden of traumatic injuries. However, the epidemiological data provided was limited and a comparison with urban areas is needed.

University Hospital at Mirebalais (UHM) [56]

In June 2013, the largest construction project in the health sector since the 2010 earthquake saw the opening of the University Hospital at Mirebalais (UHM), a 300-bed national referral hospital providing high-quality primary and tertiary care. The UHM currently operates a 21-bed modern emergency department, staffed by local physicians and nurses, but is constantly supported and trained by foreign emergency physicians and personnel. UHM currently operates one of the four CT-scanners in the entire country [57]. A recent study analyzing head CT findings at UHM from July 2013 to January 2016 found that the most common categories of neurological abnormalities were traumatic (31%), followed by vascular and infectious abnormalities [58]. The median age for these patients who suffered from traumatic brain injury was 30, and approximately 42% of those with head traumas had intracranial hemorrhage or fracture.

Strengthening emergency care: experience in central Haiti (2015) [59]

A published study in 2015 at UHM aimed to evaluate the emergency care system and epidemiology of trauma in the Central department of Haiti. The study results are summarized below.

Epidemiology: In the first year of operation, the emergency department at UHM has registered approximately 17,000 patients, with an increase in the number of visits monthly. Approximately 56% of patients were women, and 27% were children younger than 15 years of age. Common diagnoses included: gastritis, upper respiratory infections, chikungunya (due to the recent epidemic), urinary tract infection, and gastroenteritis. 2,520 of 13,781 (18%) patients seen whose data were recorded electronically sustained trauma, an estimated 210 trauma admissions per month. 48% of patients were seen due to road traffic accidents.

Discussion: Haiti is not an exception to the general pattern of inattention to emergency care, as few public resources and little recognition is dedicated to these services in the current health system. There is a need for high-quality emergency care training programs to ensure that patients receive adequate trauma care as well as to construct comprehensive emergency systems and networks. Emergency care should be an integral component to the health system in Haiti. Further research is needed in Haiti to better estimate the burden of disease, as well as the number of deaths averted and DALYs reduced by emergency care.

Traumatic injuries at an emergency department in Central Haiti (2015) [60]

A retrospective chart review of trauma patients presenting to the emergency department at UHM was conducted for the period October 2013 to March 2014. Physical charts were reviewed for all trauma patients during the study period. A serious outcome was defined as the following: a death in the emergency department, admission, spending 2 or more days in the emergency department, or a need for surgery.

Epidemiology: 1,399 patients were confirmed as trauma patients and were analyzed. 66% of patients were male, 8% of patients were children under 5, and 20% were patients between the ages of 5 and 15. The average age was approximately 27 years. 48% of visits were due to road traffic accidents, followed by falls (22%), and assaults (18%). The majority (82%) of road traffic accidents were due to motorcycles. Time to treatment was available for 75% of patients. 18% of patients arrived within 1 hour of sustaining trauma, 15% arrived more than 24-hours after sustaining trauma. 58% of patients sustained skin or soft tissue injuries, 21% had an extremity or pelvic fracture, 3% sustained intracranial injuries, and 1% sustained thoracic or abdominal injuries. 82% of patients were discharged from the emergency department, and 13% were admitted for further treatment or observation. Of those admitted, 63% (115 patients) had surgery, mainly orthopedic surgery. 17% of patients met the definition of having sustained a serious outcome. Patients involved in road traffic accidents had the highest percentage of serious injuries, followed by assaults and falls.

Discussion: The study confirms a high burden of trauma in the central region of Haiti, mainly due to road traffic accidents. Children represented a minority of trauma admissions. There were significant delays to admission as well as a low number of abdominal or thoracic injuries, which may be due to the unavailability of EMS systems. Without these systems in place, patients may have not been able to reach the hospital on time or at all, and thus may have died prior to arrival. Further studies are warranted, especially comparison with urban areas.

Trauma capacity in the central plateau department of Haiti (2014) [61]

A cross-sectional analysis was performed of two primary, three secondary, and two tertiary health facilities with the aim of assessing emergency and essential surgical care capabilities, using both the WHO Tool for Situational Analysis to Assess Emergency and Essential Surgical Care, and a comprehensive questionnaire. All of the major health care institutions in the department were chosen. Epidemiological data were gathered from emergency room logbooks or a ministry of health representative. Surveys were given to various staff members. The main results are summarized below.

Epidemiology: Primary hospitals had emergency rooms but no ORs, secondary hospitals had emergency rooms and infrastructure for surgery, but did not perform any general surgery, and tertiary hospitals had emergency rooms and ORs and performed general surgery and some subspecialty services. Tertiary hospitals admitted 540 and 830 patients per month, secondary hospitals admitted 186 and 201 patients per month, and primary hospitals were unable to provide number of admissions. Tertiary and secondary hospitals received more trauma patients than primary hospitals, with more patients being treated for motor vehicle accidents and burns.

Infrastructure: All hospitals had trauma transfer capabilities and ambulances were frequently shared between facilities. Quality improvement programs were only available in secondary and tertiary hospitals, however, trauma care guidelines were only available for one secondary and tertiary hospital. Only one tertiary hospital had a trauma registry in place and an intensive care unit. The majority of hospitals had constant electricity and water, blood banks (mainly operated by the American Red Cross), and basic laboratory capabilities.

Procedures and Human Resources: All facilities provided acute burn management. Only tertiary hospitals performed amputations, open fracture surgery, and laparotomies. No hospitals performed thoracotomies. All hospitals had emergency room physicians but only 1 hospital (tertiary) had a physician with trauma training.

Equipment and Supplies: All hospitals with ORs had functional anesthesia machines and ambulances for transfer. 5 of 7 hospitals had respiratory equipment, 4 of 7 hospitals had suctioning equipment, adult bag-valve masks, intubation equipment, ventilators, intra-osseous access kits, scalpel handles, blunt scissors, and hemostats. One tertiary hospital had a CT-Scanner. 3 of 7 hospitals had central intravenous kits and functioning x-ray machines. All hospitals had intravenous infusion equipment. None had pelvic binders and sheets were used to wrap and secure the pelvis. None had endoscopy or angiography. Medication supply varied, however tertiary and secondary hospitals had more medication.

Areas of Perceived Need: Top needs were identified as medicine and protocols, as well as machinery, training, and a trauma registry. Other perceived needs included supplies and personnel. Only 3 of 7 hospitals listed infrastructure as a top need. In terms of training, all hospitals listed ATLS, Trauma Lite, and a Rural Trauma Team Development Course as their most desired training, followed by ultrasound training, and lastly, postoperative care training.

Discussion: There is a lack of quality improvement programs and guidelines, specifically in trauma. These interventions have been shown to improve patient outcomes. All hospitals could greatly benefit from establishing a standardized trauma registry. Sustainable trauma training programs is needed for all staff levels. Additionally, trauma training could be implemented into medical and nursing school curriculums to increase trauma care capacity. Due to the cost of CT-scanners, ultrasounds provide great utility and may improve care. The lack of pre-hospital care is one of the greatest barriers to trauma care in Haiti, and it is believed that a large proportion of trauma victims do not make it to hospitals on time or at all. Emphasis is needed on implementing an emergency response system to decrease time between injury and hospital admission.

2.7.2 Northeast Department

The Northeast department has an estimated population of 394,000 [55]. For the Northeast region of Haiti, two published studies confirm a high burden of traumatic injuries.

Epidemiology of traumatic injuries in the northeast region of Haiti: a cross-sectional study (2015) [62]

The northeast region consists of three public hospitals, each operating 24-hour acute care emergency departments with designated personnel available to provide trauma care. No formal trauma surveillance currently exists at any of the three public hospitals. A cross-sectional and retrospective study was undertaken at the three public hospitals for the period October 1, 2013 to November 30, 2013. All patients presenting for treatment or evaluation of trauma were eligible for inclusion.

Epidemiology: A total of 383 patients were confirmed as trauma patients and analyzed. During the 2-month period, 227 patients were treated at the Ouanaminthe Hospital, 116 at the Fort Liberte Hospital, and 40 at the Trou Du Nord Hospital. There was an average of 6.3 injuries per data across all sites, and no statistically significant correlation between the frequency of trauma cases and the day of the week. There was medical record documentation for 37.9% of patients and registry documentation for 77% of patients. The median age was 23, and children less than 15 years of age accounted for approximately 23.1% of all trauma admissions. 62.7% of patients were male and 88.5% of patients were less than 44 years of age. Mechanism of injury was documents for half patients in the study cohort, and road traffic accidents accounted for the majority of trauma modes (65.8%), followed by assaults and accidental injuries. Anatomical region of injury was available for 44.9% of patients, and extremity trauma was the most frequently injured body region, followed by head and neck injuries, and facial trauma. Systolic blood pressure and respiratory rate were documented for 19.3% and 4.1% of patients. A single injury was the most frequently documented, and only 16.2% had more than one injury. There were no mortalities in the study cohort.

Equipment and supplies: The three hospitals represented the only 24-hour accessible health care

access points, and each emergency department is staffed by at least one nurse and one physician at all times. All hospitals had access to basic supplies including gauze, tourniquets, scalpels, sutures, and splints. None of the hospitals had access to CT-scanners, blood, spinal immobilization devices, or mechanical ventilators. Emergent surgical services were available at two hospitals.

Discussion: Trauma is a common reason for presentation in the region. Trauma victims were mostly male, in their third decade of life, and injured in road vehicle accidents. Medical record documentation was deficient at all sites, which highlights the need for improved prospective trauma surveillance to better define the burden of disease. The lack of observed deaths is most likely due to the lack of EMS systems, as severely injured patients who expired in the pre-hospital setting was not captured.

Prehospital characteristics in the Northeast department of Haiti: a cross-sectional study from a low-income setting without prehospital systems (2014) [63]

A prospective cross-sectional study was conducted in the Fort Liberte public hospital for the period April 2, 2012 to June 5, 2012. All patients presenting for non-specialty care were eligible for participation.

Epidemiology: A total of 1,270 patients were triaged to the emergency care department and ambulatory care clinic. Study data were collected from 441 patients after screening and obtaining consent. Of the 441 patients sampled, 109 (24.7%) accounted for trauma. The median age was 25.9, and 57.7% of patients were male. Only 10.4% of patients reported having care prior to arrival, and 64.2% arrived at the hospital via motorcycle taxi. There was an even distribution of blunt and penetrating injuries, and extremity trauma accounted for the majority of penetrating and blunt injuries. Median time of transport to the hospital was 65 minutes for trauma patients, with significantly longer times with those with penetrating injuries compared to blunt injuries.

Discussion: Injuries accounted for one quarter of encounters, and receipt of pre-hospital care was rare. The primary mode of arrival to the hospital was via motorcycle taxi. Prehospital care has been neglected in Haiti and interventions are needed in this area. Motorcycle taxis play a key role

in the prehospital system currently, and may represent a lay population suited for the provision of care and transport.

2.7.3 North Department

The north department has an estimated population of 1,067,000 [55]. For the North region of Haiti, there are no published studies on trauma in the literature.

Hospital Sacre Coeur (HSC) [64]

Hospital Sacre Coeur (HSC) operates as the largest private hospital in the North of Haiti, with a capacity of 200 beds. HSC is a full service tertiary care medical center and official Haitian referral center, which offers advanced specialty treatment.

Although there are no published studies in the north region of Haiti, hospital statistics were able to be found on the hospital's main website for the year 2016. HSC received 70,503 outpatient visits with 7,470 hospital admissions. There were 2,690 surgical procedures performed, 12,417 diagnostic tests, and 214,820 prescription medications filled. There were 7,554 emergency room visits and 203,408 laboratory tests conducted. 20,278 patients were tested and counseled for HIV/AIDS and there were 8,515 antiretroviral clinic visits. There were no detailed statistics on trauma-specific trends.

Justinian University Hospital (JUH) [65]

Justinian University Hospital (JUH) is a 250-bed public teaching hospital in the capital city of Cap-Haitien, located in the north department. JUH houses pediatrics, surgery, OB/GYN, outpatient and emergency facilities, a pharmacy, a laboratory, and private wards. There are no available general or trauma-specific statistics.

Hospital Bon Samaritain (HBS) [66]

Hospital Bon Samaritain (HBS) is a 75-bed private and non-profit hospital located in the city of Limbe in the North Department of Haiti. Currently, HBS 72,000 outpatients are consulted yearly. Emergency cases are admitted 24/7 with a physician on-call at all times. Small surgery is performed in the clinic for minor fractures and cuts resulting from accidents and violence. HBS has approximately 1,000 admissions to pediatrics per year. There are no available trauma-specific statistics.

2.7.4 Northwest Department

The Northwest department has an estimated population of 729,000 [55]. For the Northwest region of Haiti, there are no published studies on trauma in the literature.

Hospital Immaculee Conception de Port-de-Paix (HIC)[67]

Hospital Immaculee Conception de Port-de-Paix (HIC) is a 22-bed public secondary hospital located in the capital city of Port-de-Paix in the Northwest department of Haiti. HIC offers emergency services, maternity health care, surgery, internal and external medicine, pediatric care, as well as operates a cholera treatment center. There are no available general or trauma-specific statistics.

Beraca Medical Center [68]

Beraca Medical Center is a 78-bed private and non-profit hospital in the capital city of Port-de-Paix in the Northwest department of Haiti. Beraca Medical Center currently treats more than 28,000 patients per year and performs over 800 critical surgeries. There are no trauma-specific statistics.

Hospital Notre Dame de la Paix (HNDP) [69]

Hospital Notre Dame de la Paix (HNDP) is a 22-bed public hospital located in the Northwest department of Haiti. There are no available general or trauma-specific statistics.

2.7.5 South Department

The south department has an estimated population of 775,000 [55]. For the south region of Haiti, there are no published studies on trauma in the literature.

Hospital Immaculee Conception des Cayes (HIC) [70]

Hospital Immaculee Conception des Cayes is the south region's largest public and tertiary hospital with a capacity of 150 beds. There are no available general or trauma-specific statistics.

Hospital Lumiere [71]

Hospital Lumiere is a private 120-bed primary care medical-surgical hospital located in mountains in the south region of Haiti. There are no available general or trauma-specific statistics.

Hospital St. Boniface Haiti Foundation (SBHF) [72]

Hospital St. Boniface Haiti Foundation (SBHF) is a private and non-profit charity hospital located in the south region of Haiti with a capacity of 80 beds. In 2015, SBHF saw over 62,000 outpatient visits, treated 3,200 inpatients, delivered 1,300 babies, and conducted 5,300 community health home visits. Additionally, SBHF performs approximately 200 surgical procedures a year. There are no available trauma-specific statistics.

2.7.6 Southeast Department

The Southeast department has an estimated population of 633,000 [55]. For the Southeast region of Haiti, there are no published studies on trauma in the literature.

Hospital St. Michel de Jacmel (HSMJ) [73]

Hospital St. Michel de Jacmel (HSMJ) is a 42-bed public secondary hospital located in the capital city of Jacmel in the Southeast department of Haiti. After complete destruction in the 2010 earthquake, the official inauguration and opening of newly reconstructed hospital occurred in late 2016. There are no available general or trauma-specific statistics.

2.7.7 Artibonite Department

The Artibonite department has an estimated population of 1,728,000 [55]. For the Artibonite region of Haiti, there are no published studies on trauma in the literature.

Hospital La Providence des Gonaives (HPG) [74]

Hospital La Providence des Gonaives (HPG) is a 200-bed public tertiary hospital located in the capital city of Gonaives in the Artibonite department of Haiti. HPG currently operates an emergency department with 20 beds and 4 operating rooms, amongst others. HPG opened its doors in late 2014 and has yet to publish general or trauma-specific statistics, but does allocate resources for archiving and statistics.

Hospital Saint Nicolas [75]

Hospital Saint Nicolas is a 150-bed public hospital located in the city of Saint Marc, the western part of the Artibonite department. In early 2016, the Center for Trauma and Orthopedics was established at the hospital in an effort to cater to the rise of traumatic injuries, notably car accidents [76]. There are no available general or trauma-specific statistics.

Hospital Albert Schweitzer (HAS) [77]

Hospital Albert Schweitzer (HAS) is private and non-profit charity hospital located in Artibonite department. HAS currently operates a 131-bed hospital and is currently the only 24/7 full-service hospital in the region. According to hospital statistics found on the hospital's main website, patients admitted following motor vehicle accidents (both cars and motorcycles) represent 19% of

all surgery patients, 40% of all trauma patients, and 50% of blunt force trauma patients. Trauma stemming from road vehicle accidents are increasing, due to improved roads and an increase in the volume of traffic. HAS has 24/7 emergency care services, and currently performs approximately 150 surgeries per month, many for life-threatening conditions. Trauma care represents the majority of the HAS surgical program, as approximately 300 orthopedic and 500 wound repair procedures are conducted each year. Additionally, HAS also provides complete rehabilitation services from traumatic injury to surgery to full recovery, as well as operates a top-notch Prosthetics and Orthotics lab.

2.7.8 Grand'Anse Department

The Grand'Anse department has an estimated population of 468,000 [55]. For the Grand'Anse region of Haiti, there are no published studies on trauma in the literature.

Hospital Saint Antoine (HSA) [78]

Hospital Saint Antoine is a 114-bed public secondary hospital located in the capital city of Jeremie in the Grand'Anse department. There are no available general or trauma-specific statistics.

2.7.9 Nippes Department

The Nippes department has an estimated population of 343,000 [55]. For the Nippes region of Haiti, there are no published studies on trauma in the literature.

Hospital Sainte Therese de Miragoane [79]

Hospital Sainte Therese de Miragoane is 34-bed public secondary hospital located in the capital of Miragoane in the Nippes department of Haiti. There are no available general or trauma-specific statistics.

Hospital Jules Fleury [80]

Hospital Jules Fleury is a 30-bed public secondary hospital located in the Nippes department of Haiti. There are no available general or trauma-specific statistics.

2.7.10 West Department

The West department has an estimated population of 4,030,000 [55]. For the West region of Haiti, there are few published studies on trauma in the literature. There are numerous health facilities and hospitals in the capital city of Port-au-Prince, Haiti. However, the three main trauma facilities will be discussed in this section.

General Hospital / Hopital de l'Universite d'Etat d'Haiti (HUEH)[81]

Haiti's largest public hospital, Hopital de l'Universite d'Etat d'Haiti, commonly referred to as General Hospital, serves as the country's key public healthcare facility. Having been destroyed in 2010 after the earthquake, a new 534-bed facility is under construction. The anticipated date of full-functioning was in 2015, however, multiple crises has crippled the advancement of the construction of the General Hospital. Numerous foreign donors are involved in this $83-million-dollar project, and thus coordination has been a key issue. Between October 2013 and September 2014, it is estimated that the hospital saw more than 215,000 patients, with approximately 10% of patients hospitalized. No other hospital in Haiti is able to absorb the sheer number of patients, despite being under construction. However, since 2016, the hospital staff have been on strike, crippling most services for over a year. Strikes are due to the failure of the government to uphold their obligations to pay and raise salaries, as staff, such as nurses and doctors, were left unpaid for months at a time. The completion of the construction of the General Hospital, along with an end to the strike, which includes 19 other public health facilities, will greatly increase access to care and reduce the burden on other health facilities in the region.

Hospital Bernard Mevs Project Medishare (HBMPM)

Hospital Bernard Mevs Project Medishare (HBMPM), located in the capital city of Port-au-Prince, and described in more detail in section 2.8 of this thesis, is the premier critical-care and trauma hospital in Haiti. In the year 2014, HBMPM treated 65,000 patients, up from 60,000 in 2013. Of these patients, 2,458 were treated for trauma-related injuries, making up an average of 205 injuries per month in 2014 [82].

Doctors Without Borders (MSF) [83]

Doctors Without Borders (MSF) is a foreign non-governmental organization (NGO) which operates the Center for Traumatology and Emergency Surgery in Port-au-Prince, Haiti. MSF was established in 2012, and operates a 107-bed center. Overall, MSF has other facilities in Haiti, providing the Haitian people with 600 hospital beds for emergency care, obstetrics, gynecology, and pediatrics. Since the general strike by most major public health facilities and hospitals, MSF has seen a dramatic increase in the number of patients. The hospital beds have been continuously filled, and the center is unable to refer less severe cases to decongest its services [84]. The MSF trauma center currently has four operating rooms, however, they are unable to admit all patients with an emergency. Due to the closing of most major hospitals in the city, MSF reports receiving an average of 50 new patients per day, consisting of more than 90% trauma victims. Simultaneously, the hospital receives in ambulatory, for bandages, and consultations, approximately 150 patients daily.

2.7.11 National Level

On a national level (all 10 geographic regions and departments), a recent study published in 2015 described burden of trauma as well as the state of trauma care in Haiti. A summary of the findings is provided below.

A national trauma capacity assessment of Haiti (2015) [85]

On a national level, a trauma capacity assessment was conducted in 2014 which surveyed 12 (six tertiary and six secondary) hospitals in the 10 geographical departments in Haiti. The cross-

sectional focused on infrastructure, supplies and equipment, personnel and training, as well as procedural capabilities. The data revealed a trauma system lacking resources and structure. Of the 12 facilities surveyed, 3 had an ICU and 4 had consistent access to blood products promptly. Most facilities had regular access to radiological services, however only 1 had a CT-scanner on site. In terms of resuscitation equipment, there was a large deficiency in equipment. Only 2 facilities (both tertiary) had a general surgeon in-house at all times, however, 11 facilities had access to general surgeons on-call. All tertiary facilities had an orthopedic surgeon on-call compared with only 1 secondary facility. There were no neurosurgeons in-house, and only 2 tertiary facilities had access via on-call. 4 of the 12 facilities housed a physician with any trauma training (ATLS or equivalent). In terms of procedures performed, most facilities reported performing over 100 laceration repairs per month and treated 1 to 10 burns per month. 4 facilities treated up to 50 closed fractures per month. Secondary facilities reported an inability to treat open fractures, compared with tertiary facilities who had the necessary equipment to do so.

The study also provides basic epidemiological data the reveal that emergency rooms (ERs) across the country see large volumes of trauma. During a 1-week surveillance of trauma cases presenting to ERs, secondary health facilities treated an average of 35 trauma cases a week, and tertiary facilities 59 trauma cases a week. Adult trauma represented an average of 68% and 74% of all trauma cases in secondary and tertiary facilities in the study. Motor vehicle accidents represented, on average, 26% and 20% of all trauma cases in secondary and tertiary facilities. Trauma due to violence accounted for an average of 17% and 9% of traumatic cases in secondary and tertiary hospitals. Documentation had a high degree of variability, and the only patient information consistently recorded in the emergency room logbooks were name, age, sex, and hometown. Variables of interest including mechanism of injury, injury severity, and diagnosis were inconsistently recorded. Only 9 of 12 facilities reported the number of road traffic accidents and injuries due to violence. Time-to-treatment was infrequently recorded.

The study further revealed that none of the hospitals had implemented a trauma registry only two facilities had trauma-related quality improvement programs, and epidemiological data were gathered through ER logbooks which varied drastically in content. The study presented three major recommendations and are summarized below:

1. Infrastructure and Administration
    a. Determine the level of care to be delivered at each facility
    b. Implement a trauma registry
    c. Create a National Trauma Committee
    d. Create trauma quality improvement programs
    e. Increase capacity of care of critically injured patients

2. Physical Resources
    a. Determine essential equipment and supplies at each level of care
    b. Improve procurement and supply chains
    c. Improve distribution of resources within each health care facility
    d. Increase laboratory capabilities
    e. Increase access to blood products

3. Training and Human Resources
    a. Increase trauma training in medical schools
    b. Increase access to continuing trauma education for all medical professionals
    c. Increase training capacity of essential surgical specialties

Although all of these studies provide crucial information on the burden of trauma in Haiti, the data are not sufficient to define the burden of traumatic injuries on the Haitian people and the health system. Traumatic injuries continue to be a leading cause of morbidity and mortality in LMICs, Haiti included. Little is known about the epidemiology of trauma in Haiti, mainly the common mechanisms of trauma, severity of injury, and patterns of injuries presenting across the country. Additionally, there are no cost studies to date that measures the cost of illness on the Haitian people.

2.8 Hospital Bernard Mevs Project Medishare (HBMPM)

Hospital Bernard Mevs Project Medishare (HBMPM) currently operates in Port-au-Prince, Haiti, as the country's only hospital that offers specialized surgical capacity, critical-care capabilities, and advanced radiology all at the same site. Although no formal trauma system or network exists in Haiti, HBMPM can be categorized as a level II trauma center. HBMPM operates within a unique framework: a public-private partnership between three organizations. In 1994 HBMPM opened its doors to the public in Port-au-Prince as a pediatric and surgical specialty hospital. In parallel, Project Medishare, an NGO, was also established in 1994 with the aim of providing primary care services to the Commune of Thomonde, located in the rural Central Plateau of Haiti. In the aftermath of the January 2010 Haitian earthquake, both Project Medishare and Hospital Bernard Mevs provided critical care to the injured, acting as trauma and critical-care hospitals. In June 2010, Project Medishare shifted its operations from a tent site near the Port-au-Prince airport and into the physical plant of Hospital Bernard Mevs. The success and quality of care provided at HBMPM landed the first ever operational grant to a nongovernmental hospital by the Haitian government in 2013. This grant has been renewed each year after 2013. HBMPM thus provides an interesting case study, as it is a privately-run charity hospital, operated with the support of a foreign NGO and the Haitian government [86].

Domestic and international organizations also play a key role in the development of HBMPM, in addition to the Haitian government and Project Medishare. Various foreign-based universities, such as the University of Miami, University of Florida, University of South Carolina, and others, have greatly contributed to the creation of the infrastructure and the programs since inception. Additionally, numerous American based professional associations, such as the American Academy of Orthopedic Surgeons (AAOS) and the Accreditation Council on Graduate Medical Education (ACGME), have supported training initiatives for their residents abroad. Locally, numerous Haitian professional medical associations such as the Haitian Medical Association and the Haitian Orthopedic Surgery Society have participated in the development of HBMPM. Other players, such as the Canadian NGO Broken Earth, have also contributed greatly in the building of orthopedic and trauma surgery capacity at HBMPM following the 2010 earthquake.

HBMPM, a 50-bed hospital, currently provides services to approximately 60,000 patients per year, including outpatient clinical services. HBMPM also performs over 1,300 operations per year. New beds are currently being constructed to increase access to care, including the expansion of various departments. Private beds are being introduced in order to attract wealthier patients who are able to afford them, providing a much needed revenue source. A range of surgical services are offered at HBMPM, but some surgical services are not available at all times. Services such as general surgery, neurosurgery, orthopedic surgery, and anesthesia are available 24 hours a day, 7 days a week. Nights and weekends, however, are covered by on-call surgeons and anesthesiologists from home.

HBMPM currently hosts Haiti's four neurosurgeons, who regularly operate at HBMPM and other clinics in the Port-au-Prince area. Orthopedic surgeons also play a key role at HBMPM due to its trauma capabilities, as two orthopedic surgeons rotate on-call from home. Most non-emergent orthopedic surgeries are able to be performed during regular business hours by the emergency room staff, performing reduction, splinting, or traction as needed. HBMPM hosts one of four computed tomography (CT) scanners in Haiti, and only one is located outside of the capital city of Port-au-Prince. This greatly increases HBMPM's capacity to provide emergent neurosurgical services, potentially reducing mortality from trauma. In 2014, HBMPM and Broken Earth conducted the first week-long trauma training course, with over 80 participants. Participants included residents and attending surgeons in orthopedics and general surgery, and general principles of surgical trauma were taught. Additionally, more specific skills, such as how to place internal fixation rods and screw plates into varying bones, using donated models, were taught. Education continues to be a key part of HBMPM going forward, as there are hopes to have Haiti's first ever residency program in neurosurgery at HBMPM. This program hopes to double from 4 the country's neurosurgeons over the next decade, and is aimed at residents who have completed the 5-year general surgery residence. Two extra years of residency will be required, under the supervision of the neurosurgeons who regularly operate at HBMPM, in addition to working with foreign medical teams that participate at HBMPM.

2.9 Costs at HBMPM

Surgical care comes at high cost regardless of a nation's economic standing. Meeting and sustaining costs, however, is a major challenge in developing countries. This challenge is particularly daunting in low-income countries due to many patient's inabilities to afford healthcare. Previous research has revealed that although labor costs in developing countries tend to be significantly cheaper than developed countries, they are in proportion with the price index in that particular area, limiting the ability of patients to afford and access surgery [87,88]. Supplies and medication are also responsible for a bulk proportion of costs, surpassing the proportion absorbed by salaries, according to a study done across Hospitals in Malawi [88]. Pharmacy costs tend to be the largest driver of costs in that region. One of the main reasons for the high costs of medical supplies in low-income countries is the inability of these countries to locally produce and supply. A select few countries that have been able to produce locally have managed to lower the price of drugs, though these countries are middle-income countries [89-91].

At HBMPM, anesthesia gas used is one of the main drivers of costs in surgical care, accounting for as much as 25% of the surgical costs of any given case [86]. Surgeries at HBMPM cost the hospital from $200 USD for open biopsies under anesthesia to $800 USD for colectomies and neurosurgical procedures. HBMPM relies on the donated supplies and foreign volunteer surgical teams, but also have various methods to recuperate cash in order to pay staff and amenities. Approximately one third of the budget is covered by patient revenues. Patient revenues at HBMPM tend to vary widely, as patients pay according to a sliding scale based on means. The poorest tend to pay minimally or not at all, while wealthy Haitians belonging to the middle or upper-class, as well as expatriates, are asked to pay a premium at costs that reflect the level of quality of care. The construction of private hospital rooms at HBMPM represents an effort to increase revenues stemming from wealthy Haitians in order to supplement the care of the poor. Other sources of revenue come from fundraisers via philanthropic sources organized by both HBMPM and the NGO partners, both abroad and in Haiti. For certain procedures such as hydrocephalus, cleft lip/palate, and for breast cancer patients, Project Medishare has used online crowd-source fundraising. Additionally, government grants are used to start new programs deemed necessary as well as to fund overlapping pieces of care. The support of the government has been crucial in keeping the

hospital functional, and confirms the commitment of the government to place health care as a primary goal in the reconstruction of Haiti, especially in surgical capacity and critical care.

The costing and payment process at HBMPM is complex. Patients are first received through the emergency room (ER) or Triage. The first payments due are largely for charts and laboratory procedures. If a patient is not able to pay on site, the HBMPM administration is able to grant an authorization form where the patient is admitted with credit. Patients are informed that everything put on credit will have to be paid when the patient is dismissed. A detailed list of all procedures done for each patient at the hospital is entered into the system, whether or not they are paid via cash or credit. It is estimated that for primary care, in minor cases where hospitalization is not needed, the vast majority of patients are able to pay. For those who are unable to pay, the patient is often given time to gather funds to pay, but are ultimately exonerated if they are unable to, representing a loss to the hospital. For major cases, or cases that need hospitalization, an estimated half of patients are able to pay fully. The remaining patients are encouraged to pay what they can, which can represent anywhere from 75% to 25% or less of the total cost. Alternative methods of payment include encouraging the patient to sign documents that require them to come back at a later date to make payments. The majority of patients do not come back to pay, but there are a few who do return and pay a percentage of the fees owed or fully pay. This uncertainty of payment represents a major burden for HBMPM. In response, in certain cases, when an admitted patient is stable and able to be transferred, HBMPM is able to transfer patients to free hospitals, contingent on room and if the hospital agrees. This procedure is done if a patient is unable to pay at all, otherwise HBMPM incurs the loss. Regarding pediatrics, generally, patients admitted have the most difficulty paying. This burden is partially reduced with the continuous donations made by individuals or companies, as well as by donations of medical materials, but is nowhere near the total loss HBMPM incurs per year.

3. Objectives

This thesis has four primary objectives: To describe the epidemiology of traumatic injuries at HBMPM in Haiti, to determine the economic and social burden of disease of traumatic injuries at HBMPM in Haiti, to conduct a cost-effective analysis of implementing better traffic enforcement, and to conduct a cost-effective analysis of a trauma hospital and trauma care. The objectives are further explained in detail below.

3.1 Objective 1: To describe the epidemiology of traumatic injuries

a. Prevalence by
- Patient Parameters
  - Age
  - Gender
- Time characteristics
  - Traumatic injury by time of the day
  - Traumatic injury by day of the week
  - Time of admission
- Place of Injury Occurrence
  - Home
  - Street/Highway/Road
  - School/Education
  - Farm
  - Industry/Construction
  - Countryside
  - Commercial/Work
  - Other
- Mechanism of Injury
  - Vehicle
  - Fall
  - Burn
  - Stab/Cut
  - Gun Shot
  - Crush
  - Animal Bite
  - Drowning
  - Other
- Injury Intentionality
  - Intentional
  - Unintentional
- Security Measures
  - Safety Devices

        - Alcohol Consumption
    - Medical Documentation
        - Medical Documentation
        - Trauma Registry Form
        - Documentation of Vitals

b. Injury Characteristics
- Number of Injuries
- Anatomical Regions of Injury
- Blunt vs Penetrating
- Level of Consciousness (AVPU)
- Severity Measured by the Abbreviated Injury Score
- Severity Measured by the Injury Severity Score
- Traumatic Brain Injury Severity

c. Health Care Services
- Method of transportation to the hospital
- Time between injury and admission
- Surgery Performed

d. Outcomes
- Discharge Status
    - Alive
    - Dead
    - Transferred
    - Ran Away
    - Rehab Facility
- Initial Disposition from the Emergency Department
    - Treated and Sent Home
    - Admitted
    - Transferred
    - Dead on Arrival / Died in ER
    - Refused Treatment
- Length of Stay

3.2 Objective 2: To determine the economic and social burden of disease of traumatic injuries

a. Direct medical costs
b. Indirect costs
c. Intangible costs
d. Years of Potential Life Lost (YPLL)

3.3 Objective 3: To conduct economic evaluations of designed interventions on injury prevention

a. Cost-Effectiveness of Improved Traffic Enforcement

3.4 Objective 4: To conduct economic evaluations of designed interventions on trauma care

a. Cost-Effectiveness of a Trauma Hospital in Port-au-Prince, Haiti

4. Study Design and Methodology

4.1 Objective 1: Epidemiology of Traumatic Injuries

4.1.1 Study Design

This retrospective, hospital-based, and cross sectional chart review study was conducted for the period December 1, 2015 to January 31, 2016, at Hospital Bernard Mevs Project Medishare (HBMPM), located in the capital city of Port-au-Prince, Haiti.

4.1.2 Inclusion/Exclusion Criteria

All patients presenting for evaluation and treatment of traumatic injuries during the study period were eligible for inclusion. Traumatic injuries were identified as "an injury or wound to a living body caused by the application of external force or violence" [92].

4.1.3 Data Collection and Procedures

Data were obtained through review of the hospital's main patient logbook, patient medical charts, and trauma registry forms. The main patient logbook contains basic patient information including: date of presentation, age, gender, symptoms/ diagnosis, and reason for evaluation. Patient medical records are maintained in the hospital's archives department and are filed by name and unique medical record numbers. All patient medical records were retrieved with the assistance of HBMPM staff on-site.

Patients included in the study were first identified using symptoms/diagnosis and reason for evaluation found in the main patient logbook, and their respective medical records were then extracted for confirmation of a traumatic injury and for further data collection. Patients with non-traumatic injuries were subsequently excluded. Trauma registry forms were introduced at HBMPM in 2010 and are available in the emergency department. These forms provide demographic information, admission and injury date and time and discharge date and status,

mechanism of injury and place of injury, severity of trauma through baseline vitals, level of consciousness, number and type of injury, and whether surgery was performed (Appendix 1 & 2). These forms are stored in each patient's medical dossier if completed. All charts were reviewed regardless of whether a trauma registry form was present, in order to capture all data and to identify discrepancies. If no medical chart or trauma registry form was available, basic data presented in the main patient logbook were extracted.

4.1.4 Injury Scores

Injury scores were derived uniquely from patient medical records through patient diagnoses. The Abbreviated Injury Scale (AIS) 2005 (Update 2008) was used to calculate injury severity [93]. The AIS is an anatomically-based, consensus-derived, global severity scoring system that classifies each injury by body region according to its relative importance on a 6-point ordinal scale (1 = minor, 2 = moderate, 3 = serious, 4 = severe, 5 = critical, and 6 = maximal or unsurvivable). Body regions are grouped into the following categories: Head, Face, Neck, Thorax, Abdomen, Spine, Upper Extremity, Lower Extremity, and External/Other. The Maximum AIS (MAIS) is also presented and represents the highest (i.e., most severe) AIS code in a patient with multiple injuries. The Injury Severity Score (ISS) was also calculated and represents the sum of the squares of the highest AIS scores in three different body regions. Additionally, for traumatic brain injuries (TBI) and head injuries, a separate classification was used. The injury severity classification of TBI developed by Brasure et al. (2013) [94] was used to classify head injuries. The criteria used to classify TBI severity include the following: structural imaging, loss of consciousness, post traumatic amnesia, the Glasgow Come Scale (GCS), and the AIS score for head injuries (Appendix 3). Data on anatomical region of injury were categorized into blunt or penetrating injuries. Patients with both blunt and penetrating injuries to the same anatomical region were marked as penetrating. Multiple injuries to the same anatomical region were indicated as a single injury to the respective anatomical region in this study.

4.1.5 Statistical Methods

All data analysis and descriptive statistics were conducted using SPSS MAC, version 22.0 (SPSS

Inc., Chicago, IL, USA). Mean values were reported with standard deviations (SD) and median values with interquartile ranges (IQR). IQR describes the difference between the third quartile (Q3) and the first quartile (Q1), telling us about the range of the middle half of the scores in the distribution. Temporal variations in injury patterns were explored using linear regression analysis (95% confidence interval).

4.1.6 Ethical Clearance

This study was approved by Hospital Bernard Mevs Project Medishare administration and the Institutional Review Board of McGill University (Study number: A06-E46-17A).

4.1.7 Conflict of Interest

None to be declared.

4.2 Objective 2: The Economic and Social Burden of Traumatic Injuries

4.2.1 Study Design

Patient cost data were extracted from the HBMPM administration during the study period December 1, 2015 to January 31, 2016. Cost data retrieved from patient hospital bills included direct medical costs incurred by each patient at HBMPM.

4.2.2 Inclusion/Exclusion Criteria

All patients presenting for evaluation and treatment of traumatic injuries during the study period were eligible for inclusion, as previously described above (section 4.1.2).

4.2.3 Statistical Methods

All data analysis and descriptive statistics were conducted using SPSS MAC, version 22.0 (SPSS Inc., Chicago, IL, USA). Mean values were reported with standard deviations (SD) and median values with interquartile ranges (IQR). Statistical comparisons were analyzed with analysis of variance (ANOVA) and Pearson's correlation tests. Significance was taken as $p < 0.05$.

4.2.4 Patient Perspective and the Human Capital Approach

The economic burden of injury was measured from the patient's perspective. All costs incurred by patients associated with evaluation or treatment of traumatic injuries were reported. Costs were divided into three sections: direct medical costs, indirect costs, and intangible costs. Costs were calculated in Haitian Gourdes (HTG) and subsequently converted to US dollars. At the time of study, the exchange rate for a US Dollar was approximately 60 HTG. Direct non-medical costs were not calculated in this study, which typically include, but are not limited to, administration costs (i.e., medico-legal costs, cost of police activity and insurance administration, property damage, funeral costs, transportation, non-medical material costs, and food and accommodation) [39]. Years of Potential Life Lost (YPLL) were also calculated in this study.

4.2.5 Direct Medical Costs: Micro-Costing Approach

Direct medical costs were retrieved from patient hospital bills. Direct medical costs included consultation, hospitalization, radiology/diagnostic tests, pharmacy, rehabilitation, suture/wound care, and surgical costs. All patients seen at HBMPM are charged medical consultation fees, regardless of type of injury. The minimum fee is $4. All costs were rounded to the nearest dollar during conversion. Consultation costs range from $4 for wound care to $8 for a specialist's visits. 2nd visits cost only a fraction of 1st visits. Table 2 outlines consultation prices.

Table 2. Consultation costs. All costs are rounded to two decimal places during conversion.

Consultation Type	1st Visit	2nd Visit
General, Gynecology, Pediatrics, Ophthalmology, Dermatology, Orthopedics, and ER visit (chart)	$6	$4
General Surgery, Neurosurgery, ORL	$8	$5
Wound Care	$4	$1
Suture	$5	

All patients hospitalized are charged a $17 fee. In addition, patients are charged for each day hospitalized. Table 3 outlines hospitalization prices.

Table 3. Hospitalization costs per day.

Hospitalization	Per Day
Admission (one-time fee)	$17
Intensive Care Unit	$17
Private Room 1	$50
Private Room 2	$150
Private Nurse	$50
Pediatrics	$4
Medical Surgical Bed A	$4
Medical Surgical Bed B/C	$8

Radiology prices including CT-Scan, X-Ray, EKG and Sonography are listed below. For use of the CT-Scanner and X-Ray machine, patients are charged a set price for first time use, and a portion of the cost for additional uses, if necessary. CT-Scanner prices are priced in USD, and are converted into HTG by the administration. In the study, prices charged for the use of the CT-Scanner ranged from $169 to $238. Table 4 outlines radiology prices.

Table 4. Radiology and diagnostic costs.

Radiology	1st Use	Additional Use
CT-Scan	$220	$80
X-Ray	$17	$6
Sonography	$21	
EKG	$42	

Surgical costs vary widely depending on procedure and range from $333 to $833 for the most expensive procedures which require specialized services. Table 5 outlines some of the most frequently occurring procedures undertaken in the study cohort.

Table 5. Surgical costs by procedure.

Surgery and Orthopedics	Per Procedure
Fixateur Interne	$500
Craniotomy	$667
Tracheotomy	$667
Fracture (Reduction and Internal Fixation)	$667
Open Fracture	$667
Mandibular Fracture	$667
Tibia Fracture	$667
Dynamic Hip Screw	$667
Eye Surgery	$833

Rehabilitation costs include consultations for rehabilitation and various equipment. Table 6 outlines some of the prices associated to rehabilitation services offered at HBMPM.

Table 6. Rehabilitation and equipment costs.

Rehabilitation	Price
Evaluation / Consult	$5
Evaluation / Consult In-Patient	$8
OP Visit	$5
Stoke Visit	$5
Crutches	$8
Wheelchair	$13

Pharmacy and laboratory costs vary widely at HBMPM. Although laboratory costs are broken down by unit in each patient bill, all laboratory costs for patients were aggregated. Pharmacy costs are not broken down by unit and represent the total pharmacy bill incurred by the patient. Detailed

pharmacy prices and units consumed by each patient are available at HBMPM but were not used for this study. Pharmaceutical costs for each patient were aggregated and presented in the findings.

4.2.6 Indirect Costs: Productivity Losses

Indirect costs consist of each individual's lost productivity and ability to work, and are therefore losses in societal productivity. In this study, loss of productivity due to injury and treatment were calculated using the human capital approach, and estimated by the product of the days off work (i.e., hospitalization) over the study period and the minimum daily salary in Haiti, as mandated by the government. The working age included in this analysis is age 15 (the minimum working age) to age 63 (the average life expectancy in Haiti), inclusive [95,96]. Patients who were treated and sent home were excluded from this analysis. Indirect costs are divided into two sections: morbidity costs and mortality costs.

Morbidity costs were calculated as patient productivity losses due to hospitalization. The following formula was used:

SUM [Length of Stay X Daily Haitian Minimum Wage]

Where: *Length of Stay (LOS) is computed as days of hospitalization*
Daily Haitian minimum wage: $5.83 [97]

The total average loss of productivity for a fatal injury is the sum of each future year's lost output. For fatal injuries, the following formula was used:

$$\text{Loss of productivity} = \text{SUM}\left[w\,(1+g)^{\wedge i} / (1+r)^{\wedge i}\right]$$

Where: *w = average annual GDP per capita*
r = discount rate
g = growth rate of the economy
i = average number of years lost per traumatic injury.

The average annual GDP per capita used was $829, according to the World Bank [98]. The discount rate used was 0% (base case), 3%, and 5%. The growth rate of the economy was calculated at 0% (base case), 1.7% (GDP growth rate in 2015) [99], and 2.2% (estimated annual GDP growth rate for

year 2020) [100,101]. The average number of years lost per fatal injury was 27 years, calculated as the current average life expectancy in Haiti minus the average age of people who died due to injury in the study cohort.

4.2.7 Intangible Costs

Intangible costs (i.e., pain, suffering, and grief) attempt to quantify the social and emotional burden trauma victims and their families experience. Intangible costs are difficult to quantify as there is no database to estimate the value at the national level; however it is widely recommended to consider the figure accepted by the Asian Development bank and the International Road Assessment Programme, which amounts to 28% of total lost income [102]. For example, a patient hospitalized for 1 day will incur an indirect cost of $5.83 (daily minimum wage) and an intangible cost of $1.63 (28% of lost income). For fatal injuries, intangible costs amount to 28% of mortality costs at base case.

4.2.8 Years of Potential Life Lost (YPLL)

Years of potential life lost (YPLL) was calculated in this study to estimate the number of premature deaths due to traumatic injuries at HBMPM, expressed as years of life lost. YPLL is a method developed by the Center for Disease Control and Prevention in the United States [103]. YPLL is calculated as the sum of the differences between a predetermined end point and the ages of death for those who died before that point. The two most commonly used end points are age 65 years and average life expectancy. The use of YPLL implies a value system in which more weight is given to a death when it occurs at an earlier age, thus death at older ages are "devalued." In this study, the endpoint used is 63 years of age, which is average life expectancy in Haiti [95]. The following formulas were used:

$$\text{For each individual: } YPLL_{individual} = \text{end point} - \text{age at death}$$

$$\text{Sum of the individuals YPLLs: } YPLL = \sum YPLL_{individual}$$

4.3 Objective 3: Modelling the Cost-Effectiveness of Improved Traffic Enforcement

4.3.1 Study Design

This section aims to model the cost and effectiveness of improved traffic enforcement in Port-au-Prince, Haiti. The study design is modelled after Bishai and Hyder (2006), which measured the cost and effectiveness of injury interventions in low and middle-income regions [104]. The government perspective is adopted for this intervention, as any new program will likely need to be cost-neutral or cost-saving in order to be considered by government officials. In this study, the time horizon is one-year of intervention. Traffic enforcements refers to the strengthening of traffic regulations with increased penalties and more frequent citations for violations such as reckless driving and violating helmet and seatbelt laws. The intervention requires three key components: legislative change to implement penalties, media coverage to educate road users, and enforcement of traffic codes. Some of the following assumptions were modified to reflect conditions and costs in Haiti for more precise country measurements as opposed to regional estimates.

4.3.2 Costs and Assumptions

Legislative Costs

Legislative costs in this study are considered to be marginal, as existing laws in Haiti are already in place that reflect modern road traffic codes. No additional legislative changes are needed for the intervention.

Media Coverage Costs

Previous literature puts media promotion as an integral component of population compliance with road traffic codes [105]. In order to estimate media coverage costs, previous estimates in the literature are used, as there is no global database of media coverage costs by country or region [104].

Traffic Enforcement Costs

For traffic enforcement costs, the government perspective is adopted due to the importance to legislators deciding to enact traffic enforcement, as citations yield revenue. However, from a societal perspective, traffic enforcement costs such as policemen salaries as well as revenue from citations are opportunity costs that may be used for other purposes.

Cost Assumptions

Costs reflect sustaining traffic enforcement for one year per million inhabitants. Costs are expressed in US dollars, valued at 60 HTG per USD, prevailing exchange rates in January 2016 (Table 7). The following assumptions are made:

1. One policeman is required for every 5,000 vehicles. [104]

2. A policeman must cite 1 in every 3 vehicles per year (5 to 10 tickets per day).

3. The salary of one policemen is equal to the salary of a level 3 agent, namely $393 per month. [106]

4. One police vehicle is shared by every 2 policemen. One vehicle is valued at $25,000,with a cost of $5,000.00 per year (using straight-line depreciation). [107]

5. All existing traffic policemen are working and citing at full capacity, and that only 50% of the personnel needed for traffic enforcement is available in the current workforce. Hence, the only way to increase enforcement of traffic codes is to hire additional units. [104]

6. The number is vehicles per million persons is taken from the Office of Vehicle Insurance Against Third Party (OAVCT), Haiti's public body responsible for mandatory vehicle insurance. [108]

7. Data from the Institute for Health Metrics and Evaluation is used to estimate the number of deaths due to road traffic accidents in Haiti. [109]

8. Disability adjusted life years (DALYs) were estimated using a 1:1 ratio of deaths and those permanently disabled. A disability weight of 0.3 was used for every year lived with permanent disability. DALYs were discounted at 0%, 3%, 6%, and 10%. [104,110]

9. Traffic deaths and permanent disabilities are assumed to occur at a mean age of 20, with a national average life expectancy of 63 years. [95]

10. The intervention is expected to reduce traffic fatality by 25%. [104]

Table 7. Model assumptions and costs of sustaining traffic enforcement for one year per million persons.

Assumptions	
Vehicles per million persons	35,000
Baseline deaths per million persons	237
Baseline DALYs lost per million persons (0% Discount Rate)	13,248
Traffic policemen required	4
Costs	
Policemen Salary	$18,816
Police Vehicle Costs	$10,000
Media Costs	$3,500
Legislative Costs	$0
Total Enforcement Costs (1-Year)	$32,316

4.4 Objective 4: Cost-Effectiveness of a Trauma Hospital in Port-au-Prince, Haiti

4.4.1 Study Design

This section aims to model the cost and effectiveness of a trauma center in Port-au-Prince, Haiti. The study includes patients presenting for evaluation and treatment of traumatic injuries during the 2-month study period from December 1st, 2015 to January 31st, 2016, described in detail previously.

Disability-adjusted life years (DALYs) were calculated for each patient seen and treated for traumatic injuries during the study period. Long term disability weights from the 2013 Global Burden of Disease (GBD) study were used [111]. In order to calculate DALYs and DALYs averted due to surgery or care for each patient, the McCord and Chowdhury method was used [112], but with simplified estimates of risk of death or permanent disability, and effectiveness of treatment (Table 8). This adjusted method was followed by various researchers [113-117]. Below are a few examples of DALY calculations for select cases:

Table 8. Scoring system.

Severity of Disease	**Weight**
>95% fatal or disabling without treatment	1.0
<95% and >50%	0.7
<50% and >5%	0.3
<5%	0
Effectiveness of Treatment	
>95% chance of survival or cure	1.0
<95% and >50%	0.7
<50% and >5%	0.3
<5%	0

Example 1. Successful laparotomy for a 20-year old with a penetrating abdominal wound would avert:

43 (YLL at age 20) X

1.0 (probability of death/disability if untreated >95%) X

1.0 (probability of treatment preventing death/disability >95%) X

1.0 (disability weight equal to 1 as the injury is considered life threatening)
= 43 DALYs averted

Here, 43 is the years of potential life lost for a 20-year old as per the national expected life expectancy in Haiti.

Example 2. Successful surgery for a 25-year old with a tibia fracture would avert:

38 (YLL at age 35) X
0.7 (likelihood of permanent disability without treatment between <95% and >50%) X
0.7 (likelihood of treatment success between <95% and >50%) X
0.055 (disability weight for tibia fracture, long-term, with or without treatment)
= 1.02 DALYs averted

Example 3. Successful treatment for a 20-year old with a forearm laceration would avert:

43 (YLL at age 20) X
0 (likelihood of permanent disability without treatment <5%) X
1.0 (likelihood of treatment success >95%) X
0.006 (disability weight for open wound, short-term, with or without treatment)
= 0.0 DALYs averted

Years of Life Lost (YLL) was not discounted and conservative estimates of DALYs and DALYs averted were used. If disability weights were unavailable, cases were excluded from the calculation. It was assumed that all patients with major abdominal/chest injuries and those undergoing craniotomies would have died without treatment (i.e., severity of disease weight of 1), and that treatment was successful in preventing death (i.e., effectiveness of treatment weight of 1), unless patients died. Patients with minor lacerations and contusions generally did not incur any DALYs, thus no DALYs were averted. For traumatic brain injuries, minor/mild brain injuries did incur DALYs, however no DALYs were averted. Moderate brain injuries had a disability weight of 0.231, a severity of disease weight of 0.3, and an effectiveness of treatment weight of 0.7. Severe

brain injuries had a disability weight of 0.637, a severity of disease weight of 0.7, and an effectiveness of treatment weight of 0.3.

4.4.2 Costs and Assumptions

HBMPM provides services to approximately 60,000 patients each year, and only a fraction (less than 10%) of these patients are evaluated and treated for traumatic injuries. Thus, simply taking the fixed and operating costs for the entire year at HBMPM and dividing it over the study period will not reflect actual costs and consumption of materials. Costs were divided into fixed and variable or operating costs. Fixed costs were obtained from HBMPM's official financial statement for the year 2014, the latest version available to the public. Variable or operating costs were extracted from official patient hospital bills, in order to reflect actual consumption within the study interval. For example, for surgery, prices charged to patients are computed as packages, which reflect the approximate materials used, based on other similar cases, physician/surgeon and nurse average salaries, and other incurred costs. The majority of surgeries at HBMPM are conducted by employed surgeons, however, for more specialized cases (e.g., neurosurgery), external surgeons are contracted on a regular basis and are paid on a case-by-case basis. These payments are also included in the surgical package charged to patients. The same assumption used above is applied the remaining variable and operating costs (e.g., consultation costs reflect physician wages and materials used). Fixed and variable costs are further described below.

Fixed costs related to general and administrative costs include the following: salary and related expenses for administrative staff, renovation and repair, bank service charge, computer related expenses, office supplies, rent, travel, shipping and related expenses, utility and telephone, postage and delivery, and other expenses.

Variable and operating costs include the following: consultation, hospitalization, radiology/diagnostic tests, pharmacy, rehabilitation, suture/wound care, orthopedics and surgical costs.

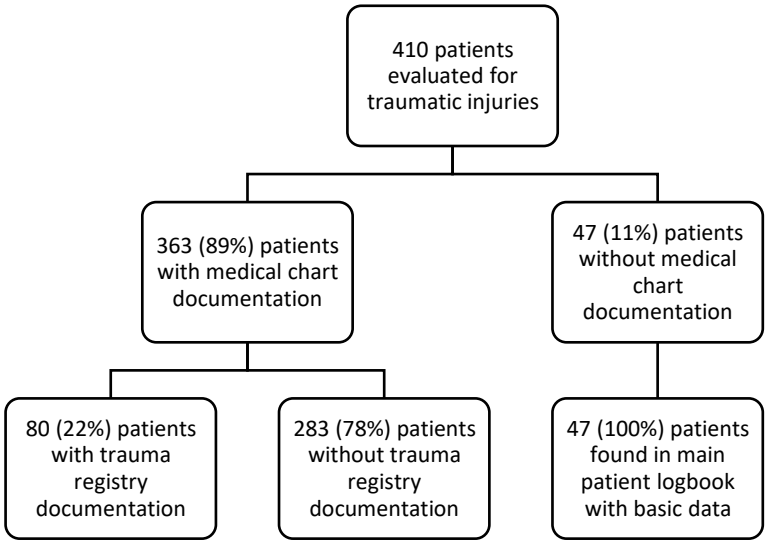
5. Results

5.1 Objective 1. Epidemiology of Traumatic Injuries: Findings

5.1.1 Study Population and Documentation

During the two-month study period, a total of 410 patients were evaluated for traumatic injuries at HBMPM. There was medical record documentation for 363 (89.0%) patients. Medical documentation for 47 (11.0%) patients were unable to be analyzed, as files were either unavailable for review or missing. For these patients, basic data presented in the main patient logbook were extracted. Of the 363 patients with medical documentation, 80 (22.0%) had a trauma registry form present. The findings are presented in Figure 4. Overall, there was major variability in data capture in the medical dossiers and trauma registry forms. The vast majority of trauma registry forms were filled in French, as the French version was widely used at HBMPM. Three categories were consistently left unfilled and were not able to be analyzed in the trauma registry forms examined, including: "3 most severe injuries," "age in months," and "additional comments/observations." Children with less than 1 years of age were consistently marked as "0" in the trauma registry forms, thus the field "age in months" was left blank for all trauma registry forms examined.

Figure 4. Study population and documentation



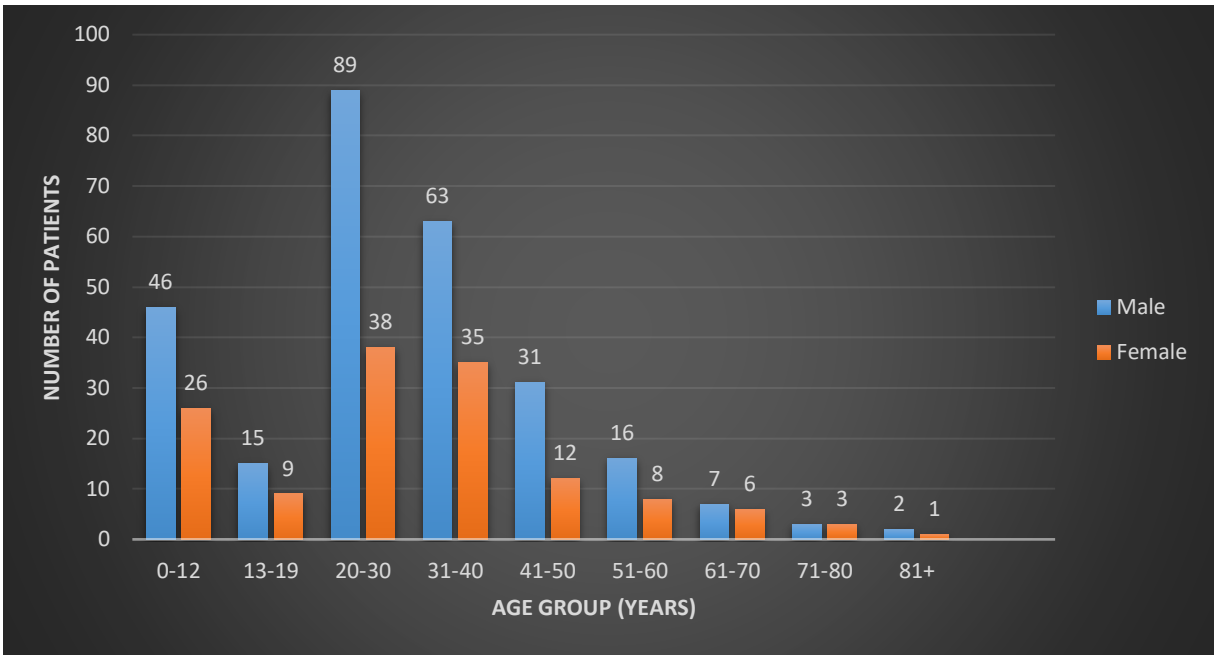
5.1.2 Study Demographics

The median and mean age in the overall population was 30 years (SD = 17.0; IQR = 18). The majority of patients presented with traumatic injuries were male (66.3%) and less than 41 years of age (78.4%). Children aged less than 13 years represented 17.6% of the study population. The findings are presented in Table 9 and Figure 5.

Table 9. Study demographics.

Age in Years	30.0 (mean); 30.0 (median); 18 (IQR)
Age Ranges	**N (%) out of 410**
0-12	72 (17.6%)
13-19	24 (5.9%)
20-30	127 (31.0%)
31-40	98 (23.9%)
41-50	43 (10.5%)
51-60	24 (5.9%)
61-70	13 (3.2%)
71-80	6 (1.5%)
81+	3 (0.7%)
Missing	0
Gender	**N (%) out of 410**
Male	272 (66.3%)
Female	138 (33.7%
Unknown	0 (0%)
Missing	0 (0%)

Figure 5. Distribution of patients admitted for traumatic injuries by age group and gender (n = 410).



5.1.3 Time Characteristics of Traumatic Injuries

A total of 213 and 197 patients presented for treatment of traumatic injuries in December 2015 and January 2016, respectively, representing an average of 6.6 injuries per day. Figures 6 & 7 illustrate the frequency of traumatic injuries based on each day of month.

Figure 6. Number of patients evaluated per day in December 2015 (n = 212).

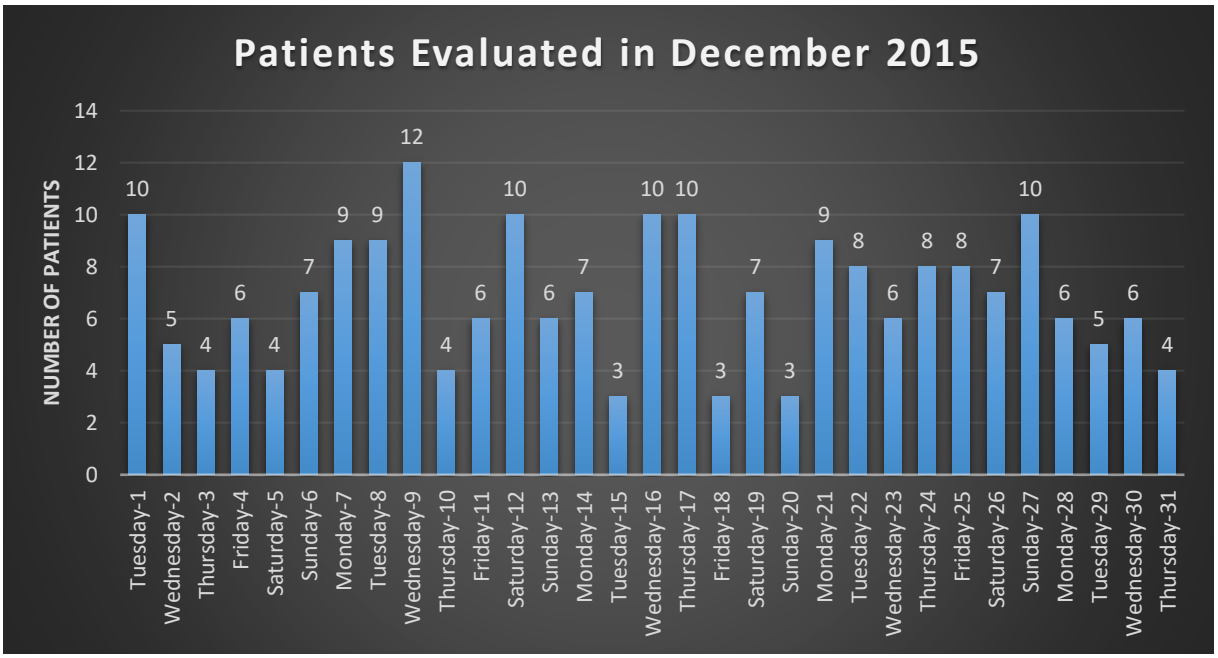
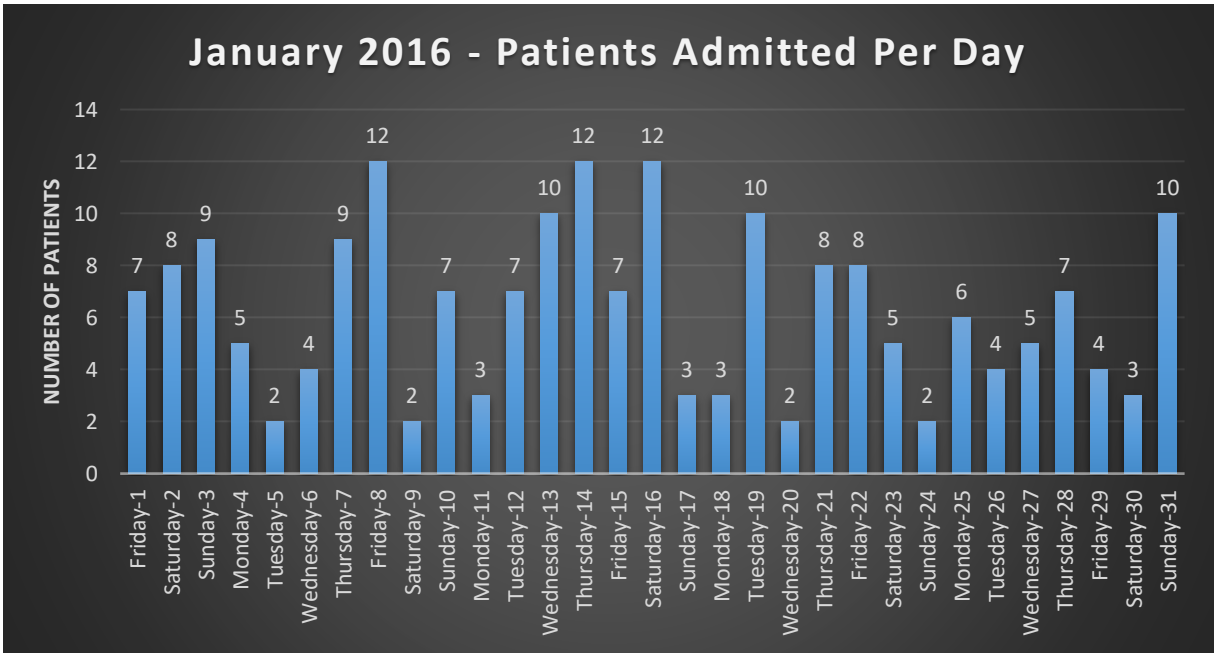
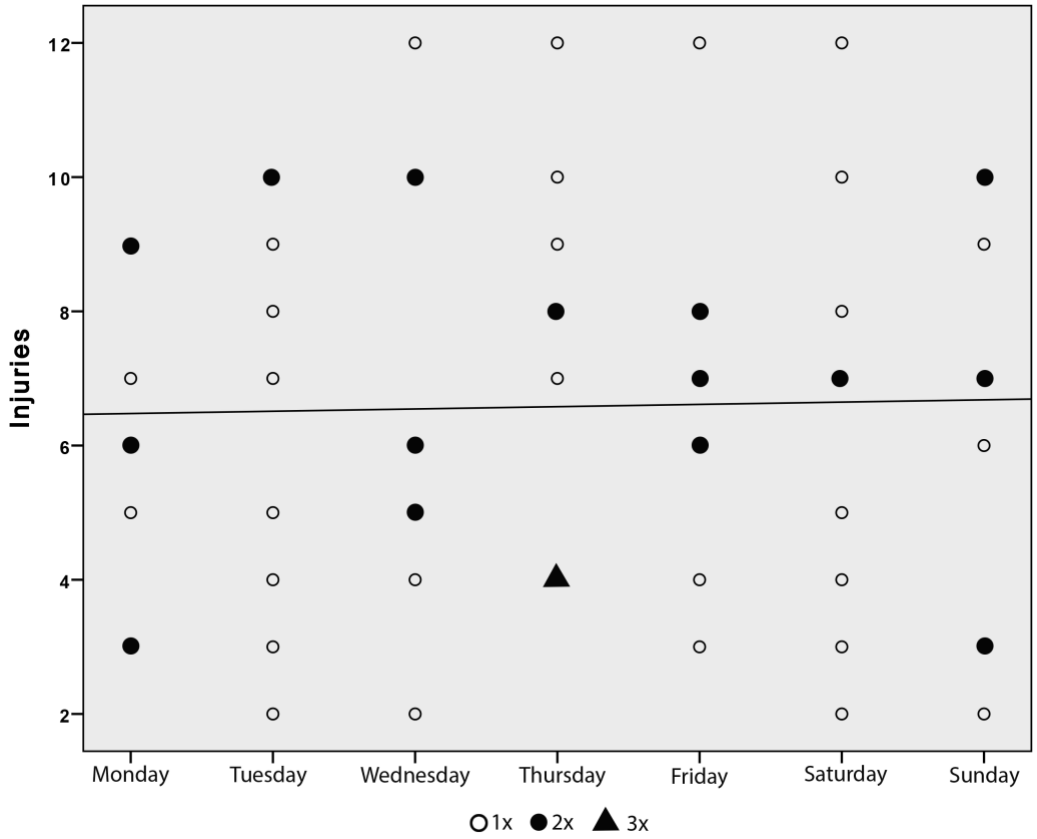


Figure 7. Number of patients evaluated per day in January 2016 (n = 196).



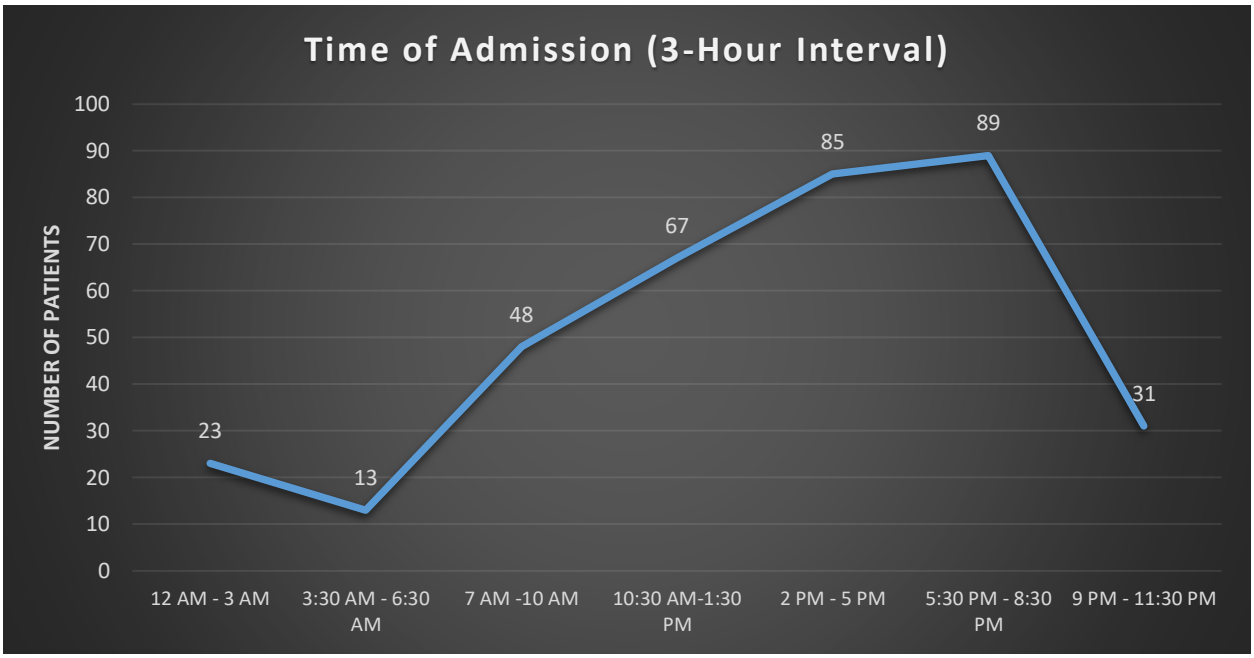
Additionally, temporal variations in injury patterns were explored using linear regression analysis (95% confidence interval). There was no correlation between the day of the week and the frequency of traumatic injuries ($R^2 = 0.02$; Figure 8).

Figure 8. Frequency of traumatic injuries by day of the week. Line shown represents linear regression with a 95% confidence interval (R^2 = 0.02).



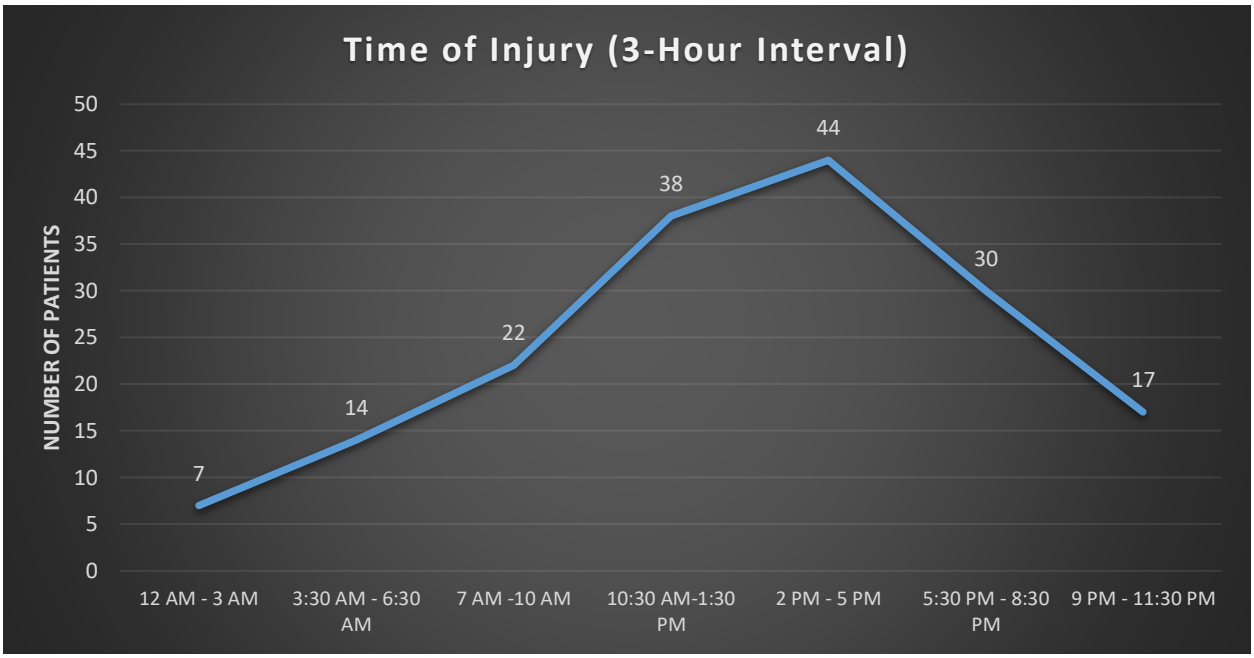
Time of admission was available for 356 (86.8%) patients in the study cohort. Time of admission was rounded to the nearest half-hour during data collection. For example, if a patient was admitted at 8:14 PM, they were noted down as an 8:00 PM admission in the study. Conversely, if a patient was admitted at 8:15 PM, they were noted down as admitted at 8:30 PM. The resulted data was then aggregated and presented here as time of patient admission, measured in 3-hour intervals. The majority of patients were admitted during daytime hours, with a steady rise which began at sunrise, a peak in the late afternoon, and a sharp decline during the night. The findings are presented in Figure 9.

Figure 9. Time of admission calculated in 3-hour intervals (n = 356).



Time of injury was available for 172 (42.0%) patients in the study cohort. Time of injury was inconsistently recorded, as patients often had difficulty accurately recalling when they had a traumatic injury. Time of injury was infrequently known and noted in patient medical charts, and in the cases where they were noted, they represented ballpark estimates. Patients tended to give rounded estimates, such as "half hour ago," "1 hour ago," or "24 hours ago." The resulted data was then aggregated and presented here as time of patient injury, measured in 3-hour intervals. The findings are presented in Figure 10.

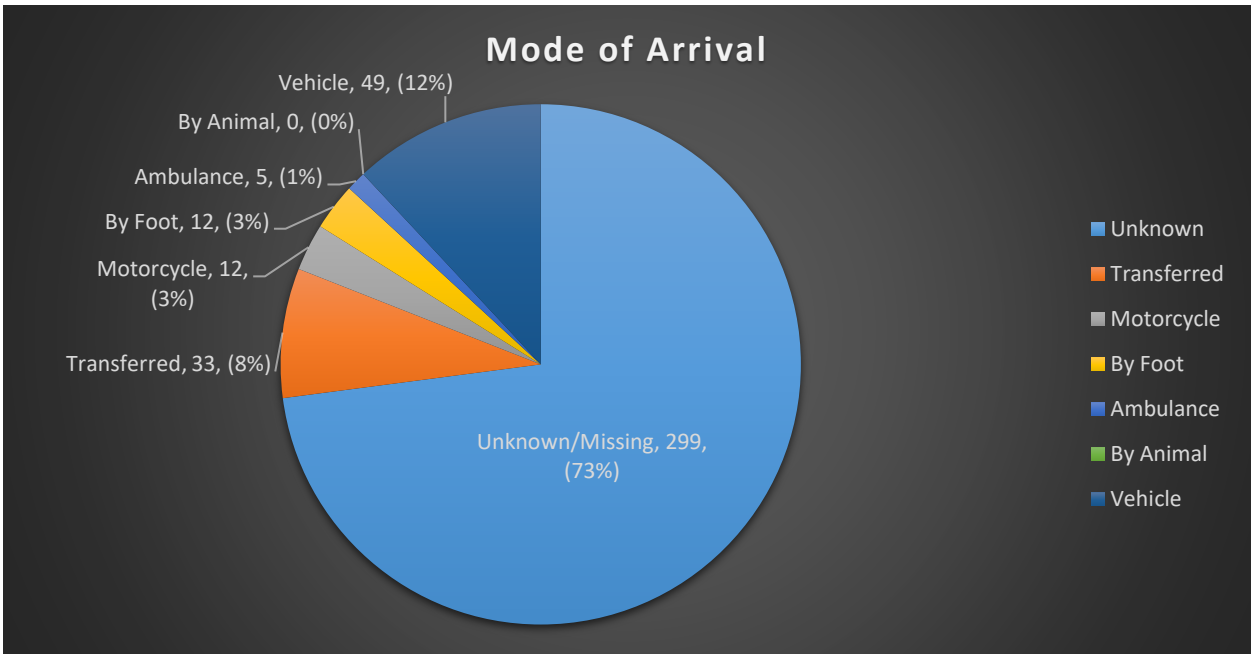
Figure 10. Time of injury calculated in 3-hour intervals (n = 172).



5.1.4 Mode of Arrival and Time-to-Treatment

Time-to-treatment data was available for 170 (41.5%) patients in the study cohort. Time-to-treatment was calculated using the difference between time of admission and injury time. The mean (SD) and median (IQR) time to treatment for all traumatic injuries was 4.3 (7.4) and 2.0 (3.1) hours, respectively. Mode of arrival data was available for 113 (27.6%) patients in the study cohort. Mode of arrival was inconsistently recorded, except in cases where a trauma registry form was present. Of 113 (27.6%) patients with mode of arrival documentation, transportation via vehicle was the most common (43.4%). 5 (4.4%) patients reported arriving via an ambulance. 33 (29.2%) patients were transferred from another hospital or facility via an ambulance. This number is high due to HBMPM being a national referral center for traumatic injuries. The findings are presented in Figure 11.

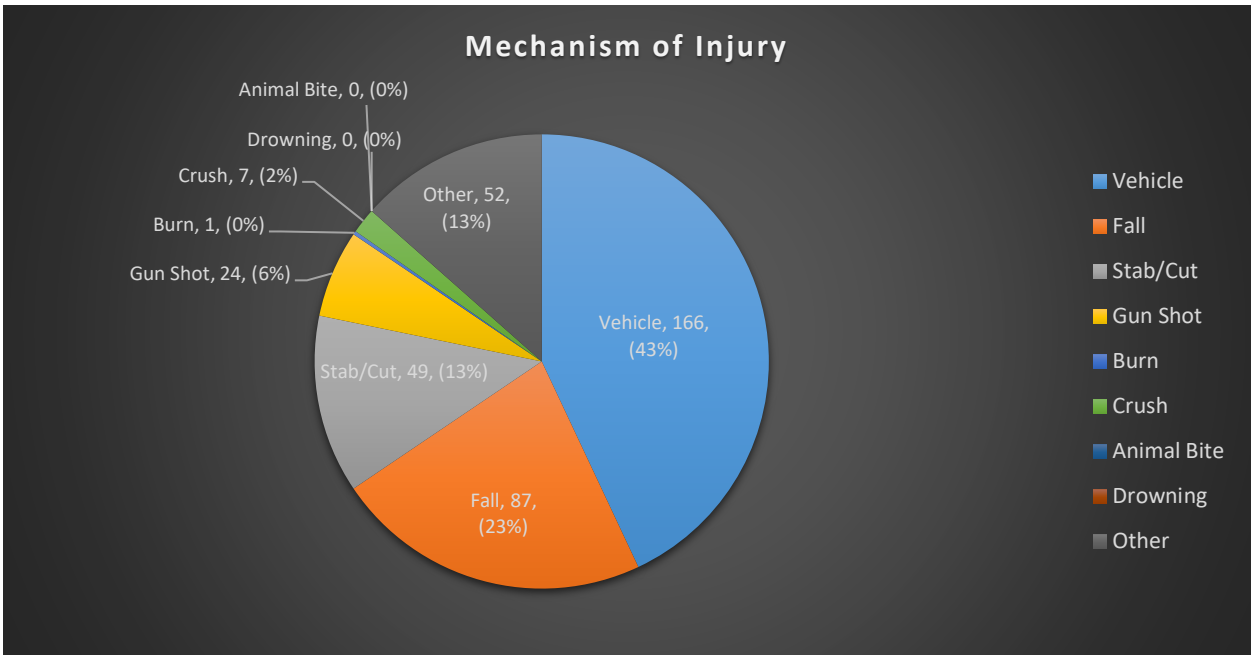
Figure 11. Mode of arrival (n = 410).



5.1.5 Mechanism of Injury, Intentionality, Place of Injury Occurrence, and Discharge Status

Mechanism of injury data was available for 386 (94.1%) patients in the study cohort. Road traffic accidents (RTAs) accounted for 43.0% of evaluations for traumatic injuries in the study cohort, followed by falls (22.5%), and stab or cuts (12.7%). "Other" category mainly included patients who were victims of violence due to rocks thrown at them, physical beatings, human bites, and a few select cases of foreign bodies lodged in the body. The findings are presented in Figure 12.

Figure 12. Mechanism of injury (n = 386).

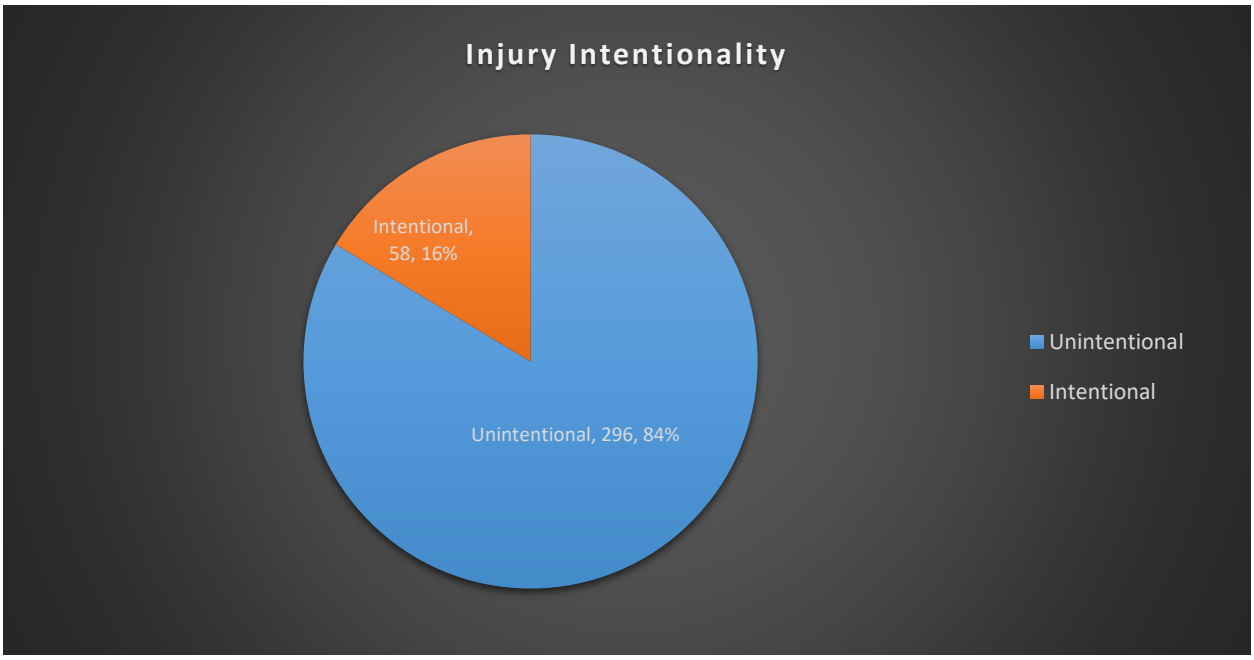


Injury intentionality data was documented for 354 (86.3%) of patients in the study cohort. The majority of injuries were recorded as "unintentional," representing 83.6% of all traumatic cases. For victims who were intentionally injured (16.4%), almost all (98.2%) revealed that they were physically assaulted. Only 1 patient in the study cohort indicated that their injury was due to sexual assault, and none of the injuries were due to drowning or self-infliction. The findings are presented in Table 10 and Figure 13.

Table 10. Injury intentionality.

Injury intentionality	**N (%) out of 354**
Unintentional	296 (83.6%)
Intentional	58 (16.4%)
Missing	56
Intentional (specified)	**N (%) out of 56**
Physical Assault	55 (98.2%)
Sexual Assault	1 (1.8%)
Drowning	0 (0%)
Self-Inflicted	0 (0%)
Unknown	0 (0%)
Missing	2

Figure 13. Injury intentionality (n = 354).



Place of injury occurrence was documented for 275 (67.1%) patients in the study cohort. Place of injury was inconsistently recorded, except when a trauma registry form was present. 64.0% of all traumatic injuries occurred on a street, road, or highway, followed by 22.2% at home. Less than 10% of injuries documented occurred in commercial areas or the workplace, school, industrial or construction zones, the countryside and farms. The findings are presented in Table 11.

Table 11. Place of injury occurrence.

Place of injury occurrence	N (%) out of 275
Street/Highway/Road	176 (64.0%)
Home	61 (22.2%)
Commercial/Work	11 (4.0%)
Farm	3 (1.1%)
Industry/Construction	3 (1.1%)
Countryside	3 (1.1%)
School/Education	2 (0.7%)
Other	4 (1.5%)
Unknown	12 (4.4%)
Missing	135

Patient discharge status was available for all patients in the study cohort. 384 (93.7%) of patients were discharged alive, 15 (3.7%) patients were deceased, and 10 (2.4%) patients were transferred

to other health facilities, and 1 (0.2%) patient ran away. Of the 15 deceased patients, RTAs accounted 7 mortalities at HBMPM during the study period, following by falls (3), gunshot wounds (1) and unknown (4). The findings are presented in Figures 14 & 15.

Figure 14. Discharge status (n = 410).

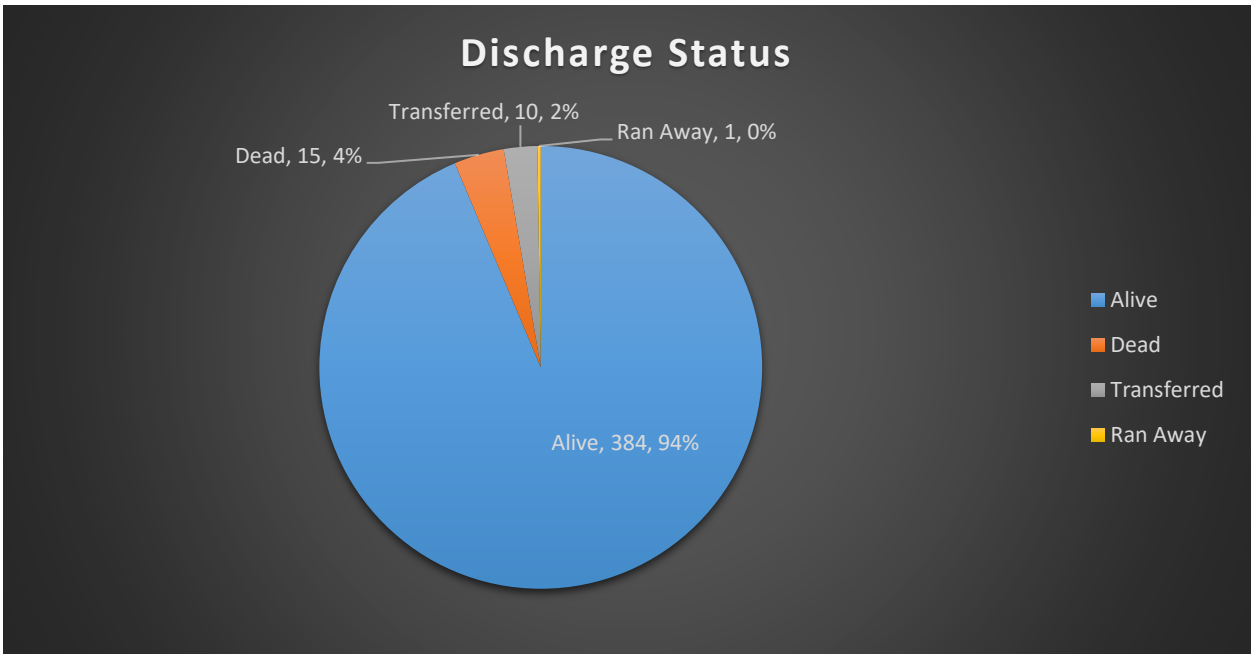
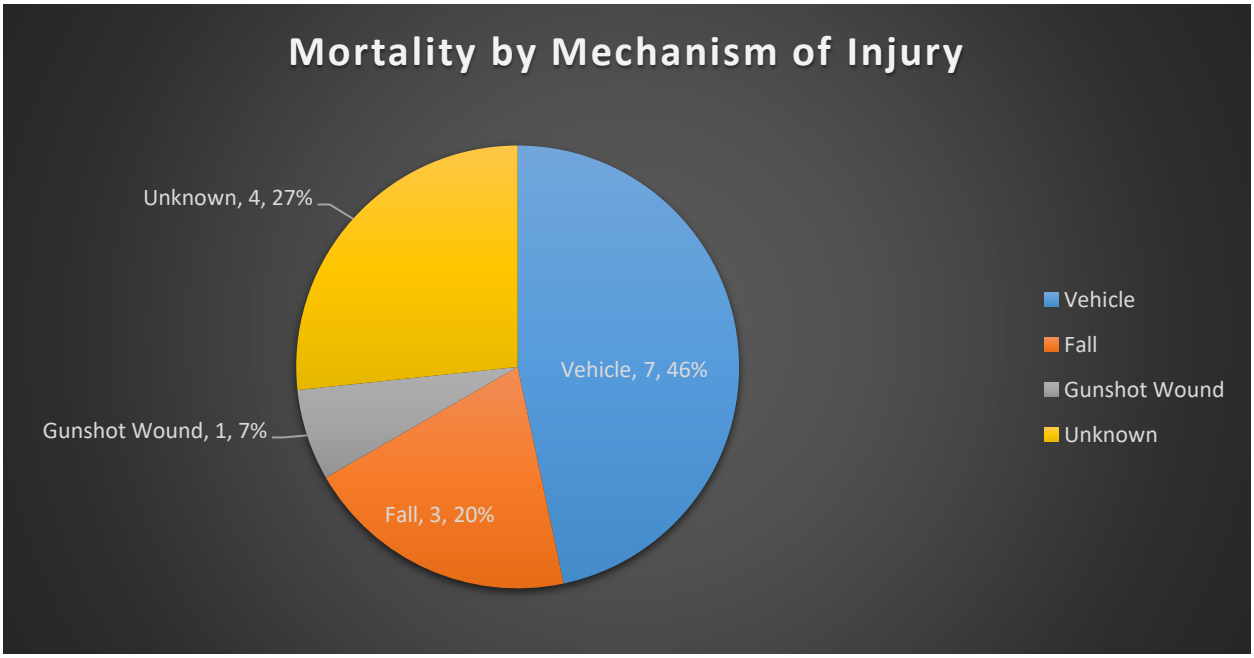


Figure 15. Mortality by mechanism of injury (n = 15).



Road Traffic Accidents Characteristics

RTAs were responsible for 43.0% of patients evaluated for traumatic injury during the study period. Vehicle type was documented for 112 or 166 (67.5%) patients involved in an RTA. 50 (44.6%) patients were injured in a motorcycle accident, 34 (30.4%) via car accident, and 22 (19.6%) as pedestrians (Table 12). Safety devices and alcohol consumption were recorded for 81 and 80 patients respectively (Table 12). Safety devices and alcohol consumption were inconsistently recorded, except in cases where a trauma registry form was present. 72 (88.9%) patients reported not wearing any safety devices at all and 60 (75.0%) reported having not been under the influence of alcohol. Only 1 (1.2%) and 3 (3.7%) patients indicated that they wore a helmet and seatbelt. 17 (21.3%) patients admitted to consuming alcohol prior to or during traumatic injury.

Table 12. Vehicle type, safety devices, and alcohol consumption.

Vehicle Type	**N (%) out of 112**
Motorcycle	50 (44.6%)
Car	34 (30.4%)
Pedestrian	22 (19.6%)
Bicycle	3 (2.7%)
Bus	2 (1.8%)
Truck	1 (0.9%)
Unspecified	54
Safety Devices	**N (%) out of 81**
Seatbelt	3 (3.7%)
Helmet	1 (1.2%)
None	72 (88.9%)
N/A	5 (6.2%)
Missing	329
Alcohol Consumed	**N (%) out of 80**
Yes	17 (21.3%)
No	60 (75.0%)
Not Sure	3 (3.8%)
Missing	330

5.1.6 Initial Patient Disposition from Emergency Department, Length of Stay, and Surgery

Initial patient disposition from the emergency department or examination room (ER) was documented for 357 (87.1%) patients. 249 (69.7%) patients were treated and sent home, and 81 (22.7%) patients were admitted for further treatment or observation. 11 (3.1%) patients were seen

initially, but refused further treatment for various reasons. The findings are presented in Figure 16. For patients hospitalized due to traumatic injuries, the average (SD) and median (IQR) length of stay was 6.6 (9.0) and 3.0 (5.0) days. Surgical information was available for 358 (87.3%) patients, and 54 (15.1%) patients underwent at least one surgical procedure as a result of traumatic injury (Figure 17).

Figure 16. Initial patient disposition from the emergency department (n = 357).

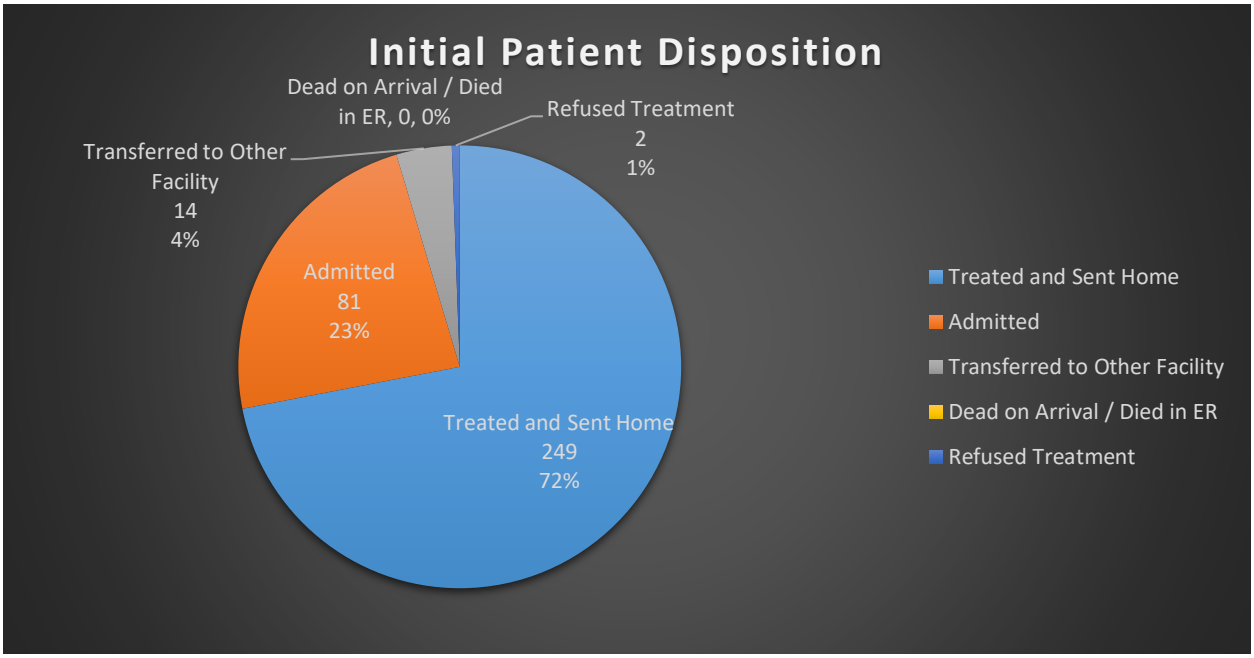
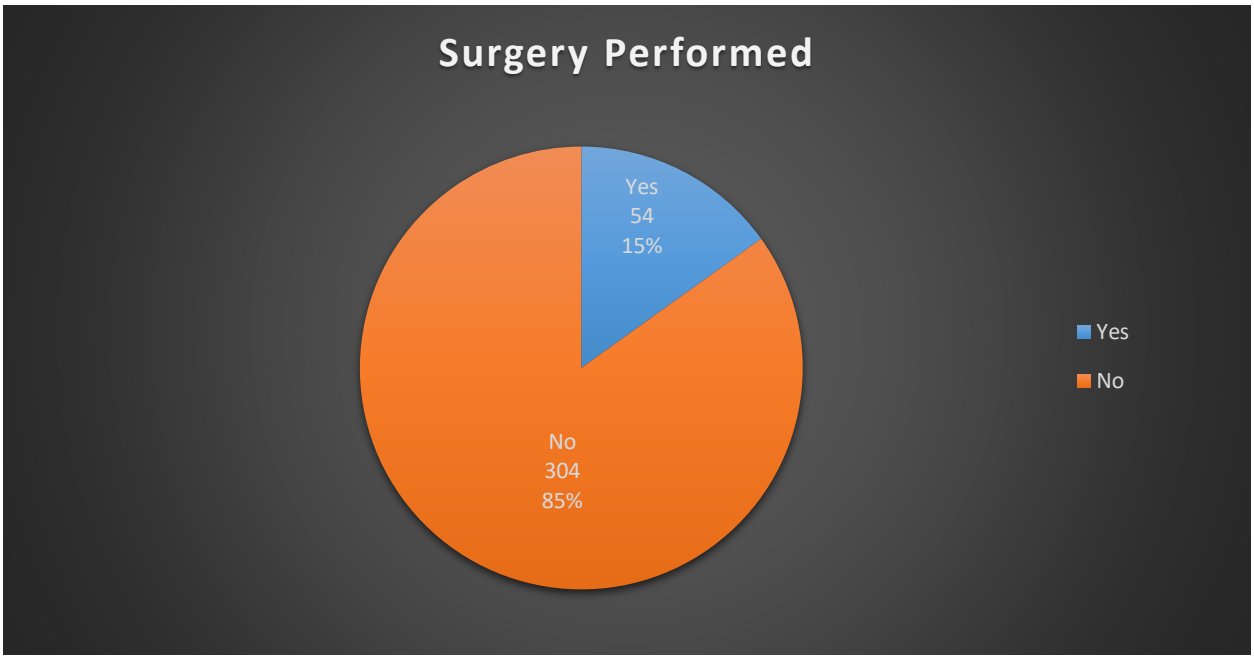


Figure 17. Surgery performed (n = 358).



5.1.7 Documentation of Vitals, Level of Consciousness, and Injury Scores

Vital signs for pulse, respiratory rate, and systolic blood pressure were documented in 73.9%, 68.5%, and 61.2% of medical charts in the study. Level of consciousness, using the AVPU scale (alert, responds to verbal stimuli, responds to painful stimuli, unresponsive), was available for 292 (71.2%) patients in the study cohort. The findings are presented in Table 13.

Table 13. Documentation of vitals and level of consciousness (AVPU).

Documentation of vitals	**N (%) out of 410**
Pulse	303 (73.9%)
Respiratory Rate	281 (68.5%)
Systolic Blood Pressure	251 (61.2%)
Level of consciousness (AVPU)	**N (%) out of 292**
Alert	279 (95.5%)
Responds to Verbal Stimuli	4 (1.4%)
Responds to Painful Stimuli	4 (1.4%)
Unresponsive	5 (1.7%)
Missing	118

Injury scores were calculated for 379 (92.4%) patients. The median injury severity score (ISS) was 1 (IQR = 3), however, 34 (9.0%) patients suffered severe trauma (ISS ≥ 16; Figure 18). 253 (66.8%) patients scored a 1 (minor) in the MAIS scale, 94 (24.8%) patients suffered moderate to

serious injuries, and 32 (8.5%) patients suffered severe to maximal injuries (Figure 19). 135 (95.1%) patients with TBI were scored, with 64.0% sustaining a mild head injury, 15.0% moderate, and 21.0% severe (Figure 20).

Figure 18. Injury Severity Score (ISS; n = 379).

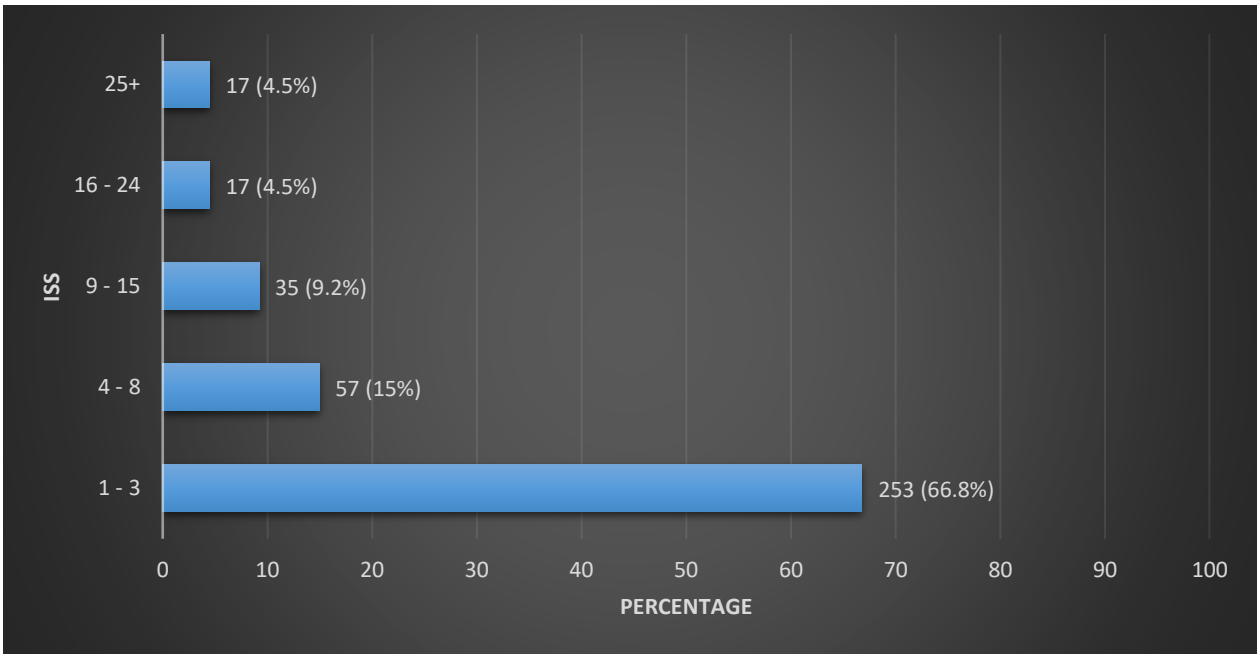


Figure 19. Maximum Abbreviated Injury Scale (MAIS; n = 379).

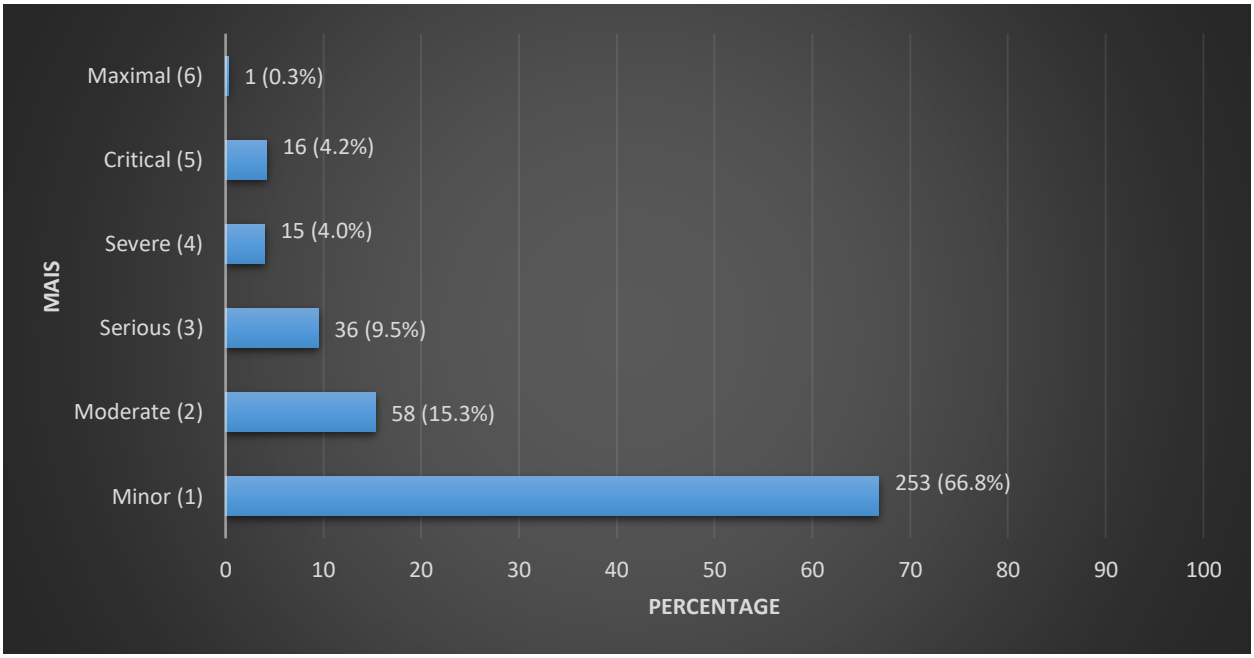
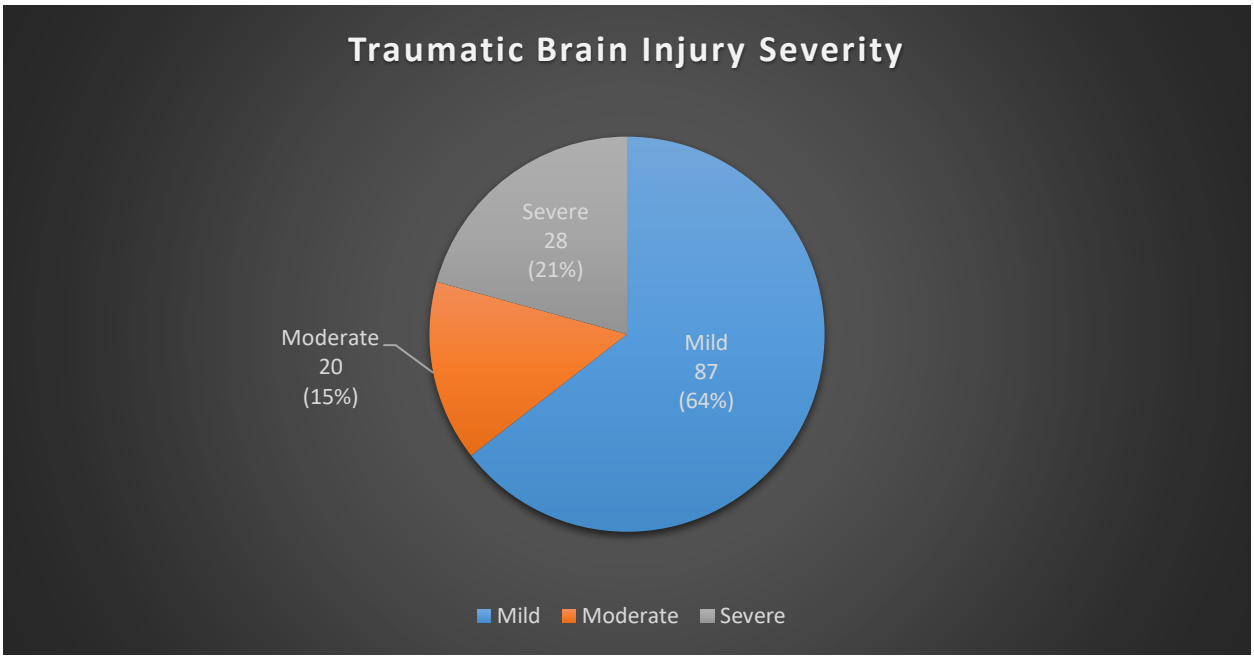


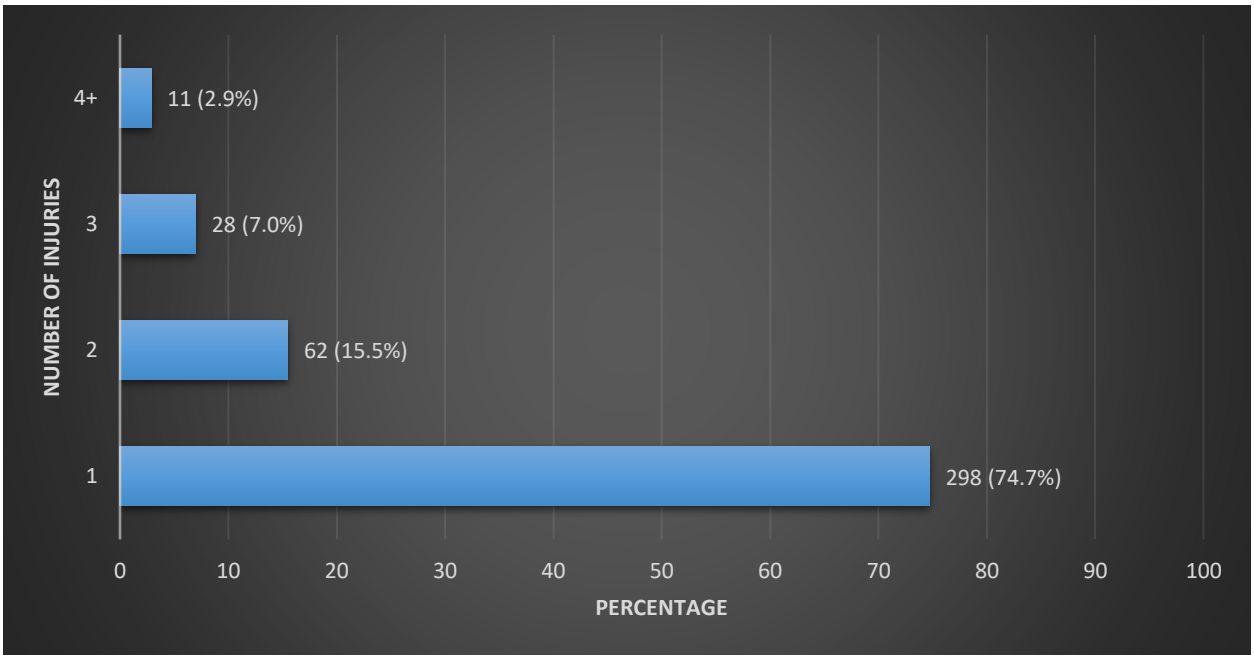
Figure 20. Traumatic Brain Injury Severity (n = 135).



5.1.8 Number of Injuries and Anatomical Regions of Injury

The total number of injuries was documented for 399 (97.3%) patients in the study cohort. A single injury was the most frequently documented (74.7%; Figure 21). 11 patients were excluded in the analysis, which may serve to underestimate the total number of injuries incurred by each patient, as these patients were diagnosed as "polytrauma" patients, but had no precise documentation of number of injuries (four were deceased).

Figure 21. Number of injuries per patient (n = 399).



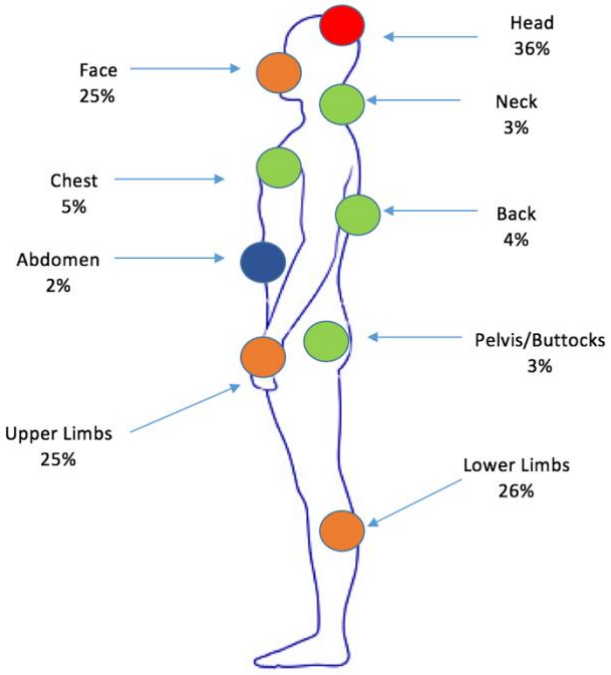
Anatomical region of injury was documented for 403 (98.3%) patients in the study cohort. Extremity trauma was the most frequently injured anatomical region (50.0%), followed by head trauma (35.2%), and face trauma (25.1%). A total of 510 body regions were injured (blunt, penetrating, or burn) in the study cohort. Blunt injuries represented 259 injuries, penetrating 250, and burn 1. Head injuries were predominantly blunt, face/neck injuries predominantly penetrating, back/pelvis/chest injuries predominantly blunt, and extremity trauma (upper and lower limbs) were approximately half blunt and half penetrating. The findings are presented in Table 14 and Figure 22.

Table 14. Type of injury by anatomical region.

Anatomic Region	**Type of Injury**			**N (%) out of 510 injuries**	**N (%) out of 403 patients**
	Blunt	Penetrating	Burn		
Head	91	51	0	142 (27.8%)	35.2%
Neck	4	8	0	12 (2.4%)	3.0%
Back	12	2	0	14 (2.7%)	3.5%
Pelvis/Buttocks	8	2	0	10 (2.0%)	2.5%
Face	27	74	0	101 (19.8%)	25.1%
Chest	13	7	0	20 (3.9%)	5.0%
Abdomen	4	4	0	8 (1.6%)	2.0%

Upper Limbs	47	52	0	99 (19.4%)	24.6%
Lower Limbs	53	50	1	103 (20.2%)	25.6%
Total	**259**	**250**	**1**		

Figure 22. Anatomical region of injury (n = 403).



5.1.9 Pediatric Trauma: A Sub-Group Analysis

Out of the total 410 patients presented for traumatic injuries, there were a total of 96 pediatric patients. Pediatric patients in this study were classified according to age as: Infants (up to 1 years old), toddlers (1-3 years old), preschool (4-6 years old), school-age children (7-12 years old), and adolescents/teenagers (13-19 years old). School-age children were the most commonly injured (29.2%). Falls (55.0%) and vehicle accidents (18.7%) were the most common mechanism of injury leading to pediatric trauma. The data revealed that while falls are the major cause of traumatic injury for children up to age of 13, beyond the age of 13 children were predominantly victims of vehicle accidents, gun violence, and interpersonal violence. Injury intentionality was documented for 81 (84.4%) of pediatric patients in the study cohort. The majority of patients (91.4%) were injured unintentionally. There were 0 mortalities documented in the study period for the pediatric population. The findings are presented in Tables 15 & 16.

Table 15. Age distribution of pediatric traumatic injuries (n = 96).

Age Ranges	**N (%) out of 96**
Infants (up to 1 years old)	3 (3.1%)
Toddlers (1-3 years old)	20 (20.8%)
Preschool (4-6 years old)	21 (21.9%)
School-age Children (7-12 years old)	28 (29.2%)
Adolescent/Teenagers (13-19 years old)	24 (25%)

Table 16. Mechanism of injury of pediatric population by age (n = 91).

Mechanism	**Age Group (N)**					**N (%) out of 91 patients**
	Infants	Toddlers	Pre-school	School-age	Adolescent	
Vehicle	0	0	2	9	6	17 (18.7%)
Fall	1	15	15	15	4	50 (55.0%)
Burn	0	0	0	0	0	0 (0%)
Stab/Cut	0	1	1	2	1	5 (5.5%)
Gun Shot	0	0	0	0	4	4 (4.4%)
Animal Bite	0	0	0	0	0	0 (0%)
Crush	0	0	0	0	0	0 (0%)
Drowning	0	0	0	0	0	0 (0%)
Other	1	2	2	1	8	14 (15.4%)
Missing	*1*	*2*	*1*	*1*	*1*	*5*
Total	3	20	21	28	24	96

5.1.10 Discussion: Epidemiology of Traumatic Injuries

The results of this study provide insight and epidemiological data on trauma at an urban trauma hospital in the capital city of Port-au-Prince, Haiti. To my knowledge, it is the first published epidemiological study providing data in the capital. More than 10% of patients in the study cohort lacked medical chart documentation, and more than 75% lacked a trauma registry form. This deficiency limits the study results, however, basic patient information was able to be extracted from the main patient hospital logbook. Due to the paper-based archiving system, medical files may be easily displaced and lost, thus an electronic medical filling system is recommended. Trauma registry forms, although available, are seldom used, thus personnel must be designated to complete them. Carbon copies of trauma forms, as well as an electronic trauma registry, are essential steps for future research studies and improved trauma surveillance. A recent study in one of the world's busiest trauma centers have shown that electronic records combined with clinician-driven registry data collection for injury surveillance, via tablets, proved to be feasible in low-resource countries, without significantly affecting workflow [33]. Additionally, a pilot-study based at Hospital Albert Schweitzer (HAS) in the Artibonite department of Haiti showed that both a provider and coordinator-based trauma registry resulted in improved data collection. The provider-based model was chosen for adoption, indicating that trauma registries are feasible tools in remote regions in poor-resource countries, potentially leading to improved trauma care and injury surveillance [118].

Similar to the other studies conducted in LMICs, the vast majority of victims were male and less than 45 years of age [16,119,120]. Children aged less than 13 years represented less than 20% of the study population. These numbers are similar to previous studies in Haiti and abroad, and may indicate validity in the study results and in the sample population [62,63]. The burden of disease is significant, as traumatic injuries are disproportionately occurring in young adults in their economic primes. During the two-month study period, the number of admissions per month was approximately 200, representing an average of 6.6 patients per day evaluated for trauma. This number is consistent with trauma patients treated for the year 2014 at HBMPM, as well a previous studies conducted in Haiti in tertiary hospitals, regardless of geographical region [59,60,82,85]. It is commonly perceived that injuries in Haiti are more likely to occur on specific days, such as

weekends, commerce gatherings, or festivals. This relationship was tested both graphically and statistically using linear regression analysis. There was no correlation between the day of the week and the frequency of injury, consistent with the study done by Aluisio et al. (2015) in the Northeast Department of Haiti [62]. The data on time-to-treatment and mode-of-arrival reveal that the vast majority of Haitians do not have access to, or have information about, the existing pre-hospital care and EMS systems in Haiti. The median time-to-treatment of 2.0 hours is high, however, the majority of the injured in this study suffered minor injuries, which may explain delays. Although an emergency service does exist, usage is low. Data and studies on the effectiveness and timeliness of such services are limited.

With regards to mechanisms of injury, RTAs were the predominant mechanism in this study, which is consistent with both studies in Haiti and other LMICs [62,119,121-123]. This trend is consistent with the primary mechanism responsible for trauma globally, and serves as an important signal for all countries, regardless of economic standing. RTAs continue to pose a huge threat to public safety and thus injury prevention programs as well as advanced surgical care for injured patients need to be investigated and potentially prioritized. Motorcycle accidents accounted for almost half of the patients involved in an RTA in this study. This spike is particularly alarming as regulation and enforcement has lagged behind the vast increase in the number of motorcycles on the road following the 2010 earthquake. Motorcycle drivers, although mandated by law to wear a helmet, are rarely penalized for not doing so.

Data on patient disposition revealed that while most patients were treated and sent home the same day, approximately 25% needed to be admitted for further observation or surgery. 15% of all patients required at least one surgical procedures (e.g., open reduction internal fixation), signifying huge costs as surgical procedures range from $330 to $833 at HBMPM. This is the first published epidemiological study on traumatic injuries in Haiti that provides injury severity scores. Although the majority of patients had minor injuries and were discharged the same day, approximately 10% of all trauma patients suffered severe and/or critical injuries. Further, 20% of patients that had a diagnosed brain injury were classified as severe. With four computed tomography scanners (one located at HBMPM) and four neurosurgeons operating in all of Haiti, emergent neurosurgical services are severely limited, and as a result an increase in mortality from head traumas is expected

[86,124,125]. Anatomical region of injury data also revealed that lower and upper extremities were the most frequently injured body parts, followed by head and facial trauma. These findings are consistent with similar findings done in LMICs and in Haiti [62].

Limitations

Due to the retrospective and hospital-based study design, the study likely suffered from selection bias as only patients presented for care were eligible for inclusion. Misclassification bias was minimized as all patients with trauma-like symptoms were initially included for data extraction, and subsequently excluded if the reason for presentation was medical and not traumatic in nature. Cross-sectional studies do not provide information on the incidence of injuries, which are important to trauma care system development. Although these biases may be substantial, epidemiological data stemming from hospitals provide an important starting point in quantifying the burden of illness.

Conclusion

This study provides data on traumatic injuries in the capital city of Port-au-Prince, Haiti. The majority of patients had minor injuries, however, traumatic brain injury was common. Road traffic accidents are the primary reason for injury, thus prevention initiatives may provide substantial public health benefits. Medical record documentation was variable and trauma registry forms were seldom used. Interventions aimed at improving documentation and trauma surveillance to better define the burden of trauma is needed.

5.2 Objective 2. Burden of Disease of Traumatic Injuries: Findings

5.2.1 Direct Medical Costs

During the period December 1, 2015 to January 31, 2016, 410 patients were treated for traumatic injuries at HBMBPM. Direct medical costs were available for 404 patients (98.5%) in the study cohort. The total direct medical costs during the study period was $97,586. The mean (SD) and median (IQR) hospital bill charged was $242 ($542) and $29 ($230). The mean medical bill is equivalent to approximately 41.4 days of work at the Haitian minimum salary of $5.83 per day.

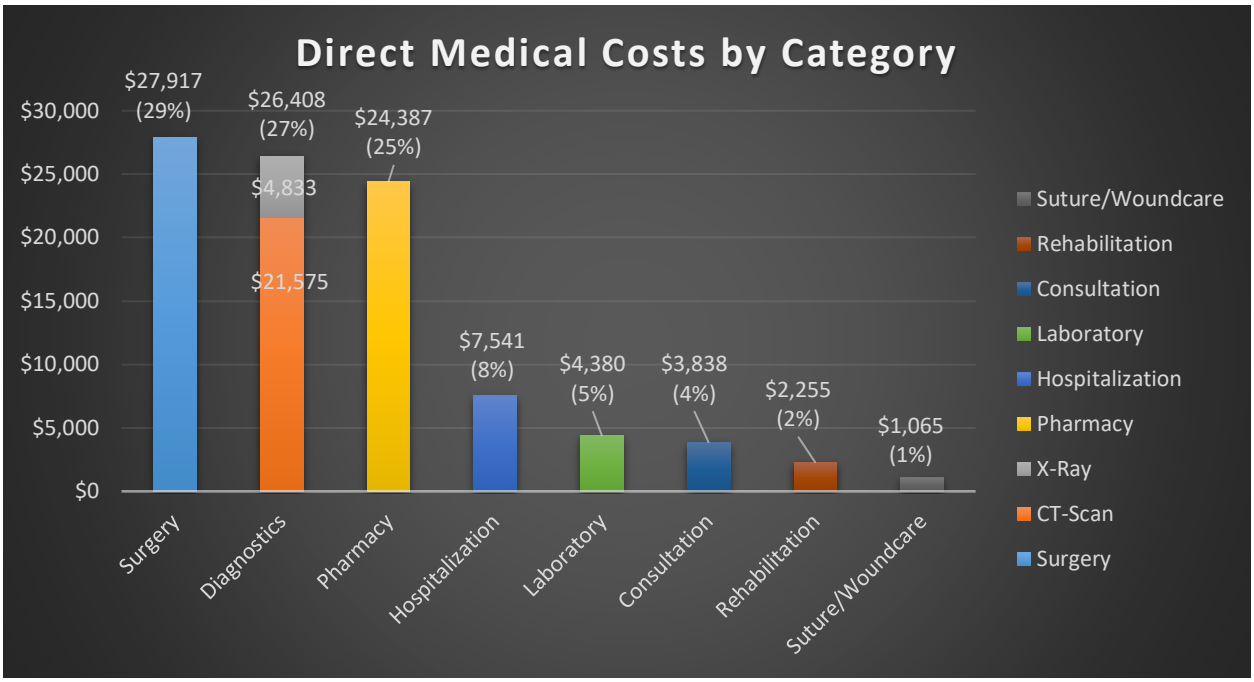
Mean Medical Bill = $242

Median Medical Bill = $29

Mean Working Days ≈ 41.4

Analysis on direct medical costs per cost category revealed that surgical costs accounted for the majority of patient incurred costs, totaling $27,917 (28.6%) of all direct medical costs. Following surgical costs were radiology/diagnostic tests and pharmacy costs, a total cost of $26,408 (27.1%) and $24,387 (25.0%) for all injured patients. Hospitalization costs accounted for $7,541 (7.7%) of all direct medical costs. Laboratory, consultations, rehabilitation and suture/woundcare costs were the least costly with a total cost of $4,380 (4.5%), $3,838 (3.9%), $2,255 (2.3%), and $1,065 (1.1%) of all direct medical costs (Figure 23). The average and median pharmacy bill was $71 and $9.

Figure 23. Direct medical costs by category (2016 US$; n = 404).



5.2.2 Indirect Costs

In the study cohort, 311 of 410 patients met the inclusion criteria for productivity loss, namely, patients aged 15 to 63 years, inclusively. Of the 311 eligible patients, 52 were hospitalized for at least one day. The mean (SD) and median length (IQR) of stay in the study cohort was 6.6 (9.0) and 3.0 (5.0) days.

For productivity costs of injured persons (morbidity costs), total costs equaled $2,357, with a mean (SD) cost of $45 ($68) per hospitalized patient (Table 17; see Appendix 4 for detailed calculations).

For productivity costs of death (mortality costs), the present value of lost production per deceased patient caused by injury for the study ranged from $12,746 (5% discount rate; 0% growth rate) to $22,383 (base case; 0% discount rate; 0% growth rate) to $30,130 (0% discount rate; 2.2% growth rate; Table 17). See Appendix 5 for detailed calculations.

Table 17. Indirect costs (2016 US$).

Indirect Costs	Total ($)	Mean ($)	Total Cost at Base Case (%)
Morbidity Costs (n = 52)	2,357	45	1
Mortality Costs (n = 14)			99
Economic Growth Rate 0%			
0% discount rate	313,362	22,383	
3% discount rate	219,086	15,649	
5% discount rate	178,444	12,746	
Economic Growth Rate 1.7%			
0% discount rate	393,512	28,108	
3% discount rate	266,966	19,069	
5% discount rate	213,360	15,240	

Economic Growth Rate 2.2%		
0% discount rate	421,820	30,130
3% discount rate	283,682	20,263
5% discount rate	225,442	16,103

5.2.3 Intangible Costs

Costs due to pain, grief, and suffering for all hospitalized and deceased patients, regardless of age, totaled $88,401, with a mean cost of $1,473 per hospitalized/deceased patient (Table 18). For patients who were hospitalized and not deceased (n = 46), there was a total intangible cost of $630, with a mean cost of $14 per patient. See Appendix 6 for detailed calculations.

Mean Intangible Cost = $1,473

5.2.4 YPLL

In the study cohort, 375 years of potential life were lost due to traumatic injuries at HBMPM from December 1st, 2015 to January 31st, 2016. The average number of years lost was approximately 27. 1 patient was omitted, as the patient did not make the cut-off point of 63 years of age. See Appendix 7 for detailed calculations.

YPLL = 375

5.2.5 Total Cost of Traumatic Injuries

Total costs during the study period was $501,706, with a mean cost of $1,224 per injury for all patients in the study cohort (at base case; Table 18). This is equivalent to approximately 210 days of work at the Haitian minimum wage per injury. The average cost per injury is approximately equal to 148% of GDP per capita.

Total Cost of Injury = $501,706

Mean Cost per Injury = $1,224

Mean Working Days ≈ 210

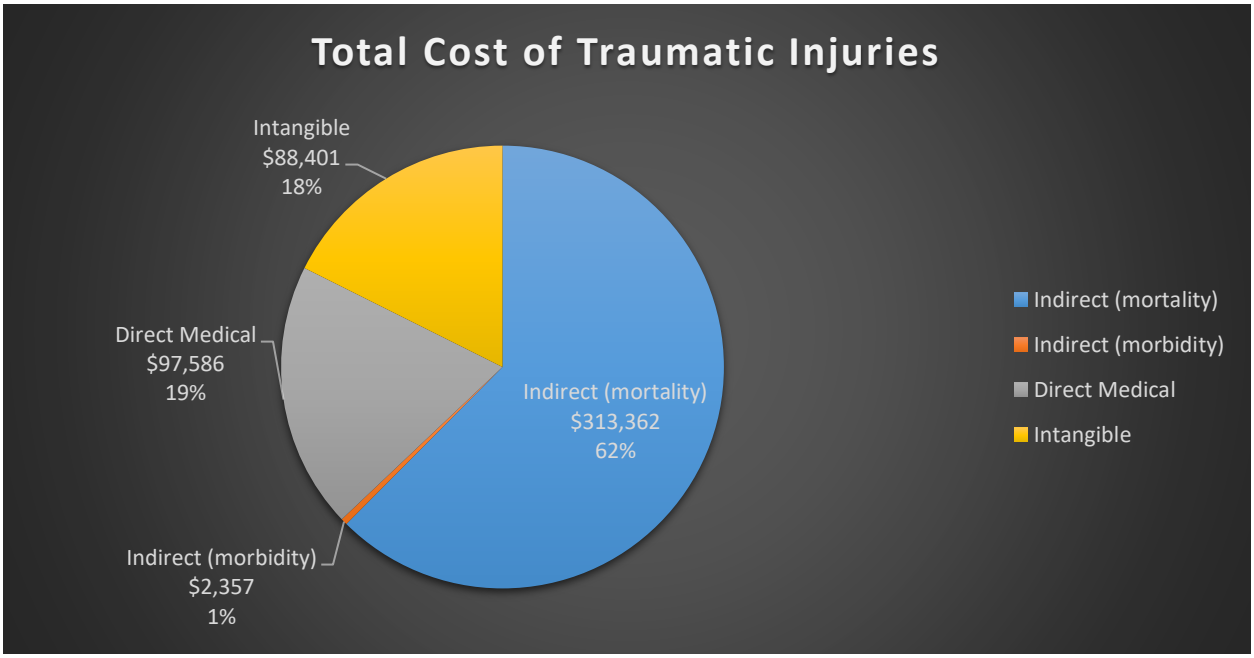
Indirect costs totaled $315,719, accounting for 63% of all costs. Direct medical costs totaled $97,586, accounting for 19% of all costs. Intangible costs totaled $88,401, accounting for 18% of all costs (Table 18, Figure 24).

Table 18. Total cost of traumatic injuries (2016 US$). *Base case represents a 0% discount rate and 0% growth rate for productivity cost of death.

Cost Category	Total ($)	Mean $ (SD)	Proportion of Direct / Indirect / Intangible Costs (%)	Total Cost (%)
Direct Costs (n = 404)	97,586	242	100	19
Surgery	27,917		29	
Diagnostics	26,408		27	
Pharmacy	24,387		25	
Hospitalization	7,541		8	
Laboratory	4,380		5	
Consultation	3,838		4	
Rehabilitation	2,255		2	

Suture/Woundcare	1,065		1	
Indirect Costs	315,719		100	63
Productivity cost of hospitalized persons (n = 52)	2,357	45	1	
Productivity cost of death (n = 14; base case)	313,362	22,383	99	
Intangible Costs (n = 60)	88,401	1,473		18
Total Cost of Illness	501,706	1,224		100

Figure 24. Total Cost of Traumatic Injuries (2016 US$). Indirect (mortality) costs are presented at the base case.



5.2.6 Costs by Mechanism of Injury

Costs incurred by road traffic victims accounted for the largest proportion of total costs, totaling $254,407 (50.7%; Table 19 & Figure 25). This is followed by costs incurred by participants treated for falls, gunshot wounds, stab/cuts, and crush injuries. However, mean costs (direct, indirect, and intangible) revealed that gunshot wound victims had the highest mean costs, followed by patients involved in road traffic accidents, falls, crush injuries, and stab/cuts (Table 19 & Figure 26). Analysis on direct medical costs by mechanism of injury revealed that gunshot wound victims had the highest mean medical bill, followed by patients involved in road traffic accidents, crush injuries, falls, and stab/cuts (Table 19; Figure 27).

Table 19. Costs (2016 US$) by mechanism of injury. RTAs (road traffic accidents); GSW (gunshot wound).

Mechanism of injury		Direct medical	Indirect (morbidity)	Indirect (mortality)	Intangible	All costs
RTAs (n = 166)	*Total*	51,697	1,686	156,681	44,343	254,407
	Mean	311	10	944	267	1,533
	SD	637	40	4,512	1,264	5,886
Falls (n = 87)	*Total*	19,238	88	67,149	18,826	105,301
	Mean	221	1	772	216	1,210
	SD	546	7	4,107	1,150	5,283
Stabs/cuts (n = 49)	*Total*	3,394	41	0	11	3,446
	Mean	69	1	0	0.2	70
	SD	185	4	0	1	187
GSW (n = 24)	*Total*	8,437	397	22,383	6,378	37,595
	Mean	352	17	933	266	1,566
	SD	636	43	4,569	1,278	5,866
Crush (n = 7)	*Total*	1,635	41	0	11	1,687
	Mean	234	6	0	2	241
	SD	543	15	0	4	562
Other (n = 53)	*Total*	5,767	58	0	16	5,842
	Mean	109	1	0	0.3	110
	SD	267	5	0	1	271
Unknown (n = 24)	*Total*	7,417	47	67,149	18,815	93,428
	Mean	309	2	2,798	784	3,893
	SD	512	8	7,562	2,117	9,809

All injuries (n = 410)	*Total*	97,586	2,357	313,362	88,401	501,706
	Mean	238	6	764	216	1,224
	SD	539	28	4,070	1,140	5,292

Figure 25. Total costs by mechanism of injury (2016 US$).

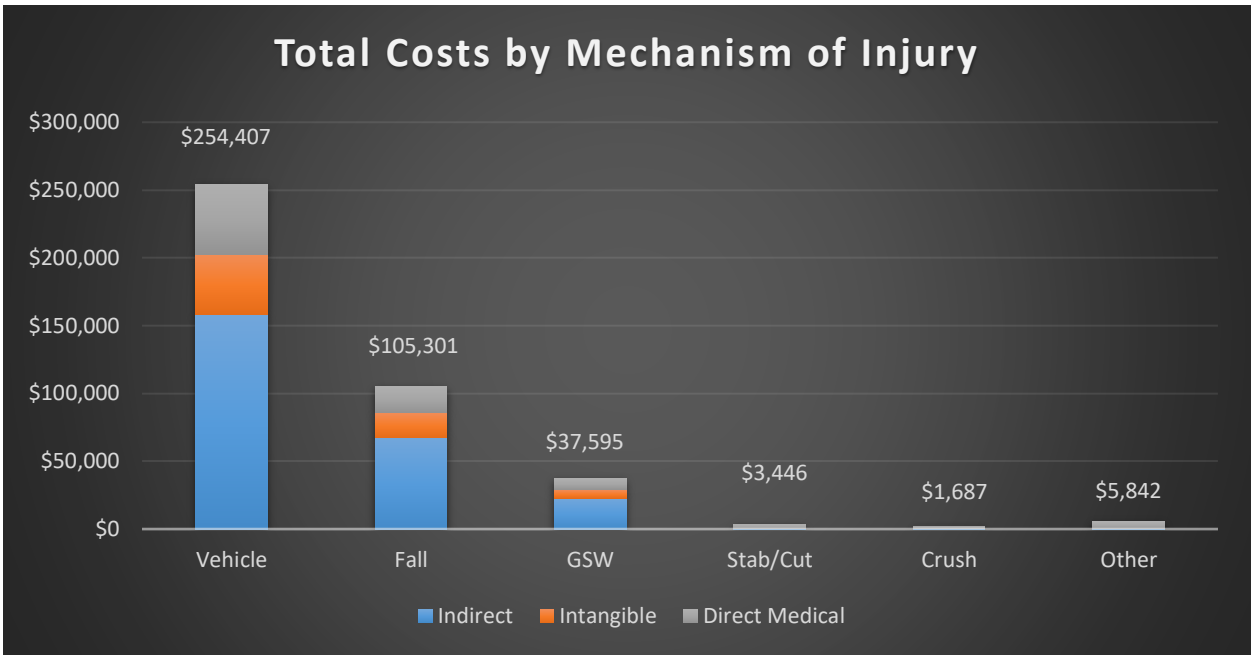


Figure 26. Mean costs by mechanism of injury (2016 US$).

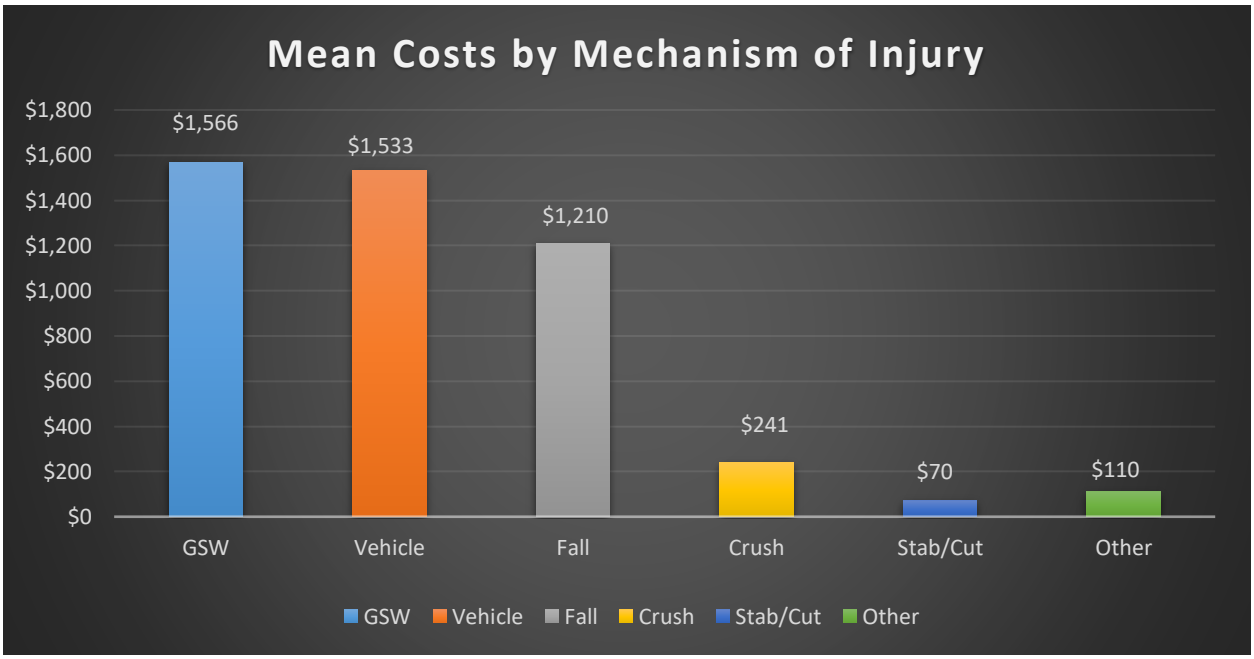
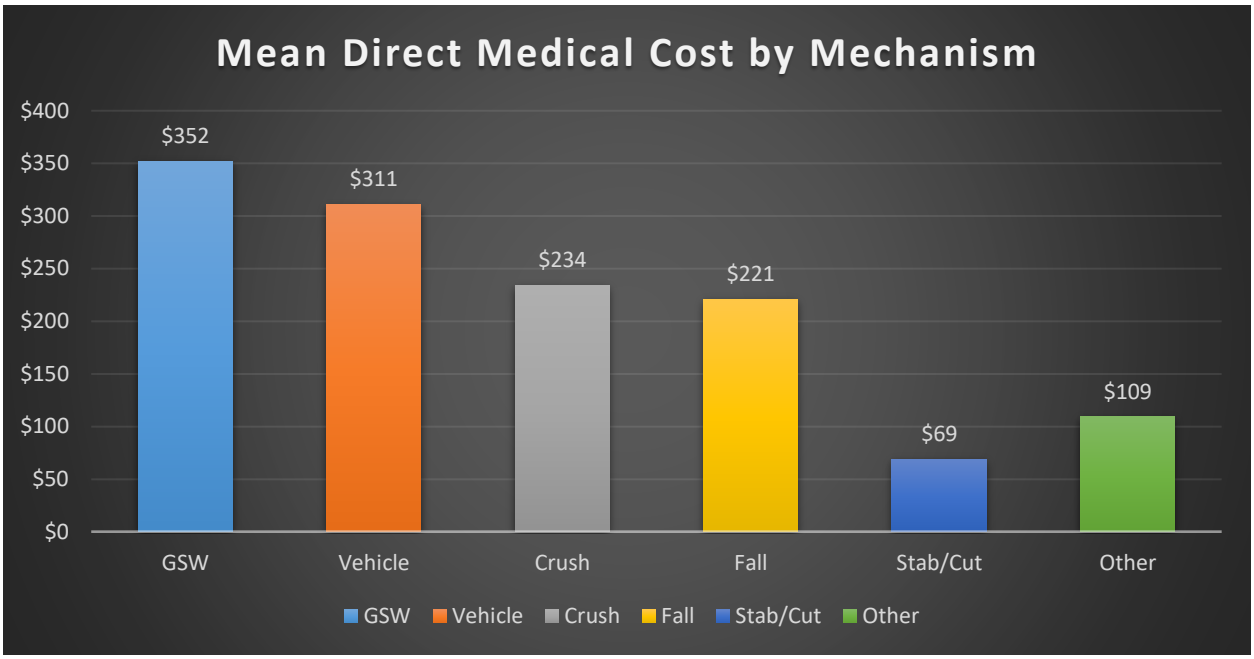


Figure 27. Mean direct medical costs by mechanism of injury (2016 US$).



5.2.7 Costs by Injury Severity

Analysis on mean costs by injury severity revealed that costs ranged from $62 for minor injuries to $13,675 for critical injuries. Only 1 patient suffered a maximal or unsurvivable injury, incurring a total cost of $29,256 (Table 20 & Figure 28). Analysis on mean direct medical costs by injury severity revealed that costs ranged from $62 for minor injuries to $1,151 for critical injuries. Only 1 patient suffered a maximal or unsurvivable injury, incurring a direct medical cost of $606 (Table 20 & Figure 29).

Table 20. Costs by injury severity (2016 US$).

Injury Severity (MAIS)	Total Direct Medical (N; mean)	Total Mortality (N; mean)	Total Morbidity (N; mean)	Total Intangible (N; mean)	Total	Mean Cost
Minor (n = 253)	$15,558 (250; $62)	$0 (0; $0)	$146 (9; $16)	$41 (9; $5)	$15,745	$62
Moderate (n = 58)	$21,056 (57; $369)	$0 (0; $0)	$245 (10; $25)	$69 (10; $7)	$21,370	$375
Serious (n = 36)	$16,296 (33; $494)	$22,383 (1; $22,383)	$578 (5; $116)	$6,429 (6; $1,071)	$45,686	$1,269
Severe (n = 15)	$15,070 (15; $1,005)	$22,383 (1; $22,383)	$245 (9; $27)	$6,336 (9; $704)	$44,034	$2,936
Critical (n = 16)	$17,262 (15; $1,151)	$156,681 (7; $22,383)	$764 (11; $69)	$44,085 (14; $3,149)	$218,792	$13,675
Maximal (n = 1)	$606 (1; $606)	$22,383 (1; $22,383)	$0 (0; $0)	$6,267 (1; $6,267)	$29,256	$29,256

Figure 28. Mean economic costs (2016 US$; SD) by injury severity. Maximal (n = 1).

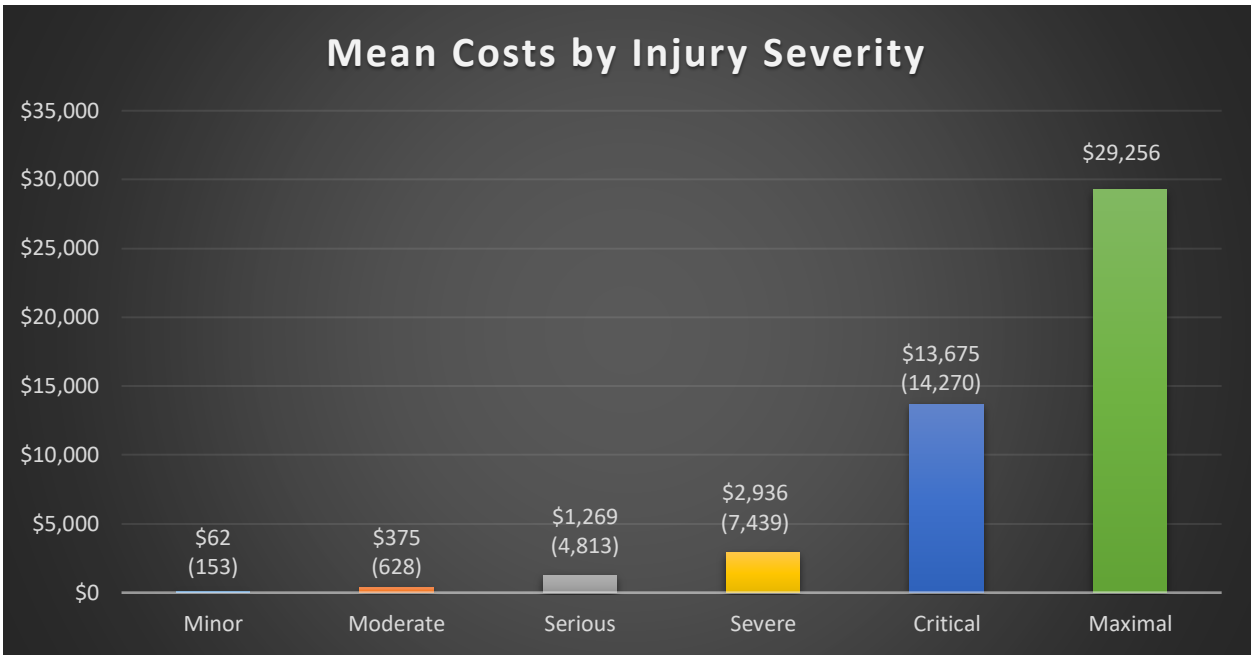
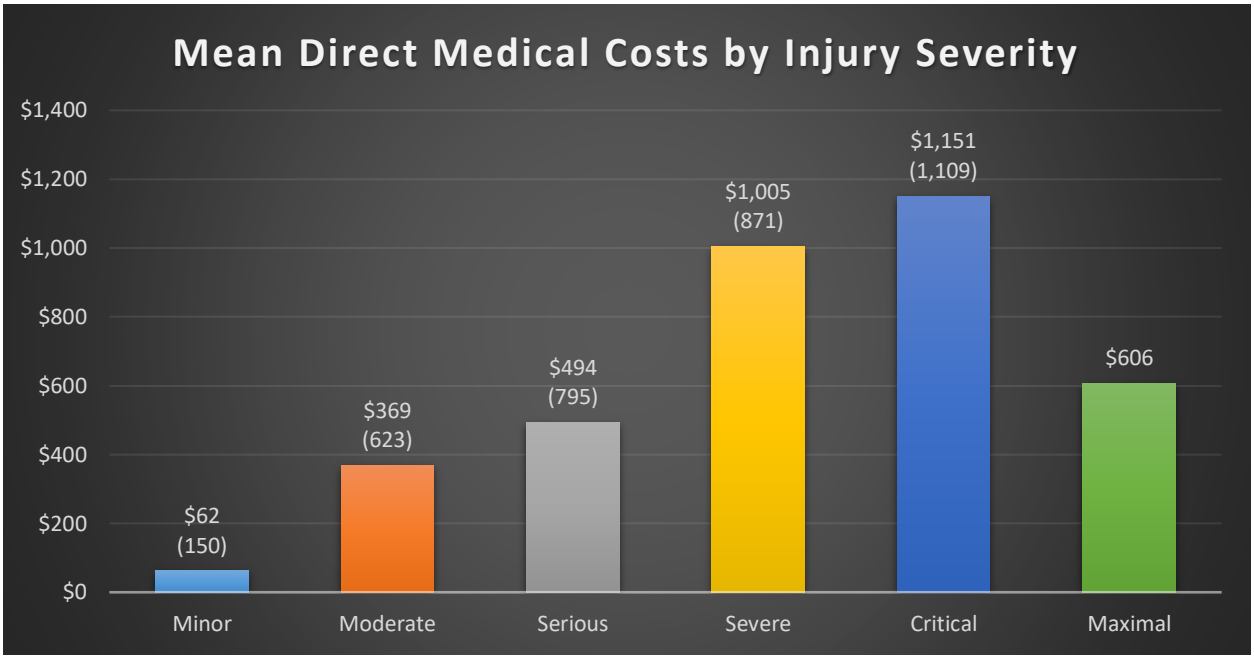


Figure 29. Mean direct medical costs (2016 US$; SD) by injury severity. Maximal (n = 1).



5.2.8 The Correlation Between Injury Severity and Costs

There was a positive correlation between the MAIS, ISS, and TBI scores and total economic costs (Table 21). There was a positive correlation between the MAIS, ISS, and TBI scores and the direct medical costs (Table 21). ANOVA tests revealed that total economic costs were different between the MAIS, ISS, and TBI groups. ANOVA tests revealed that direct medical bills were different between the MAIS, ISS, and TBI groups (Table 21). However, standard deviations were large for all injury severity groups.

Table 21. Correlation between injury severity and costs. All costs refer to direct, indirect, and intangible costs.

Statistical Test	Variable 1	Variable 2	R	P-Value
Pearson's Correlation	All Costs	ISS	0.63	< 0.001
Pearson's Correlation	All Costs	MAIS	0.52	< 0.001
Pearson's Correlation	All Costs	TBI	0.52	< 0.001
Pearson's Correlation	Direct Medical Cost	ISS	0.48	< 0.001
Pearson's Correlation	Direct Medical Cost	MAIS	0.53	< 0.001
Pearson's Correlation	Direct Medical Cost	TBI	0.56	< 0.001
ANOVA (1-way)	All Costs	ISS		< 0.001
ANOVA (1-way)	All Costs	MAIS		< 0.001
ANOVA (1-way)	All Costs	TBI		< 0.001
ANOVA (1-way)	Direct Medical Cost	ISS		< 0.001
ANOVA (1-way)	Direct Medical Cost	MAIS		< 0.001
ANOVA (1-way)	Direct Medical Cost	TBI		< 0.001

5.2.9 Discussion: The Economic and Social Burden of Traumatic Injuries

The average economic cost per injured patient was $1,224. Haiti's GDP per capita in 2015 was $829 [98], thus the cost outweighed the average economic production per capita, therefore traumatic injuries have a significant effect on the country's economy. Indirect costs and intangible costs accounted for 62% and 18% of all injuries. 99% of the indirect cost was due to mortality costs compared to morbidity, which is the case in numerous studies conducted. One reason for such high mortality costs is due to the young age of patients who typically incur traumatic injury. The high burden due to indirect and intangible costs provide an argument for the use of these costs, as they provide a more complete picture of the real burden of illness, as direct medical costs only represented 19% of all costs in the study.

The Cost of Injury

Direct, Indirect, and Intangible Costs

A few published studies have described the cost of injury and trauma care in LMIC's. The average cost (including direct, indirect, and intangible costs) in the study sample for all injuries was $1,224, representing 148% of the cost as a percentage of GDP per capita. Three published studies in LMICs, one in China and two in Vietnam, indicate that the cost of injury per patient in Haiti was much higher, ranging from slightly more expensive to 15 times higher, and a cost as a percentage of GDP per capita of at least five times greater and up to 25 times greater [126-128]. However, more complete cost studies are needed in similar LMIC's in urban hospitals as well as regional comparisons.

Direct Medical Costs

In terms of direct medical costs, the average cost of injury in the study was $242, representing 29% of the cost as a percentage of GDP per capita. Two published studies in LMICs in urban hospitals, one in Ghana and one in Nepal, indicate that the direct medical cost of injury per patient in the study was much higher, ranging from two times to five times greater per injury, and a cost as a percentage of GDP per capita of up to 8 times greater [18,129]. Other published studies have

described the direct medical costs of hospitalized patients. The average medical cost of a hospitalized patient (defined as patients admitted for at least one day) in the study was $964, representing 116% of the cost as a percentage of GDP per capita. Five studies in urban hospitals (two in Jamaica; one in Turkey; one in China; and one in Brazil) indicate that the direct medical cost per hospitalized patient was significantly higher in the study, ranging from one and a half times to 10 times greater per hospitalization, and a cost as a percentage of GDP per capita of at least two times greater and up to 10 times greater [130-134]. Only one published study in 1999 in an urban hospital in Turkey indicated a higher direct medical cost per hospitalization, however, approximately half of the 347 patients analyzed had an ISS of 16 and greater (i.e., severe trauma), compared to approximately 10% in this study [135].

The Cost of Road Traffic Accidents

Direct, Indirect, and Intangible Costs

Total costs due to road traffic accidents were the costliest as they represented the majority of injuries, with an average cost (including direct, indirect, and intangible costs) of $1,533, representing 185% of the cost as a percentage of GDP per capita. Multiple studies in LMICs have described the costs associated with road traffic accidents. Four publishes studies (one in Vietnam; one in Belize; one in Ghana; and one in China;) indicate that the total cost of a road traffic injury was significantly higher in these studies, ranging from one and a half times to six times lower per injury, and a cost as a percentage of GDP per capita of at least one times greater. However, two of these studies had lower costs as a percentage of GDP per capita than the current study [136-139]. Four other published studies (two in Nigeria; one in Pakistan; one in Vietnam) indicate the contrary, that the total cost of road traffic injury was significantly lower in these studies. Costs ranged from four times to 50 times greater per injury in this study, and a cost as a percentage of GDP per capita of at least five times greater and up to 90 times greater [140-143].

The average cost of a hospitalized patient due to road traffic injury in the study was $4,416, representing 533% of the cost as a percentage of GDP per capita. Two published studies in urban hospitals in LMICs (one in Thailand; one in Mexico) indicate that the average cost of a hospitalized

patient was significantly higher in the study, ranging from one and a half times to five times greater per hospitalization, and a cost as a percentage of GDP per capita of at least eight times greater [144,145]. One study conducted in five urban hospitals in India indicated a higher cost per hospitalized patient of five times greater, however, the cost as a percentage of GDP per capita was eight times greater in this study [146]. The high costs in the Indian case study are largely due to the indirect mortality costs, which doubled in amount compared to this study.

Direct Medical Costs

In terms of direct medical costs, the average direct medical cost of a road traffic injury in the study was $313, representing 38% of the cost as a percentage of GDP per capita. One published study conducted at an urban hospital in Ghana indicated that the direct medical cost was greater than 10 times the medical cost in this study, however, one Colombian study conducted in multiple urban hospitals indicate that the average medical cost per person was approximately twice as high [140,147].

Other published studies have described the direct medical costs of hospitalized patients. The average medical cost of a hospitalized patient in the study was $1,081, representing 130% of the cost as a percentage of GDP per capita. Three studies in urban hospitals in LMICs (one in Jordan; one in Kenya; one in China) indicate that the direct medical cost per hospitalized patient was significantly higher in the study, ranging from one and a half times to 10 times greater per hospitalization, and a cost as a percentage of GDP per capita of at least one and a half times greater and up to 10 times greater [148-150].

The Cost of Injuries from Gunshot Wounds

Direct Medical Costs

The average direct medical cost of a gunshot wound patient in the study was $384, representing the highest mean by mechanism of injury. One published study in South Africa revealed that the average direct medical cost of treating a serious abdominal firearm-related injury was approximately $17,400 [151]. For comparison, one severely injured individual in the study cohort

with an abdominal injury due to a GSW incurred a total direct medical cost of $2,633. This patient underwent a laparotomy, with a length of stay of 33 days (10 in the ICU). This comparison indicates that South Africa has significantly higher direct medical costs associated with serious gunshot wound victims. More studies are needed in other LMICs for comparison.

Cost by Category

The cost of surgery, diagnostic tests, and pharmacy costs accounted for more than 80% of direct medical costs. Patients with traumatic brain injury incurred high diagnostic costs due to the high cost of CT-scans, as 80 patients in the study cohort underwent at least one CT-scan. Pharmacy costs were high, with a mean of $71 per patient in the study cohort. One study in Haiti which compares 60 essential medicines to four other LMICs revealed that most of the available medicines were priced higher than the International Reference Price [152]. More comparison studies on pharmacy costs and unit cost of services are needed to understand more clearly the drivers of cost due to injury in Haiti and other LMICs.

Cost by Injury Severity

The average cost (direct, indirect, and intangible) in the study cohort ranged from $62 for a minor injury to $13,675 for a critical injury. The average direct medical cost ranged from $62 for a minor injury to $1,151 for a critical injury. There was a positive correction between each injury score and the direct medical costs. Additionally, medical bills were statistically different within each score.

Limitations

There are a number of limitations in this study. First, it is important to note that the prices charged to patients in this study do not necessarily reflect Haitian market prices during the study period. For example, physician fees may not accurately reflect the relative skill level and time required for different procedures. There was no attempt to adjust observed market prices to reflect true opportunity costs [153]. Second, pre-hospital costs and transport costs were not included in this study,

as no data was available. Further, a small percentage of patients refused further care and left against medical advice or were transferred to other health facilities. Third, indirect costs only accounted for patient productivity losses and did not include social isolation, economic dependence, and family lost time for care-giving [153,154]. Additionally, indirect costs were estimated using days of work loss due to hospitalization and the daily minimum wage. These costs were unable to be estimated directly from the subjects concerned, or stratified by patient occupation, age group, or gender due to limitations of data in Haiti [155]. Fourth, disability or permanent disability and long term absence was not calculated. It is possible that some patients were permanently or slightly disabled, and thus would have not been able to return to work. Direct and indirect costs related to further rehabilitation, care, and home-care were not included in this study, and therefore could underestimate true costs if the study covered long term follow-up and consequences.

Conclusion

This study provides the first estimates on the cost of injury in Haiti, however, this study was conducted in a single and semi-private hospital in the capital city and is therefore not fully representative of Haiti. Overall, injuries lead to a significant economic burden to individuals treated in Port-au-Prince, Haiti. Programs aimed at reducing the incidence and severity of injuries would likely result in savings for the individuals, families, and society. The Haitian healthcare system is predominantly based on out-of-pocket payments, and Haitians suffer from the worst poverty and health outcomes in the western hemisphere. High medical costs may lead to catastrophic financial losses to injured persons and families, substantially risking further impoverishment. Affordable health insurance would likely be an effective measure in protecting against further impoverishment.

5.3 Objective 3. Modelling the Cost-Effectiveness of Improved Traffic Enforcement

5.3.1 Model Outcomes

An estimated 13,248 DALY's are lost due to road traffic accidents per million persons per year in Haiti. Assuming the intervention reduces mortality and permanent disability by 25% at a 1:1 ratio, an estimated 3,313 DALY's are saved per million persons per year (0% discount rate). Given an estimated total cost of $32,316 for traffic enforcement for this intervention, the cost per death averted is $539. The cost per DALY saved ranges from $10 (0% discount rate) to $39 per DALY saved (10% discount rate; Table 22). See Appendix 8 for detailed calculations.

Table 22. Cost per death averted, life year saved, and DALY saved by sustained intervention for 1 million persons (25% reduction).

Cost per death averted	$539
Cost per life year saved	$13
Cost per DALY saved discounted at 0%	$10
Cost per DALY saved discounted at 3%	$17
Cost per DALY saved discounted at 6%	$26
Cost per DALY saved discounted at 10%	$39

A 25% reduction from baseline traffic deaths stems from a Brazilian study and may not be extrapolated to Haiti [156]. One study that implemented a similar intervention in Rwanda showed a 30% reduction in traffic fatalities [157]. In Uganda, a similar intervention achieved a 17% reduction in mortality [158]. In an attempt to address this uncertainty, a more conservative estimate of 15% reduction in traffic deaths and permanent disability has been modeled.

Assuming the intervention reduces mortality and permanent disability by 15% at a 1:1 ratio, an estimated 1,983 DALY's are saved per million persons per year (0% discount rate). Given an estimated total cost of $32,316 for traffic enforcement for this intervention, the cost per death averted is approximately $898. The cost per DALY saved ranges from $16 (0% discount rate) to $65 per DALY saved (10% discount rate; Table 23). See Appendix 9 for detailed calculations.

Table 23. Cost per death averted, life year saved, and DALY saved by sustained intervention for 1 million persons (15% reduction in traffic fatalities).

Cost per death averted	$898
Cost per life year saved	$21
Cost per DALY saved discounted at 0%	$16

Cost per DALY saved discounted at 3%	$28
Cost per DALY saved discounted at 6%	$43
Cost per DALY saved discounted at 10%	$65

5.3.2 Additional Medical Care Savings

Implementing an intervention to counter injuries will undoubtedly prevent non-fatal injuries and those slightly but not permanently disabled, leading to additional medical care savings. To date, there is no data on the incidence and severity of non-fatal traffic accidents in Haiti, however, an estimate can be calculated. The International Road Assessment Programme (IRAP) recommends a ratio of 10 serious injuries per fatal injury [110]. Additionally, an estimated 28 minor or slight injuries are estimated to occur per fatal injury [104]. Medical costs by injury severity can be calculated using the data generated in the cost of injury in section 5 of this thesis.

Using the intervention model mentioned above and the injury severity ratios, preventing 1 traffic fatality is associated with the prevention of 1 permanent disability, 10 serious injuries, and 28 slight injuries. Costs related to slight injuries were calculated using average medical costs of both minor and moderate injuries in this study, as per the MAIS score. Serious injuries were calculated using the direct medical costs of serious injuries, as per the MAIS score. If the intervention succeeds in preventing 1 traffic fatality, 10 serious injuries (10 x $494 = $4,940), and 28 minor or moderate injuries (28 x $118 = $3,304), then there would be additional cost savings worth an estimated $8,244. If the intervention is successful in reducing traffic fatalities by 25%, an estimated 60 lives would be spared, 60 permanently disabilities, 600 serious injuries, and 1,680 minor or moderate injuries avoided per million inhabitants receiving this intervention per year. The additional medical care savings associated with the prevention of minor/moderate and serious injuries leads to an estimated net savings of:

> [$32,316 (cost of enforcement)] – [(600 serious injuries x $494) + (1,680 minor/moderate injuries x $118)] = - $462,234

If the enforcement costs of such an intervention are accurately estimated at $32,316 for one year of traffic enforcement for 1 million inhabitants, then the intervention would save more money, in terms of the direct medical costs of those slightly and seriously hurt, than it costs if only 4 deaths were prevented (4 x $8,244 = $32,976). If indirect and intangible costs were considered for those

slightly or seriously injured, the intervention would save more money than it cost if only slightly over 2 deaths were prevented (2 x $16,022 = $32,044).

5.3.3 Police Revenues

With a conservative estimate of 35,000 vehicles per million inhabitants, and a traffic police force operating at full capacity and only covering 50% of traffic enforcement, an estimated 4 additional policemen are required for the intervention (i.e., one policeman per 5,000 vehicles). Each policeman is required to cite 1 in every 3 vehicles, accumulating 5 to 10 tickets or citations per day. Current traffic fines range from $8.33 for refusing to stop at a red light or slowing down at a yellow light or operating a motorcycle without a helmet, to $16.67 for reckless driving or exceeding speed limits, to $166.67 for driving without a license plate [159]. One officer citing an average of 1,667 cars or motorcycles a year at the lowest fine of $8.33 will generate $13,886 of revenue per year. The intervention requires 4 policemen per million inhabitants, yielding an estimated revenue of $55,544 per year, far exceeding the estimated cost of $32,316 needed to implement the intervention. However, a significant and unknown portion of the revenue from citations are lost to bribes and are kept as income [160]. To adjust for this, an estimated 25% loss of revenue due to bribery has been modeled. The intervention, controlling for bribes, now yields an estimated revenue of $10,415 per year per officer, for a total of $41,660. This model shows that citations typically yield more than sufficient revenue to counter the police costs of enforcement, even when adjusting for potential loss of revenue through bribes.

5.3.4 Discussion: Modelling the Cost-Effectiveness of Improved Traffic Enforcement

Cost-effective analysis of injury prevention interventions has seldom been used in the developing world and in Haiti. This is the first estimate for the case of Haiti. The reasons for the lack of research into injury prevention are plenty: low investments in injury research, injuries not being prioritized and identified as a public health issue, and a lack of appropriate capacity in Haiti and the developing world [104,161,162]. Modelling the costs and effectiveness of such interventions provides compelling evidence. Haiti cannot afford to wait for trials in other low-income countries in order to implement its own. Adopting the World Health Organization's Choosing Interventions that are Cost-Effective guidelines, an intervention that per DALY avoided costs less than three times the national annual GDP per capita is considered cost-effective, and one that costs less than once the national annual GDP per capita is considered highly cost-effective [41]. Given an annual GDP per capita of $829 [98], the intervention modeled in this section is highly cost effective, ranging from $10 (0% discount rate, 25% reduction in fatalities) to $65 (10% discount rate, 15% reduction in fatalities) per DALY saved or averted. Additionally, medical care savings associated with slight or serious injuries have the potential to outweigh enforcement costs only if as a few as four deaths are prevented, given the injury severity ratios mentioned previously. Police revenues are also expected to outweigh enforcement costs, making this intervention a revenue-yielding initiative by the government.

When compared to estimates provided by Bishai and Hyder (2006) on the cost per DALY averted with better traffic enforcement for 1 million inhabitants in the Sub-Saharan African (SSA) region (discounted at 3%; 25% reduction in fatality), the costs were similar [104]. This study yielded an estimate of $17 per DALY averted versus $12 in the compared study. There was no attempt to standardize the costs to maximize the comparison. The SSA region was chosen for comparison as the conditions in this region are closest to the Haitian setting, based on GDP per capita, number of vehicles, as well as costs of enforcement. One published study in South Africa has shown that the cost of a one-year enhanced seatbelt enforcement program would be modest, and highly beneficial in terms of saved lives and injuries, yielding both positive net benefits to society and yielding sufficient revenue from fines to cover costs [163]. A cost-effectiveness of traffic enforcement study conducted in Uganda revealed that the cost of enforcement was offset by citations by a factor of 4, with a statistically significant reduction in in road traffic deaths by 17%, with an estimated cost

of $603 per death averted or $27 per life year saved discounted at 3% [158]. This is comparable to the model in this study, which estimates a cost of $539 per death averted or $17 per life year saved (25% reduction in fatality) to $898 per death averted or $28 per life year saved (15% reduction in fatality).

Limitations

There are a number of limitations in modelling and assessing injury interventions. First, it is clear that the rate of discount affects the cost-effectiveness estimate, and thus should be considered as an important factor when comparing with other interventions locally or other countries and regions. Currently, there is no standard or universally accepted discount rate. Second, the assumptions in this study were modelled after the Bishai and Hyder (2006) model, and some of the assumptions adopted may not be applicable to the Haitian setting despite attempts to retrieve locally relevant estimates. Third, the model only uses injury cost estimates from HBMPM derived in the study, and may or may not reflect the cost of medical care at other institutions that provide trauma care in Haiti. Fourth, the ratio of fatalities to slight and serious injuries vary by country and region, and only serve as a guide for extrapolating road traffic injury patterns. Currently there are no country estimates for this. Fifth, other competing interventions have not been modelled for comparison in this study, despite numerous studies showing that interventions such as the installation of speed bumps, initiative aimed at promoting motorcycle and bicycle helmets, and other common and modern road safety initiatives are cost-effective. Future studies and additional models are needed to compare competing interventions in Haiti in order to prioritize possible interventions based on cost-effectiveness.

Conclusion

With the expansion and pavement of roads, driven by economic growth and a sharp rise in demand for motor vehicles, expected to occur, fatality rates due to road traffic accidents are expected to rise dramatically, as evidenced by various developing countries [164,165]. In response, both trauma care and initiatives aimed at reducing injuries due to road traffic accidents are imperative. A pilot study to measure the costs and reduction in traffic fatality is needed in Haiti to provide empirical

evidence to policy makers, potentially displaying that interventions such as those outside the health sector can be very cost-effective investments that can provide substantial public health benefits. Cost-effectiveness analysis, such as the one proposed, provides a compelling tool for policy makers that is both systematic and based on scientific evidence rather than historical or political beliefs and patterns.

5.4 Objective 4. Cost-Effectiveness of a Trauma Hospital in Port-au-Prince, Haiti

5.4.1 Model Outcomes

Total fixed and variable costs during the 2-month study period amounted to an estimate of $135,897 (Table 24). Fixed costs were estimated at $38,311, driven primarily by general/administrative salaries, followed by rent. Variable costs or operating costs totaled $97,586, driven primarily by surgical, diagnostic, and pharmacy costs.

Table 24. Fixed and variable Costs (US$) for December 2015 to January 2016 (2-month period).

Fixed Costs	**Cost**
General/administrative salary and related expenses	$9,167
Rent	$6,758
Utility and phone	$2,908
Travel, shipping, and related expenses	$2,300
Office Supplies	$1,915
Renovation and repair	$1,797
Computer related expenses	$1,409
Bank service charge	$873
Postage and delivery	$394
Other expenses	$10,790
Total	$38,311
Variable/Operating Costs (N = 404)	
Surgery	$27,917
Diagnostics	$26,408
Pharmacy	$24,387
Hospitalization	$7,541
Laboratory	$4,380
Consultation	$3,838
Rehabilitation	$2,255
Suture/Woundcare	$1,065
Total	$97,586
Grand Total	**$135,897**

A total of 410 patients were seen during the study period, however, DALY calculations were only available for 390 (95.1%) patients, due to missing data on diagnosis. Of the 390 patients, 370 patients were 63 years of age or younger. Thus, DALYs averted for those over 63 years of age were excluded, however, the burden (DALY) and the costs incurred for these patients remain. Details of the conditions/procedures, DALYs, and DALYs averted are shown in Table 25.

Table 25. Burden of conditions and effectiveness of treatment (n = 370). Patients with multiple conditions were assigned to the most severe condition (i.e., a patient with a fracture and a laceration was assigned to "Fractures," and all DALYs and DALYs averted were aggregated.

Condition	# of Patients	DALYs	DALYS Averted
Soft Tissue Injury[a]	199	57	0
Traumatic Brain Injury[b]	88	846	347
Fractures[c]	49	128	42
Life Threatening Injuries[d]	5	158	158
Other[e]	15	65	18
Deceased Patients[f]	14	351	0
Total	**370**	**1605**	**565 (35%)**

[a] Includes abrasions, contusions, and lacerations
[b] Includes all conditions/procedures to the head (i.e., craniotomy)
[c] Includes dislocations
[d] Includes all other life threatening conditions/procedures (i.e., laparotomy)
[e] Includes all other conditions/procedures (i.e., burns, tooth loss, nerve damage)
[f] All deceased patients in study cohort aged 63 years and younger

Most patients in the study cohort suffered minor injuries such as soft tissue injuries, thus no DALYs were averted for the majority of patients. The majority of DALYs incurred and averted were for patients suffering from traumatic brain injury. There were 5 life threatening injuries, excluding any life threatening traumatic brain injury, averting 158 DALYs. An estimated 565 of 1605, or 35%, of DALYs were averted by treatment during the study period. This amounts to an average of 4.3 DALYs per patient and 1.5 DALYs averted per patient. At a total cost of $135,897, this gives a cost-effectiveness of $241 per DALY averted.

$241 per DALY Averted

5.4.2 Discussion: Modelling the Cost-Effectiveness of a Trauma Center

This study estimated the cost per DALY averted during a 2-month period at a trauma hospital in the capital city of Port-au-Prince, Haiti. Conservative DALY estimates were used and the method used has been consistent with the few studies published on injuries and trauma care in LMICs, as described in the methods section of this thesis.

One study published in 2011 in the outskirts of Haiti revealed that a short orthopedic mission, which treated 93 patients (130 procedures), averted a total of 326 of 527 DALYs (5.6 DALYs per patient; 62%), at a total cost of $111,681, giving a cost-effectiveness of $343 per DALY averted [116]. The majority of procedures in this patient population were for debridement, amputation or stump revision, with few undergoing applications of external fixators and internal fixation. The results presented in this thesis are similar, with fewer DALYs incurred per patient and slightly lower costs at $241 per DALY averted.

One study published in 2009 in the capital city of Port-au-Prince, Haiti, estimated the cost-effectiveness of a surgical trauma center operated by a non-governmental organization, Doctors Without Borders (MSF) [113]. During a 3-month period, 4,404 patients were seen, representing an estimated burden or DALY of 18,991. 7,377 DALYs were averted by treatment at a total cost of $1.6 million, giving a cost-effectiveness ratio of $223 per DALY averted. In the same study, a similar trauma center operated by MSF in Nigeria revealed a cost-effectiveness ratio of $172 per DALY averted. These estimates are in line with the current study, and are considered within the WHO threshold for cost-effectiveness. The large number of patients compared to the current study is partly due to a period in Haiti described as a period of acute urban warfare, following the coup d'état in 2004.

Other studies in LMICs, such as one conducted in a surgical unit of a private hospital in India, which treated 2,580 patients with surgical procedures, averted a total of 9,351 DALYs (3.6 DALYs averted per patient), with a cost-effectiveness of $165 for all surgical interventions [117]. For injuries, 348 cases avoided an estimated 431 DALYs, giving a cost–effectiveness of $511. The present study favors comparatively, however, both studies are within the WHO threshold for cost-effectiveness. Two other studies, one in a district trauma hospital in Cambodia and in small

hospital in Sierra Leone, had a cost-effectiveness ratio of $77 and $33 per DALY averted [114,115]. In the Sierra Leone study, medical and surgical costs were not disaggregated and included pediatrics, general surgery, and orthopedic surgery (both elective and emergent), and thus it is reasonable to assume that surgical activity may be higher than the reported $33 per DALY averted.

These studies represent the small literature base on the effectiveness of trauma care or surgery in LMICs, and at a cost of $241 per DALY averted, the present study is in line with the few published reports. The percentage of DALYs averted compared to other studies is low, primarily due to DALYs incurred by those with relatively minor injuries, such as minor lacerations, which were included in this study, along with all deaths, regardless of if they occurred before the perioperative period [112]. Additionally, the cost-effectiveness ratios are not out of line with more conventional public health activities. Interventions such as vitamin A supplementation reported a cost-effectiveness ratio of $6 per DALY averted, a therapeutic feeding program in Zambia 53$, pneumococcal conjugated vaccination $200, ARV treatment $400, full childhood immunization $438, and rotavirus vaccination $540, highly active anti-retroviral therapy $922, breast feeding promotion $930, and oral rehydration therapy $1,062 [42,166-170]. Cost per DALY averted studies are an increasing popular mean of assessing the cost-effectiveness of strategies. In a recent systematic review of DALYs averted, 479 studies from the year 2000 to 2015 were conducted [171]. The majority of these studied were conducted in Sub-Saharan Africa (SSA). The disease areas most studies were communicable, maternal and nutritional disorders (67%), followed by non-communicable diseases (28%), and injuries (2%). The authors argue that most studies have focused on SSA and Asia, particularly infectious and parasitic diseases, due to the priorities of funding agencies and disease burden. However, their study also highlights certain diseases and condition, such as injuries, that are under-represented in the literature relative to the burden they impose. The authors conclude that these disparities underscore the need for the scientific community and governments to revisit health economic research priorities.

Limitations

There are many weaknesses in this model that need to be commented upon. The first major limitation is the subjective and arbitrary nature of weighting disabilities, anticipated outcomes

without treatment, and the effectiveness of treatment. More studies are needed to validate the methods and the results of this study despite the use in many studies. Second, the fixed costs used in this study reflect the average cost for operations for the year 2014 at HBMPM, and may or may not reflect costs during the study period. However, costs were similar in 2014 when compared to the year 2013. Even if fixed and operating costs were underestimated by 100%, the intervention would still be highly cost-effective using the WHO threshold. Third, a single institution study may not be representative of the population of Haiti or the healthcare sector, and thus a larger scale study with a representative sample of hospitals is needed for policy implications. A large scale study will undoubtedly provide a better estimate cost-effectiveness of surgery or trauma care, which would likely establish such an intervention as a priority in public health policy making. Fourth, the biases related to the cross-sectional study design, such as misclassification bias and missing data, are to be noted.

Conclusion

Surgical and trauma care appears to be highly cost-effective in this study based on the WHO threshold, and is in line with studies done on surgery and trauma care in LMICs, as well as other conventional public health interventions. Despite potential biases in this single institution study, the argument can be made, supported by the literature base, that trauma care and the management of injury in LMICs is a feasible feat, and should be included in any basic healthcare system. Traumatic injury is expected to rise with further development and motorization, and thus a comprehensive trauma system with surgical capabilities may provide substantial health benefits and reduce the burden of injury and the long-term consequences involved in such injuries.

6. Discussion

Haiti serves as a unique case study, as it is an island susceptible to various natural disasters such as hurricanes and earthquakes, coupled with a struggling health system and poor infrastructure. The burden of trauma in LMICs and in Haiti poses a great challenge to already struggling and deficient health care systems, which is exacerbated by the lack of resources, compounded by that fact that there is no organization to take care of trauma patients. There is very little data on trauma in Haiti, which is important information needed to understand the burden of disease and cost of illness of trauma. For these reasons and more, it was necessary to develop this study to provide much needed data, as well as to develop health care systems that are cost-effective, regionally specific, and confined by the financial situation on the ground. The current study aims at providing these data and models with the aim of starting the process.

Although countries like Haiti suffer from a host of diseases and conditions, particularly infectious diseases, the burden of trauma cannot be ignored. Injuries are largely preventable, provided that proper interventions are enacted, mainly through interventions such as the enforcement of traffic laws to protect both bystanders and those involved in vehicles. The larger issue of violence in Haiti requires strong governance and economic opportunity for mitigation. Those physically assaulted as well as victims of gun violence suffer tremendously in Haiti, as perpetrators are seldom held responsible with a weak judicial system plagued with corruption. While this "disease" bears a heavy mark on the Haitian society and on the healthcare system as a whole, trauma is rarely the focus of attention, and foreign donors continue to focus on other disease areas, such as HIV/AIDs and cholera treatment, for instance. This thesis sets out to describe the epidemiology of traumatic injury at the nation's premiere trauma center, to describe the costs associated with trauma care, and to assess the cost and effectiveness of interventions on both the prevention and trauma-care side. The goal is to bring to light this issue of traumatic injury, and to eventually engage the international community and Haitian policy-makers in talks to implement a successful trauma care network with effective care.

The results of this retrospective and hospital-based chart review study provide key data on injury characteristics for patients treated at the nation's leading trauma hospital. This study provides the

first published data in stemming from the capital city, and adds to the dearth of information on trauma in Haiti. HBMPM's medical records and archiving department is fully staffed and functional, however, despite being a premiere hospital with backing from foreign organizations, private donations, as well as government grants, improvement in medical record documentation is crucial. The study revealed that approximately 10% of medical charts were missing during the study period. One of the main reasons for missing documentation is due to the paper-based archiving system that exists today, and the vast number of patients. Medical charts are easily displaced and extremely difficult to identify, as they are organized in alphabetical order by patient names. Additionally, some charts were lost in transition during construction periods, as well as some taken by patients. This issue of medical documentation is not a unique issue to HBMPM, but all studies published recently have raised this concern. HMBPM represents one of the better equipped hospitals, as most hospitals in the country do not allocate resources at all. An electronic medical filing system would serve best, but the necessary resources and dedication is needed and is unlikely at this moment, as most resources are dedicated to providing care, as the hospital runs on a deficit each year.

Trauma registries have proven to provide key information necessary for improvement of care in developed countries. Countries continuously monitor trauma trends and quality of trauma care, by measuring, for instance, potentially preventable deaths. In order to truly quantify the burden of traumatic injuries in Haiti, as well as understand the implications, a national trauma registry would be welcomed. Although HBMPM does currently use a paper trauma registry form, it is seldom used in the emergency department, as there are no clearly designated personnel to fill out these forms. Two issues have been identified that may serve to guide future efforts at establishing a national trauma registry. First, although the trauma registry form is available, these forms are placed in patient medical record files, and no carbon copies are made. This proves to be an extremely difficult and tedious process if one is to research trauma, as patients have to be identified through the main hospital logbook, and then medical charts are to be extracted, and subsequently trauma forms evaluated. An electronic trauma registry, which has been proven to work in other low-resource areas and in Haiti, would provide substantial improvement. Second, even if these trauma registry systems are implemented in various hospitals across the country, the value that they provide is largely unknown by those providing care and completing these forms. This

development speaks volumes about the state of research in Haiti as a whole. No matter if and how the trauma registry system is set-up, it is ultimately up to healthcare practitioners and staff on the ground to see value in injury surveillance that can ultimately lead to an improvement in care. Without a commitment to this, which will likely need an educational program to those currently and those planning on becoming healthcare practitioners, a national trauma registry will provide little value.

This study, and others conducted in remote parts of Haiti and other LMICs, has shown that the vast majority of victims are male and less than the age of 45. Due to the young age of victims, the burden of disease remains high, as it affects individuals who are considered to be in their economic primes. In terms of the sheer number of injuries in Haiti, it is extremely difficult to identify the numbers of injured. With no trauma registry and no local injury surveillance, quantifying this number is difficult. However, there is a remarkable finding that may provide us with an idea of this number. This study, along with others, primarily the national study conducted by McCullough et al. 2016, confirm that tertiary hospitals around the country see an estimated 200 trauma victims a month. Epidemiological data provided by these studies serve as the only estimates for Haiti. In order to further monitor injury trends, a national effort is needed by many actors. Epidemiological data from hospitals, statistics from the national police, and other sources such as coroner's reports, can provide a more complete picture. However, it is highly unlikely to conduct such a large scale study at this moment. The first feasible step would be to require all main hospitals in the country to collect trauma data and to essentially establish a national trauma registry. However, data will likely be incomplete, especially for those deceased in the pre-hospital setting, which will underestimate the true burden of disease.

Healthcare practitioners, both local and foreign, who operate in Haiti have documented their experiences quite extensively. Trauma is often the talk of conversation, primarily because of the host of natural disasters in the past decade, that have claimed more than 300,000 lives. However, for ordinary individuals that live and work in Haiti, insecurity and chaos on the streets of Port-au-Prince and elsewhere are the topic of conversation. This study has confirmed that most traumatic injuries are due to road traffic accidents, which is the number one mechanism responsible in the world. The explosion of motorcycles in the city have made it a nightmare to navigate the roads.

With helmet use uncommon, despite official regulation mandating it, it is expected that traumatic brain injury be a major culprit. No study on traumatic injuries have provided injury severity scores in Haiti. With conservative scoring, limited by patient diagnoses, the data revealed that the majority of patients had minor injuries, such as minor lacerations and soft tissue injuries. There is no other data to compare these findings with, which would serve to validate or invalidate these findings. However, despite this, a more pressing development has come to light. As hypothesized, traumatic brain injury is a common occurrence, exacerbated by the sheer number of road traffic accidents, with little safety precautions taken. This development is particularly alarming, as there are only four CT-scanners in all of Haiti, along with four neurosurgeons. There is a massive need for both radiology/diagnostics technology and neurosurgeons in Haiti, as the prognosis for those involved in head traumas are undoubtedly expected to be poor.

Data on morbidity and mortality due to traumatic injury have failed to convince policy makers in developing countries to invest in trauma care and prevention. Providing an estimate of costs due to traumatic injury may serve as an alternative tool in doing so. When all cost aspects were evaluated in this study, it became clear that the average cost in the study sample was greater than the annual GDP per capita of Haiti. This indicates that a traumatic injury has the possible effect of negating an entire year or more of economic production per victim. Although it is difficult to compare the cost of traumatic injury to other publishes studies in LMICs due to various methods, discount rates, and approaches, this study revealed high costs. There are no other cost studies in Haiti to compare this data too. When direct medical costs were calculated, Haiti had higher costs than most of the cost studies published in the literature. This was the case even when the vast majority of injuries were minor in the study sample. There are many possible explanations for this increase of cost of care. First, the high costs of CT-scans (approximately $200) drove up the cost of care, as many victims required it. One of the driving costs for CT-scans at HBMPM is the fact that there are no local qualified technicians that are specialist in CT-scanner reparation. When the CT-scanner is broken or malfunctioning, HBMPM is obliged to contract an external consultant from the United States to fly to Haiti to repair the machine. There are currently no technicians or spare parts in Haiti to fix these ongoing issues. In comparison, one of the four CT-scanners in Haiti is located at the University Hospital of Mirebalais, located in the Central Department of Haiti. While this university hospital charges a very low price for CT-scan use, the machine is rarely in

function, primarily due to the same maintenance issues experienced at HBMPM. Second, surgical packages, such as surgery to repair a tibia fracture, amounted to approximately $700. Third, pharmacy costs were high, primarily due to the high cost of medication in Haiti compared to the International Reference Price. These three cost categories accounted for more than 80% of costs. It is difficult to precisely determine why these costs are high without a detailed study on unit healthcare costs in LMICs. Cost data in developing countries, and in Haiti, are extremely hard to obtain, unless published by the governments of these countries. In Haiti, there are no guidelines or regulation on healthcare unit costs, as numerous actors provide healthcare services, such as NGOs and private charities. It is also important to note that these costs are considered excessive due to the socioeconomic condition of the country. Without the donations and grants provided, the essential services provided at HBMPM would not be possible. Due to HBMPM being a semi-private hospital, it is known and expected to be less expensive than privately owned hospitals, and slightly more expensive than public hospitals, such as the General Hospital. Due to these public hospitals giving care practically free of charge, the hypothesis is that direct medical costs would be lower compared to those at HBMPM. However, the quality of care and access to care in these often ill-equipped hospitals poses a major challenge. They are simply unable to offer quality care as government allocated resources are scarce. For example, General Hospital charges patients only for material use, as doctors, nurses, and staff salaries are paid for by the government. At HBMPM, surgical packages are computed using the cost of material expenses and average salaries. While these costs may not be considered high from the point of view of a developed country, the same cannot be said of Haiti. With half of the population surviving on less than $2 dollars a day, healthcare is out reach for most. Further, with unemployment above 50%, an injury can cost an employee his job, as he or she is likely to be replaced if the injury requires a long absence. With no health insurance for the majority of Haitians, any injury can potentially cause a catastrophic social and economic burden to the individual and their family.

Ultimately, the government of Haiti bears the cost of injury as the majority of citizens are unable to pay, thus crowding public health facilities and HBMPM. One way to mitigate the costs of injury is to prevent injuries altogether. This study aimed to provide the first country-specific model on the cost and effectiveness of improving traffic enforcement to counter injuries. The objective of this model is to provide an accurate estimation of the costs of implementing such an intervention,

and the hypothetical savings, in terms of medical costs, as well as human lives. The model in this study proved that a police force dedicated to traffic enforcement has the potential to save numerous lives and years lived in disability, at a meager cost ranging from $10 to $65 per DALY averted. The model showed that this intervention could also save thousands of dollars in terms of averted medical expenses alone. From a governmental perspective in a low-resource country, it is difficult to justify an intervention with hypothetical benefits in the future. However, the model showed that if enforcement is implemented properly, revenues from citations would outweigh enforcement costs, and potentially be a new revenue source for the government to expand services. Other countries, both developed and developing, have conducted pilot studies that have showed this. This intervention requires a meager investment and has the potential to save lives and reduce the cost of illness of traumatic injuries in Haiti. It is naïve to suggest that traumatic injuries, particularly those incurred due to road traffic accidents, are going to plateau or decrease. The newly elected President of Haiti, Jovenel Moise, has made it a priority to establish thousands of kilometers of roads, connecting various cities in the country. With the expansion of roads, the slight improvement in economic conditions, and the infatuation with motorcycles, fatality rates are expected to rise dramatically. Thus it is imperative that this development is accompanied by an increase in education of road safety, as well as strict enforcement of road traffic codes. Other road interventions, such as the installation of speedbumps, have also proven to be cost-effective and merit implementation. However, the emphasis should be placed on general enforcement of traffic codes, as this intervention covers many aspects of road safety.

Despite interventions aimed at reducing traumatic injuries, injury is often inevitable. In the case of Haiti, this is particularly true, as the country is prone to natural disasters including seasonal hurricanes, earthquakes, mudslides due to deforestation, coupled with political violence. The study set out to estimate the cost and effectiveness of a trauma center in the city of Port-au-Prince. The aim was to establish whether or not trauma care was “cost-effective” compared to a threshold established by the WHO. The cost per DALY averted was measured for the sample in this study, and all costs associated with care and operations were calculated. The estimated cost-effectiveness ratio was $241 per DALY averted, which is considered highly cost-effective according to the WHO. This amount is in line with many other common and conventional interventions. Surgical care has seldom been a focus of attention in low-resource countries, primarily due to the perceived

costs. However, this model shows that when the impact of care is measured in comparison to its costs, surgical care should be a staple in healthcare provision as it reduces disability and can be life-saving.

This study has shown that trauma represents a significant burden of disease and a high cost of illness, exacerbated by high penetrating and traumatic brain injuries, which carry high costs due to diagnostic, surgical, and pharmacy costs. Time to care and treatment is long, as no formal EMS systems are currently in operation, which can delay patients from accessing critical care on time. Various prevention and trauma care interventions have been shown to be highly cost-effective in this study, which should be piloted in Haiti in the near future. Additionally, a healthcare system with regional trauma centers in each geographic department would be required in order to have a comprehensive trauma care system and network to be able to meet the needs of the population. A feasibility and implementation study should be done to model this system in order to understand the costs and benefits, with eventual implementation.

7. Conclusion and Recommendations

7.1 Novelty and Contribution to the Advancement of Knowledge

At the present time, trauma care in Haiti is not organized at any level. Injuries, and in particular motor vehicle accidents, continue to present a major cause of burden of illness and remains a disease that is not well understood from the epidemiological, preventive, and health services perspective. There are no indicators to determine the cost effectiveness of and hence priority ranking of possible interventions that can reduce the burden of illness. This current study attempts to address these issues. This is the first study assessing the epidemiology and outcomes of patients injured in the capital city of Port-au-Prince, Haiti, at the nation's leading trauma center. This is also the first cost of illness study conducted in Haiti on trauma. Additionally, this is the first study to assess the potential impact of possible interventions, while considering regional and national factors that can affect feasibility. Health economic assessments of trauma care remains controversial and the current study provides insight on conducting these types of studies on trauma and in a developing country that is currently in crisis. The use of health economic models to define achievable interventions in a society with minimal resources is also unique about the current study. The hope is that this important piece of work will aid in future development programs, and that more research will be conducted on trauma in Haiti in hope of improving injury surveillance and care for the Haitian people. Below are a summary of the main findings and recommendations that will help improve trauma care and injury surveillance and prevention.

7. 2 Recommendations for Trauma Care and Injury Surveillance

1. Standardization of documentation

Standardization of documentation, especially in hospital main logbooks and emergency department logs, is a target for specific intervention to create or improve a locally relevant trauma surveillance program with a view to a targeted public health intervention.

2. Implement a national trauma registry

The implementation of a national trauma registry will provide much needed data on trauma that will help understand the culprits of traumatic injury, but will also provide data to monitor quality of care, with the hope of improving access and care for all.

3. Increase care capability

It is clear that Haiti lacks the necessary personnel and technology to cater to the sheer number of those affected by traumatic injury. There is a huge need for radiology and diagnostic training, as well as the distribution of these technologies to better serve the entire population, especially those in rural areas. Additionally, there is a severe lack of orthopedic and neurosurgeons in Haiti. Educational programs aimed at increasing capacity and training residents in these specializations will be highly beneficial.

4. *Establish a trauma care network*

In order to implement a successful trauma care network with effective care, three major requirements are needed:

1. Efficient pre-hospital care that identifies the patients with life-threatening injuries, implanting on-site stabilization with rapid transport to a hospital where definitive care can be provided (requires a functioning pre-hospital system such as the Centre Ambulancier National initiative, which is currently closed due to mismanagement and lack of resources).

    a) This will require training of emergency medical technicians (EMTs) to provide on-site basic and advanced life support as required.

2. Accurate triage algorithms that enable the identification of patients with major injuries that require treatment in specialized trauma centers, and those with less severe injuries that can be managed in other facilities (currently non-existent).

a) For patients with major injuries, transport to a specialized hospital and initiation of definitive care must happen within 60 minutes (i.e., referral centers such as HBMPM).

3. Designation of level I trauma centers dedicated to the care of patients with life threatening injuries; level II trauma centers where severely injured patients can be stabilized prior to transport to a level I center, or where patients with less severe injuries can be managed; and level III trauma centers where injured patients in remote areas can be stabilized and subsequently transported to level I center.

    a) Level I trauma centers have to be optimally located to facilitate access via ground transport and must be proximal to locations of high trauma volume. A level I trauma center must be built in the capital city of Port-au-Prince, and then each of the 10 geographic departments operating a level II trauma center with staff trained in trauma, critical-care, and rehabilitation.

    b) Level I trauma centers must emphasize training of surgeons, physicians, and nurses on the management of trauma patients and must allocate resources for trauma care.

5. *Commitment to enforcing traffic codes*

A commitment to enforcing traffic codes will undoubtedly reduce the burden of traumatic injury for individuals and reduce the burden on the healthcare system. A police force dedicated to enforcing rules and prioritizing road safety will save lives and provide a revenue stream for the government, making this intervention highly sustainable.

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9. Appendix

Appendix 1. Trauma registry form (French version).

Dossier #

REGISTRE DE TRAUMATISMES(HAITI)

1. _____ ER # 2. _____ Nom _____ Prénom

3. **Date de naissance :** _ / _____ / _____ _____ **Age:** _____ an(s) **si âge < Année** **Age :** _____ mois
jj / mm / aaaa

4. **Sexe:** ☐ Masculin ☐ Féminin ☐ inconnu

5. **Hôpital:** _____ **5a. Commune:** _____

6. **Date d'admission:** _____ / _____ / _____ **Heure:** _____ ☐ AM ☐ PM
jj / mm / aaaa heure

7. **Date blessure:** _____ / _____ / _____ **Heure:** _____ ☐ AM ☐ PM
jj / jj / aaaa heure

8. **Moyen de Transport**
1 ☐ Ambulance 4 ☐ à cheval
2 ☐ voiture 8 ☐ Autres (spécifier) _____
3 ☐ à pied 9 ☐ Autres

9. **Date de décharge:** _____ /_____/_____ **10.Statut du décharge** ☐ Vivant ☐ décédé ☐ Transféré ☐ Abandon ☐ Décision du médecin
JJ / mm /aaaa

11. ☐ **Involontaire** ☐ **Intensionnelle:**
☐ Noyade
☐ Agression Physique
☐ Auto inflige
☐ Agression Sexuelle
☐ Inconnu

12. **Victime ?**
☐ Tremblement de terre _____
☐ Cyclone _____
☐ Incendie _____
☐ Inondation _____
☐ Autres _____

13. **Mécanisme/ blessure: Comment la personne a-t-elle été blesse?**

☐ **Véhicule:** ☐ Voiture ☐ Tap-Tap ☐ Motocyclette ☐ Bicyclette ☐ Bicyclette vs voiture
☐ Bicyclette vs voiture ☐ Motocyclette vs voiture
☐ **Chute:** ☐ Arbre ☐ Tap-Tap ☐ Cheval ☐ maison/ bâtiment ☐ Autre _____
☐ **Brulure:** ☐ Eau ☐ Flamme ☐ Gasoline
☐ **Coupe**
☐ **Fusillade**
☐ **Morsure d'animal**
☐ **Bousculade**
☐ **Noyade**
☐ **Autres:** _____

14. **Mesure de sécurité:** ☐ Ceinture Attache ☐ Casque ☐ Aucun ☐ NA

15. **Lieu ou les blessures sont produits:**
1 ☐ Maison
2 ☐ Rue
3 ☐ Ecole
4 ☐ Ferme
5 ☐ Terrain de jeu
6 ☐ Industrie/ construction
7 ☐ Campagne
8 ☐ Commercial
9 ☐ Rivière/ lac/ piscine
10 ☐ Autres zone de transport
98 ☐ Autres (Préciser) _____
99 ☐ Inconnu

16. **Caractéristiques Cliniques:**
Pulsation _____ /mn Fréquence respiratoire _____ /min Tension artérielle systolique _____ mm Hg

Dossier #

REGISTRE DE TRAUMATISMES(HAITI)

17. Niveau de conscience:

4 ☐ Alert
3 ☐ Répond au stimuli verbal
2 ☐ Répond au stimuli douloureux
1 ☐ Ne répond pas

17a Nombre de blessures: ☐ 0 ☐ 1 ☐ >1 **17b. Nombre total de blessures:** _____

18. Alcool consommé ? ☐ Oui ☐ Non ☐ Pas sur

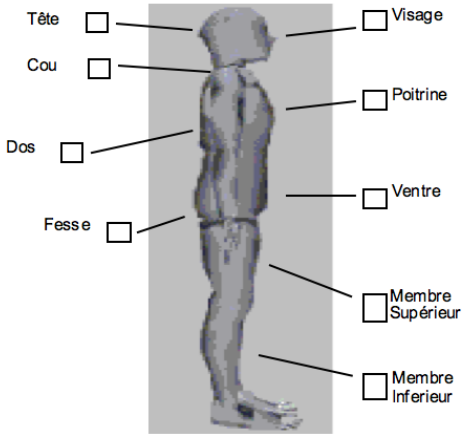
19. Disposition initiale du patient de la salle d'urgence :

1 ☐ Traite et envoyé a la maison
2 ☐ Admis
3 ☐ Transféré a un autre établissement .si transféré préciser ou _____
4 ☐ Décédé a son arrive
5 ☐ Décédé a la sale d'urgence

S'il-vous-plaît vérifiez toutes les blessures et entrez :
1= émoussé
2=pénétrante
3=brulant

Encercler les trois blessures les plus graves, si <3 encercler le nombre exacts :

Blessures:



20. Profession du patient: _____

21. Opération : ☐ Oui ☐ No

Forme remplie par: _____ le: _____

Commentaires/Observations :

Appendix 2. Trauma registry form (English version).

Dossier #

HAITI TRAUMA REGISTRY

1. _____ ER # 2. _____ Last Name _____ First Name

3. **Date of Birth:** ____ / ____ / ____ mm / dd / yyyy **or age in** ____ yrs **If <1 yr then age in** ____ months

4. **Sex:** ☐ Male ☐ Female ☐ Unknown

5. **Hospital:** _____ 5a. **District:** _____

6. **Admission Date:** ____ / ____ / ____ mm / dd / yyyy and **Time:** ____ hour ☐ AM ☐ PM

7. **Injury Date:** ____ / ____ / ____ mm / dd / yyyy and **Time:** ____ hour ☐ AM ☐ PM

8. **Mode of Arrival**
   1 ☐ Ambulance 4 ☐ By animal
   2 ☐ Other vehicle 8 ☐ Other (specify) _____
   3 ☐ By foot 9 ☐ Unspecified

9. **Discharge Date:** ____ / ____ / ____ mm / dd / yyyy **10. Discharge Status** ☐ Alive ☐ Dead ☐ Transferred ☐ Ran Away ☐ Rehab Facility

11. ☐ **Unintentional**
    ☐ **Intentional:**
    ☐ Drowning
    ☐ Physical assault
    ☐ Self inflicted
    ☐ Sexual assault
    ☐ Unknown

12. **Mass Casualty?**
    ☐ Earthquake _____
    ☐ Hurricane _____
    ☐ Fire _____
    ☐ Mass Transit _____
    ☐ Flooding _____
    ☐ Other _____

13. **Mechanism of Injury: How was the person hurt?**
    ☐ **Vehicle:** ☐ Car ☐ Tap-Tap ☐ Motorcycle ☐ Bike ☐ Bike vs Car ☐ Pedestrian vs MV ☐ Bike vs Motorcycle ☐ Motorcycle vs Car
    ☐ **Fall:** ☐ Tree ☐ Tap-Tap ☐ Horse ☐ House/Building ☐ Other _____
    ☐ **Burn:** ☐ Water ☐ Flame ☐ Gasoline
    ☐ **Stab/cut**
    ☐ **Gun Shot**
    ☐ **Animal Bite**
    ☐ **Crush**
    ☐ **Drowning**
    ☐ **Other:** _____

14. Safety devices: ☐ Seatbelt ☐ Helmet ☐ None ☐ NA

15. **Place of injury occurrence:**
    1 ☐ Home
    2 ☐ Street/highway/road
    3 ☐ School/Education
    4 ☐ Sports field
    5 ☐ Farm
    6 ☐ Industry/construction
    7 ☐ Countryside
    8 ☐ Commercial
    9 ☐ River/lake/pool
    10 ☐ Other transport area
    98 ☐ Other (specify) _____
    99 ☐ Unknown

16. **Clinical Features:**
    Pulse _____ /min Respiratory rate _____ /min Systolic blood pressure _____ mmHg

Dossier #

HAITI TRAUMA REGISTRY

17. Level of consciousness (select one):

4 ☐ Alert
3 ☐ Responds to verbal stimuli
2 ☐ Responds to painful stimuli
1 ☐ Unresponsive

17a Number of injuries: ☐ 0 ☐ 1 ☐ >1 **17b. Total number of injuries:** _____

18. Alcohol consumed? ☐ Yes ☐ No ☐ Not sure

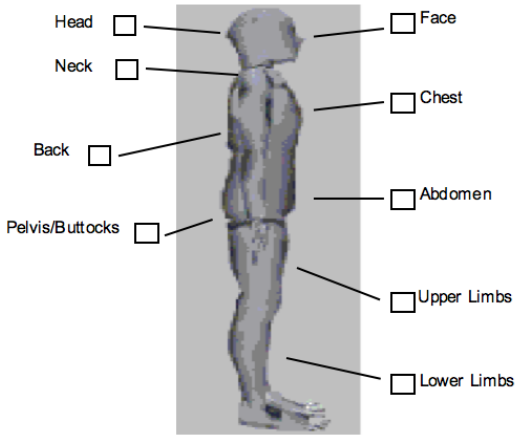
19. Initial patient disposition from emergency department / examination room:

1 ☐ Treated and sent home
2 ☐ Admitted
3 ☐ Transferred to other facility. If transferred, specify where_____
4 ☐ Dead on arrival
5 ☐ Died in emergency department

PLEASE CHECK ALL INJURIES AND ENTER:
1=blunt
2=penetrating
3=burn

Circle the three most severe injuries, if <3, circle the exact number.

Injuries:



20. Patient's occupation: _____

21. Surgery: ☐ Yes ☐ No

Form Filled Out By: _____ Date Completed: _____

Additional Comments/Observations:

Appendix 3. Brasure et al. TBI severity classification.

Table 2. Criteria used to classify TBI severity

Criteria	TBI SEVERITY		
	Mild	Moderate	Severe
Structural imaging	Normal	Normal or abnormal	Normal or abnormal
Loss of consciousness	<30 minutes	30 minutes to 24 hours	>24 hours
Post traumatic amnesia	0–1 day	>1 and <7 days	>7 days
Glasgow Coma Scale score (best available score in 24 hours)	13–15	9–12	3–8
Abbreviated Injury Scale score: Head	1–2	3	4–6

Source: Brasure et al., 2012

Appendix 4. Loss of productivity for hospitalized patients (morbidity costs; n = 52). *Patient # is not an identifier and is used to denote sequential order.

Patient #*	Length of Stay (days)	Morbidity cost (2016 US$)
1	6	35
2	17	99
3	7	41
4	1	6
5	2	12
6	8	47
7	6	35
8	1	6
9	3	18
10	33	193
11	1	6
12	1	6
13	1	6
14	2	12
15	33	193
16	1	6
17	5	29
18	4	23
19	8	47
20	7	41
21	7	41
22	1	6
23	1	6
24	1	6
25	5	29
26	10	58
27	2	12
28	3	18
29	6	35
30	56	327
31	1	6
32	1	6
33	7	41
34	1	6
35	2	12
36	23	134
37	18	105
38	9	53
39	3	18
40	2	12
41	4	23
42	2	12
43	4	23
44	3	18
45	50	292
46	7	41
47	3	18
48	15	88
49	1	6
50	1	6
51	1	6
52	7	41

Appendix 5. Loss of productivity for a fatal injury (2016 US$; average number of years lost per fatal injury is 27).

Years	Base case scenario (0% discount rate; 0% growth rate)	5% discount rate; 0% growth rate	0% discount rate; 2.2% growth rate
1	829	829	829
2	829	790	847
3	829	752	866
4	829	716	885
5	829	682	904
6	829	650	924
7	829	619	945
8	829	589	965
9	829	561	987
10	829	534	1008
11	829	509	1031
12	829	485	1053
13	829	462	1076
14	829	440	1100
15	829	419	1124
16	829	399	1149
17	829	380	1174
18	829	362	1200
19	829	344	1227
20	829	328	1253
21	829	312	1281
22	829	298	1309
23	829	283	1338
24	829	270	1367
25	829	257	1398
26	829	245	1428
27	829	233	1460
Total	**$22,383**	**$12,746**	**$30,130**

Appendix 6. Intangible costs for all hospitalized and deceased patients (2016 US$; n = 60). *Patient # is not an identifier and is used to denote sequential order.

Patient #*	Intangible cost (2016 US$)
1	10
2	28
3	11
4	2
5	3
6	13
7	10
8	2
9	5
10	54
11	2
12	2
13	2
14	3
15	54
16	2
17	8
18	7
19	13
20	11
21	6279
22	6267
23	6267
24	2
25	2
26	6269
27	8
28	16
29	3
30	5
31	10
32	91
33	2
34	2
35	11
36	2
37	3
38	38
39	29
40	15
41	5
42	3
43	7
44	3
45	7
46	5
47	82
48	6267
49	6267
50	11

51	6267
52	5
53	25
54	6267
55	6269
56	6269
57	6269
58	6267
59	6279
60	6267
Total	**88,401**

Appendix 7. Years of potential life lost. *Patient # is not an identifier and is used to denote sequential order.

Deceased Patient #*	Age (years)	YPLL
1	54	9
2	40	23
3	27	36
4	40	23
5	22	41
6	34	29
7	36	27
8	26	37
9	29	34
10	55	8
11	33	30
12	28	35
13	60	3
14	23	40
Total		375

Appendix 8. Cost per death averted, cost per life year saved, and cost per DALY averted (25% reduction; 2016 US$).

Baseline Deaths	Deaths averted	Cost (2016 US$)	Cost per death averted (2016 US$)
237	60	32,316	539

Baseline Life Years Lost	Life years saved	Cost (2016 US$)	Cost per life year saved (2016 US$)
10,191	2,548	32,316	13

Baseline DALYs Lost	DALYs saved	Cost (2016 US$)	Cost per DALY saved (2016 US$)
13,248	3,313	32,316	10

Appendix 9. Cost per death averted, cost per life year saved, and cost per DALY averted (15% reduction; 2016 US$).

Baseline Deaths	Deaths averted	Cost (2016 US$)	Cost per death averted (2016 US$)
237	36	32,316	898

Baseline Life Years Lost	Life years saved	Cost (2016 US$)	Cost per life year saved (2016 US$)
10,191	1,529	32,316	21

Baseline DALYs Lost	DALYs saved	Cost (2016 US$)	Cost per DALY saved (2016 US$)
13,248	1,983	32,316	16