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The Impact Of Diabetes Mellitus On Length Of Stay And Mechanical Ventilation Among Motor Vehicle Accident Patients In A Level-1 Trauma Center

Olyvia Branch

THE IMPACT OF DIABETES MELLITUS ON LENGTH OF STAY AND MECHANICAL VENTILATION AMONG MOTOR VEHICLE ACCIDENT PATIENTS IN A LEVEL-1 TRAUMA CENTER

By Olyvia A. Branch, B.S.E.

A Thesis

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Department of Respiratory Therapy

Under the supervision of Dr. Rachel E. Culbreth, PhD, MPH, RRT

Byrdine F. Lewis College of Nursing and Health Professions

Georgia State University Atlanta, Georgia

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ACCEPTANCE

This thesis, THE IMPACT OF DIABETES MELLITUS ON LENGTH OF STAY AND MECHANICAL VENTILATION AMONG MOTOR VEHICLE ACCIDENT TRAUMA PATIENTS, by OLYVIA A. BRANCH was prepared under the direction of the Master's Thesis Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree Master of Science in the Byrdine F. Lewis College of Nursing and Health Professions, Georgia State University. The Master's Thesis Advisory Committee, as representatives of the faculty, certify that this thesis has met all standards of excellence and scholarship as determined by the faculty.

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To my parents, I just want to take this space to tell you how much I love you. I thank you so much for supporting me and allowing me to find my own way and just providing me with unconditional love. I thank God every day for the blessings he gave me in you. Dear Lord, you continue to show me why you are an amazing God. I love you and I thank you for getting me to this point. To the coolest professors at Georgia State, each one of you has helped me at different points throughout the past two years and I owe you my utmost appreciation. To the two best people that GSU RT has brought me, I would not have made it without you Daisy and Marcia. And lastly to Dr. Rachel, my thesis chair, I thank you so very much for everything. You are amazing and you made this possible for me. Thank you, I will forever be grateful.

Love, Olyvia

Table of Contents

THE IMPACT OF DIABETES MELLITUS ON LENGTH OF STAY AND MECHANICAL VENTILATION AMONG MOTOR VEHICLE ACCIDENT PATIENTS IN A LEVEL-1 TRAUMA CENTER

By

Olyvia Branch

(Under the Direction of Dr. Rachel Culbreth)

ABSTRACT

Background: Diabetes Mellitus (DM) is a metabolic disease that affects the body's ability to properly maintain accurate blood glucose levels, generally presenting as either Type I or Type II. DM has grown into a worldwide pandemic that has affected more than 422 million people, with 35 million residing in the United States. This disease is one of the most chronic health issues in the United States with over $176 billion in medical cost, due to the long-term treatment it requires and complications that may arise. Diabetics have also been found to be at a 19 percent greater risk for motor vehicle accidents (MVA) than non-diabetics, influenced by several the risk factors associated with the disease. Not only has the driving capability of the diabetic population been found to be affected, but their ability to recover is of interest as well.

Objective: The purpose of this study was to determine how DM may impact the length of stay and ventilator duration for MVA trauma patients at a Level-1 Trauma Center.

Methods: Data was collected retrospectively among patients involved in motor vehicle accidents in intensive care at a major level-1 trauma center (n=2,802). Descriptive statistics were computed and Mann-Whitney U Tests, Chi-Square tests, and Independent Samples T-Tests were conducted to examine differences in diabetic patients and demographics, comorbidities, and patient outcomes (length of stay, ventilator days, and length of ICU stay).

Results: Among all the patients (n=2802), 8.8% were confirmed to have DM, and 92.7% were non-diabetic. Although the percentage of diabetic males was greater, there was no significant difference (*p*=0.179) between the number of males and females effected by DM. The mean age of diabetic patients and non-diabetic was found to be significant (*p*<0.001). The mean age for diabetic patients was 58.14 years in age and non-diabetic patients was 39.04 years in age. Race (*p*=0.380) was not significantly different, with 8.7% of diabetics in the African American population, 9.4% of Caucasians, and 6.8% of Asians. Total length of stay in the ICU (*p*=0.008) was significant with a median of 4 days for diabetic patients, and 3 days for non-diabetics. Total length of stay in the hospital (*p*=0.009) was significant as well, with a median of 10 days for diabetic patients and 7 days for non-diabetics. Total LOS on a mechanical ventilator (*p*=0.02) was also found to be statistically significant, with diabetic patients spending a higher number of days on the ventilator compared to non-diabetic patients.

Conclusion: MVA patients with Diabetes Mellitus may require additional interventions during their ICU and hospital stay in or to address and manage the challenges presented by the disease. The diabetic population presents with higher rates of wound infection, UTI, pneumonia, cardiac arrest, MI, ARDS, as well as unplanned intubations. Patients with DM are more likely to develop any complication following a traumatic event over patients without. Since the average age for diabetic patients is almost 60 years, people tend to develop multiple comorbidities such as obesity and other health issues. This may exacerbate their DM and make it difficult to properly maintain especially following a traumatic event such as an MVA.

List of Figures

List of Tables

CHAPTER I

INTRODUCTION

Background

Diabetes Mellitus (DM) is a chronic metabolic disease that negatively impacts the body's ability to maintain accurate blood glucose levels. The two most common forms of DM consist of Type I and Type II. Type I DM is characterized by poorly functioning or damaged pancreatic cells, with onset of symptoms more commonly occurring in childhood or adolescence, but not excluding adulthood.[1,2] Patients with Type I DM require the administration of exogenous insulin through injection or insulin pump in order to sustain life. Type II DM is generally developed later in adulthood due to the prevalence of obesity and other comorbidities that cause cells to become resistant to the hormonal function of insulin. Excess body fat accumulation is the leading cause for the formation and multiplication of insulin resistant cells throughout the body.[2,3]

Although Type II DM comprises about 90% of diabetes cases, it is considered to be less detrimental than Type I DM due to its preventable nature.[4] Modifiable risk factors for Type II DM include obesity/overweight, physical inactivity, smoking, hypertension, and abnormal cholesterol levels; all which can be controlled or reversed by practicing healthy lifestyle choices.[5] However, there are several non-modifiable factors such as family history, race/ethnic background, age, and history of gestational diabetes, that may increase a person's risk to developing prediabetes, ultimately leading to Type II DM.[4,5]

DM has grown into a worldwide pandemic that has plagued more than 422 million people globally, with 34.2 million residing in the United States in 2018.[6] In the state of Georgia alone, every 1 in 10 adults have been diagnosed with DM, resulting to over 1 million confirmed cases, and impacting over 12.1% of the adult population.[7] CDC data from 2017 indicates the treatment of DM resulted in over 16 million hospital visits, which contributed to $376 billion in nationwide medical cost; $237 billion in direct medical cost and $90 billion in reduced productivity in the workplace.[6] The extravagant cost is a product of long-term treatment plans that consist of inpatient hospital care, prescription medication, physician office visits, anti-diabetic agents, and complications that may arise due to the exacerbation of uncontrolled DM.[8]

Of the millions of people living with DM in the United States, a majority will seek or currently hold a driver license. Persons with DM have been found to be at greater risk for motor vehicle accidents (MVA) than non-diabetics.[9] However, a majority of previous MVA studies on the diabetic population specifically focused on those who were “insulin-treated” or had Type I DM, due to the greater prevalence of hypoglycemic events. [9,10] This population is more prone to suffer debilitating neurological effects that impair driving capability. [10,11] When a driver experiences a hypoglycemic event, driving performance, reaction time, and hand eye coordination start to deteriorate.[10] A hypoglycemic event may lead to lightheadedness or black out spells, which can directly cause an MVA if the person is actively driving.[10]

Not only is the driving capability of the diabetic population under surveillance, but their ability to recover from an MVA is of interest as well. Previous data indicated that diabetics have an increased hospital length of stay (LOS) when admitted for any medical procedure, no matter the type.[8] When observing diabetics the days following an elective surgery, they experienced a mean hospital LOS of 9.08 days compared to 4.76 days for non-diabetic patients, resulting in a mean cost increase of nearly $4,000 for the diabetic patients.[12] The occurrence of death, myocardial infarction, pneumonia, and acute kidney injury were also found to be significantly increased in the sample of diabetic patients.[12,13] The presence of DM has a strong association with increased risk for developing further complications, which may lead to multiple intubations or readmissions.[8,13]

Statement of the Problem

Little research exists pertaining to the analysis of how motor vehicle accidents may specifically impact injury severity and recovery experienced by patients presenting with Diabetes Mellitus. A majority of previous studies assessing number of ICU days, number of days spent on a mechanical ventilator, as well as hospital LOS and total hospital cost of diabetic patients are not associated with motor vehicle trauma, but more so focus on post-operative care, as well the management of other issues such as hypoglycemic events, diabetic ketoacidosis, hyperglycemia, and respiratory distress. Although these studies are helpful in determining the best treatment plan for diabetic patients, the type of injuries acquired during an MVA may require different approaches to patient care.

Data involving MVA trauma was highly concentrated on the presence of obesity, and its impact on patient injury severity level as well as injury location.[14,15] Various analysis techniques are needed to determine if non-diabetics, Type I diabetics, and Type II diabetics, will each experience a different severity of injuries and time to recovery. This may directly impact hospital length of stay and time spent on a ventilator based on their diabetic classification. Although there is substantial amount of literature on the effect of DM on driving capability, further research is needed to determine if DM actually has an impact on recovery from MVA trauma over patients who are non-diabetic. Therefor due to a lack of supportive research, it is unclear if Type I and Type II DM truly has a significant impact on hospital length of stay and duration on mechanical ventilation following a motor vehicle accident.

Purpose of the Study

The purpose of this study is to determine how Diabetes Mellitus may impact hospital length of stay, ICU length of stay, and ventilator duration, for motor vehicle trauma patients at a Level-1 Trauma Center.

Research Questions

1. What is the prevalence of diabetes among patients involved in motor vehicle accidents in a level-1 trauma center?
2. Are there differences in length of stay between diabetic and non-diabetic patients involved in motor vehicle accidents?
3. Are there differences in mechanical ventilation duration between diabetic and non-diabetic patients involved in motor vehicle accidents?
4. What is the prevalence of diabetic patients involved in motor vehicle accidents that also have other comorbidities?

Definition of Terms

Cellular Respiration: Metabolic reactions and processes that take place in the cells of organisms to convert chemical energy from oxygen molecules or nutrients into adenosine triphosphate (ATP), and then release waste products.

CDC: The United States Centers for Disease Control and Prevention is the national public health agency of the United States.

Diabetic Ketoacidosis: Diabetic ketoacidosis is a serious complication of diabetes that occurs when your body produces high levels of blood acids called ketones. The condition develops when your body can't produce enough insulin. Insulin normally plays a key role in helping glucose, a major source of energy for your muscles and other tissues, enter your cells.

Diabetes Mellitus: A condition defined by persistently high levels of blood (glucose) in the blood. The two most common are Type I and Type II diabetes.

Exogenous Insulin: Any insulin that your body doesn't make on its own, that you receive via injection, insulin pump, or most recently by inhalation device.

Glucose: A Simple sugar which is an important energy source in living organisms and is a component of many carbohydrates. It is primary source of energy produced from digesting carbohydrates into a chemical that the body can easily convert to energy

GLUT-4 Vesicles: An insulin-regulated glucose transporter that is responsible for insulin-regulated glucose uptake into fat and muscle cells.

Dysglycemia: A nonspecific term for any alteration in serum glucose that encompasses both hypoglycemia and hyperglycemia.

Insulin: A peptide hormone produced by beta cells of the pancreatic islets; it is considered to be the main anabolic hormone of the body. It regulates the metabolism of carbohydrates, fats and protein by promoting the absorption of glucose from the blood into liver, fat and skeletal muscle cells.

Insulin Resistant: In states of insulin resistance, the same amount of insulin does not have the same effect on glucose transport and blood sugar levels. Risk factors for insulin resistance include obesity, sedentary lifestyle, family history of diabetes, various health conditions, and certain medications. Insulin resistance is considered a component of the metabolic syndrome

Islet of Langerhans: The pancreatic islets or islets of Langerhans are the regions of the pancreas that contain its endocrine (hormone-producing) cells, discovered in 1869 by German pathological anatomist Paul Langerhans.

LOS: Medical abbreviation for Length of Stay

MVA: Motor Vehicle Accidents involving an automobile, motorcycle, motor scooter, or all-terrain vehicle

Pancreatic β-cells: β cells are a type of cell found in pancreatic islets that synthesize and secrete insulin and amylin. Beta cells make up 50–70% of the cells in human islets. In patients with Type 1 diabetes, beta-cell mass and function are diminished, leading to insufficient insulin secretion and hyperglycemia.

Hypotheses

1. Motor vehicle accident trauma patients with Diabetes Mellitus will experience a greater length of stay in the ICU, greater amount of time on a mechanical ventilator, as well as an increased total length of stay in the hospital than non-diabetic patients.
2. The mean age of diabetic patients in the ICU will be higher than that of non-diabetic patients
3. Males will account for a greater percentage of diabetic patients in the ICU than women
4. African Americans will account for a greater percentage of diabetic patients in the ICU than any other race/ethnic group

Assumptions

1. All of the patients in this study have the correct diagnoses for diabetes mellitus and other comorbidities.
2. All of the patients admitted to the intensive care unit are documented in this thesis.

Significance of the Study

In the United States motor vehicle accidents are a leading cause of death and injuries that require hospitalization. With DM being one of the most common chronic diseases, millions of those afflicted are required to transport themselves daily via motor vehicle.[9] As the prevalence of diagnosed diabetes and pre diabetes continues to rise, it is of great importance that healthcare practitioners understand how DM may impact patient recovery, as well as be able to provide optimal treatment following an MVA. For diabetic patients, as hospital LOS increases, more diabetes related complications begin to arise, leading to increased hospitalizations, and possibly leading to a decline in quality of life. Motor vehicle accident diabetic patients in the ICU present a unique problem of requiring acute emergency care while also requiring management of a chronic metabolic disease that negatively impacts a patients' mortality rate.[15]

CHAPTER II

LITERATURE REVIEW

Pathophysiology

DM is a chronic health condition that effects the manner in which the pancreas regulates and releases insulin, in order to properly transfer sugar, or glucose, into the body's cells. [2,4,16] As the body consumes food, it is broken down by acid and enzymes in the stomach and small intestine and transformed into glucose, which is then absorbed into the bloodstream. As blood glucose levels become elevated, metabolic signals trigger pancreatic β-cell receptors on the islet of Langerhans to release insulin into the blood.[3,4] Insulin is found to be the only hormone in the human body capable of binding to cell receptors that stimulate GLUT-4 vesicles to migrate to the surface of the cell.[3,4] Once the vesicles reach the surface, they penetrate through the cell membrane and allow the passage of glucose. From there, the process of cellular respiration is initiated to manipulate glucose into ATP.

Type I Diabetes Mellitus

When the manufacturing of insulin and the exocrine functions of pancreatic β-cells are adulterated, the formation of Type I DM will persist.[16] Type I DM is caused by gene abnormalities and environmental factors, such as viruses, that provoke an autoimmune response that attack and destroy insulin producing β-cells.[1,3] Damage to β-cells causes metabolic glucose signaling to become an incomplete pathway and restricts the body from producing any insulin or only producing a minimal amount. Type I DM rapidly progresses within a few weeks to a few months after initial onset.[1,2] Due to the development of the disease in childhood and adolescence, it is often referred to as juvenile diabetes. Another name given to Type I DM is insulin dependent diabetes based on the required injection of exogenous insulin.[3.12] Although the widely accepted name for Type I DM is juvenile diabetes, the onset may occur at any age.[18] When onset occurs well into maturity, it is regularly initially misdiagnosed as Type II DM until further testing ensues.[1,18]

Diabetic Ketoacidosis

Individuals experiencing a Type I diabetic event exhibit signs and symptoms of polyuria, polydipsia, weight loss, nausea/vomiting, excessive tiredness and diabetic ketoacidosis (DKA).[1,17] DKA is a life-threatening symptom of both Type I and Type II DM that is capable of inducing a diabetic coma or death.[17,19] The process of DKA occurs when the body experiences low insulin levels and glucose is prohibited from transferring across the cell membrane.[17,19] If cells cannot participate in the uptake of glucose to manufacture energy, liver enzymes begin to break down fat, leading to the release of acidic ketones into circulation. When a rapid surge of ketones enters the bloodstream a dangerous decrease in blood pH can occur. [17,19]

Type II Diabetes Mellitus

Type II DM develops from two main mechanisms of action. First, the production of insulin deteriorates over time leading to an insufficient amount of insulin in the blood to properly maintain homeostatic blood glucose levels.[2,8] Although low to non-existent insulin is characteristic of Type I DM, the decrease in available insulin in Type II DM is a result of genetics and poor lifestyle choices, and not autoimmune destruction of pancreatic β-cells.[2,3] Secondly, as insulin receptors on the cell membrane grow increasingly resistant and less sensitive to the binding of insulin, the body's cells lose the ability to utilize the hormone. Insulin resistance is believed to develop from the onset of inflammatory responses throughout the body.[3] Recent literature suggest the presence of adipose tissue and chronic inflammation promoted the body's production of various cytokines, that are linked to disruption of the insulin signaling pathway. [3] When this pathway is damaged, glucose is again restricted from entering the cell.

Global Prevalence

The presence of DM is becoming the world's fastest growing chronic disease, and one of the most prevalent issues burdening available healthcare resources and medical cost in every inhabited country in the world.[20,21] The top 10 countries with the largest diabetic populations include from greatest to least, include China, India, United States, Pakistan, Brazil, Mexico, Indonesia, Germany, Egypt, Bangladesh.[20,21]

The International Diabetes Federation (IDF) estimated that since 2017, children and adolescents less than 15 years of age, have contributed to an increase of nearly100,000 novel Type I DM cases each year.[21] As of 2019, a total of 463 million adults were estimated to be living with DM, representing 9.3% of the global adult population, age 20–79 years old. This number is predicted to increase to 578 million (10.2%) in 2030, and 700 million (10.9%) in 2045.[20,21] As age increases, the prevalence of DM increases as well. Adults ages 65-79 years old account for more than 111.2 million (19.9%) of the global diabetic population.[21]

Prevalence Within the United States

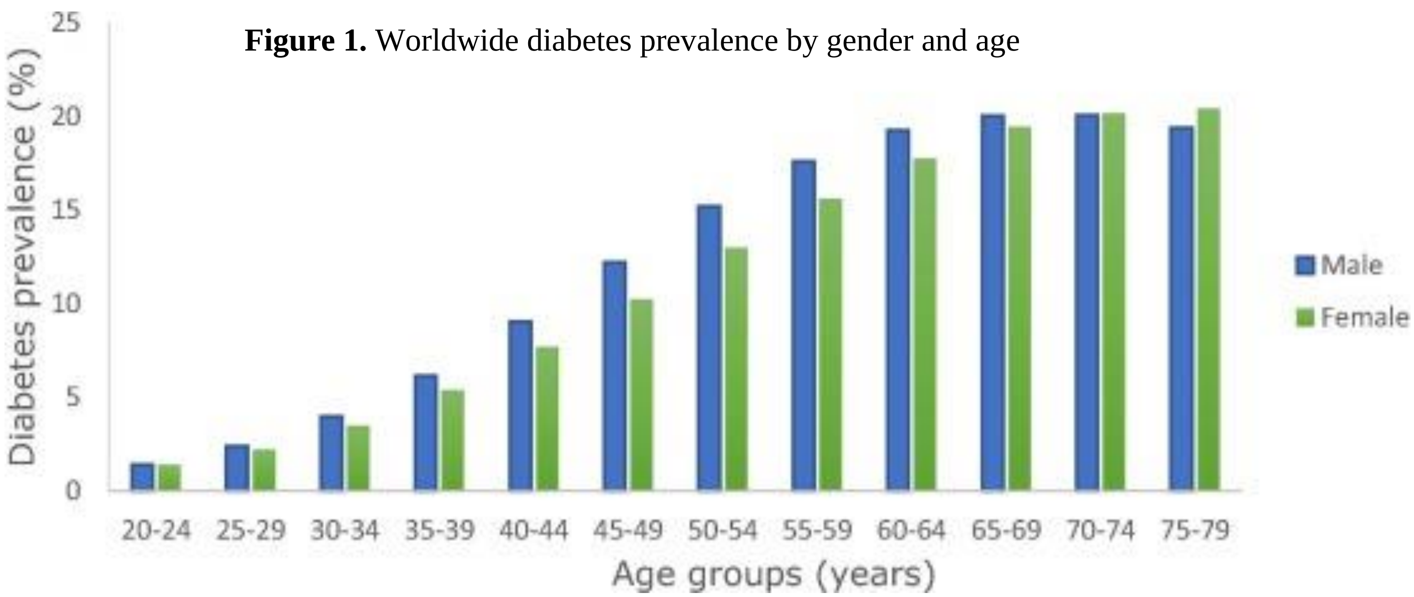
The CDC's *National Diabetes Statistics Report: 2020*, presented data collected in the United States from 2017 and 2018, including all adults age 18 years and older. The report provided detailed feedback on the allocation of DM within the country. In 2018, 34.2 million (10.5%) adults had a confirmed diagnosis of either Type I or Type II DM. 88 million (34.5%) adults were diagnosed with prediabetes, and 7.3 million adults had not reported or had not known their diabetic status.[6] Diabetes remains a relevant issue in all race/ethnic populations residing in the US, currently impacting 14.7% of Native Americans/Alaskan Natives, 12.5% of

Hispanics, 11.7% of African Americans at, 9.2% Asians, and 7.5% of Caucasians.[6] DM was found to be the 7th leading cause of death in adults aged 50 years and older with 83.1 diabetic related deaths per 100,000 death certificates examined.[6] Diabetics are also predicted to die 4.6 years earlier, develop disabilities 6 to 7 years earlier, and spend about 1 to 2 more years in a disabled state than adults without diabetes.[6,20]

Prevalence Based on Gender

Diabetes is more prevalent in the male population, afflicting 9.6% of all males worldwide in contrast to 9.0% of all females (Figure 1).[21] CDC data from 2017 indicated that a higher percentage of men (37.4%) than women (29.2%) are diagnosed with prediabetes in United States.[6]

Figure 1. Worldwide diabetes prevalence by gender and age



Due to men being more biologically predisposed to the development of DM, male age becomes a risk factor once they reach 40 years of age. While female age does not become a risk factor until they reach 45 years of age.[6,21] The difference in disease progression between the sexes is more strongly correlated to the accumulation of visceral body fat and less associated with BMI, as was once believed.[21,22] The development of body fat related health issues in men is faster to develop at a lesser percentage of fat accumulation than women.[22] Therefore, women can experience a greater fluctuation in body fat before they start to develop obesity/overweight related health issues when compared to their male counterpart.[21]

Diabetes Mellitus Impact on Driving Capability

With millions of cars on the road in today's world, the driving capability of diabetic patients has been greatly studied to determine if complications associated with DM (including hypoglycemia, double vision, or altered mental status) are a contributing factor to the occurrence of motor vehicle accidents.[23] It has been indicated that the hypoglycemic events that diabetics may experience is the leading cause to the increased incidences of MVA in this population.[23] When an unsuspecting driving starts to experience a hypoglycemic event, all skills associated with driving start to deteriorate including driving performance, reaction time, decision making, and hand eye coordination.[23,24] Because of these debilitating effects that occur at such a sudden onset, the American Diabetes Association urges drivers to disclose their diabetic status and receive further evaluation for driving capability.[23]

Hypoglycemic events are never planned; therefore, diabetics must have sufficient control in managing their disease. A previous study tested the driving capacity of 480 diabetic drivers. A total 102 (25%) of the drivers experienced a hypoglycemic event while driving.[23,24,28] The main characteristics of participants that experienced an event while driving wear less than 60 years of age and had DM for less than 15 years.[23] When the investigators recanted patient interviews, they discovered only 23.5% of participants discussed the risk of driving as a diabetic with a health care practitioner.[23] The study suggested that if more diabetics would seek help and knowledge with managing their disease, MVA due to hypoglycemia would decrease.[23,24]

A virtual driving simulation study discovered that even if a diabetic person is not actively experiencing a hypoglycemic event, they still presented with slower foot transfer to brake time and slower brake time period.[25] Diabetics also experienced faster times to collisions struggling to avoid objects such as trees, buildings, signs, and other cars.[24,25] The research indicated that normoglycemic diabetics presented with a decline in cognitive function, slower reaction times, and lack of pedal control, which all lead to poor outcomes in driving situations.[25]

Diabetes can lead to many problems including nerve damage to the lower extremities of a patient's body.[25,26,27] This may cause the development of an insensate plantar foot, pedal ulcerations, soft tissue and bone infection, and limb amputation.[26] The research suggest that all of these issues lead to impairment of diabetic driving. Limb amputation was specifically looked at in driver ability.[25] Although limb amputation may affect return to driving it, it showed beneficial results in delayed response time. It was observed that many older amputees were not returning to driving after surgery depending on the body part amputated.[25] However, driving ability was only assessed after amputation and not before in these particular patients. The data indicated that drivers with lower extremity sensory neuropathy does lead to slower brake response times with abnormally long brake reactions compared to drivers without diabetes or lower extremity neuropathy.[25,27,28] A 2015 study found that 28% of MVA rear end cases were a result of delayed response time.[25] When comparing drivers with diabetes to those without, there was a 36% higher chance of diabetic drivers experiencing an MVA.[25,28] The research concluded that lower extremity neuropathy is one of the main causes of delayed reaction time and more research is needed to continue and test this finding.[25,26,27,28]

Impact of DM Related Comorbidities/Complications on Hospital Cost and LOS

DM has become a steadily growing economic vacuum due to the large proportion of healthcare costs allocated to long term treatment plans needed to properly manage the disease.[29] The development of DM and related comorbidities also increase the time and cost spent treating this population.[29,30] A past analysis that evaluated data from a 2008 Healthcare Cost Utilization Project, discovered that diabetics experience increased hospital LOS when admitted for any medical procedure, non-specific to the type.[12,29,30] Diabetics were studied during the days following an elective surgery, are were observed to experience a mean hospital LOS of 9.08 days, while non-diabetic patients experienced a mean of 4.76 days.[12] The mean hospital cost for DM patients was $19,547, with only $15,873 for non-diabetics, nearly a $4,000 difference.[12] The occurrence of death (1.42% vs 0.93%), myocardial infarction (1.6% vs 0.59%), pneumonia (2.88% vs 0.32%), and acute kidney injury (11.2% vs 2.53%), were all significantly increased for diabetic patients.[12,31] The study concluded that diabetic patients experience significantly increased rates of DM related complications and that result in the accumulation of greater hospital cost.[12,30,31]

A recent retrospective database analysis performed in 2019, reviewed a longitudinal cohort of DM patients based in Taiwan in 2012.[30] The authors identified and examined 11 DM related comorbidities and complications including ulcers, amputation, blindness, end-stage renal disease (ESRD), congestive heart failure (CHF), fatal ischemic heart disease (IHD), nonfatal IHD, fatal myocardial infarction (MI), nonfatal MI, fatal stroke, and nonfatal stroke. For each hospitalization, the authors reported on length of stay, total costs of hospitalization, and inpatient drug costs.[29,30] The sample included 27, 473 DM patients who incurred a total of 29, 582 diabetic related hospitalizations over the course of the study.[30]

The data indicated that more men (62.5%) than women (37.5%) were hospitalized due to a related complication of DM.[30] About 93% of the patients experienced at least one complication-related hospitalization, with the most prevalent being nonfatal stroke (34.7%), nonfatal IHD (28.7%), CHF (14.4%), and ESRD (13.9%).[30] Amputation required the longest LOS with a mean of 21.4 days, followed by non-fatal stroke (13.36 days), and ulcers (12.7 days). The greatest hospital cost reported was the treatment of non-fatal ischemic heart disease, equaling $10, 761 USD after converting from the Taiwanese dollar.[30] When comparing the cost of this treatment to that of the elected surgeries in the previous study, it is understood that medical procedures overseas is less expensive than surgery in the US due to the high cost of healthcare experienced in this country.

A second Taiwanese study conducted in 2014, shared similar results, reporting that total medical costs, hospitalization costs, and risk of hospitalization all significantly increased with the number and severity of diabetes related comorbidities and complications.[30] Additionally, a 2016 Chinese study specifically indicated that prescription drugs and laboratory tests were the two most expensive factors that increased hospitalization costs for diabetics patients.[30] The authors suggested that the hospitalization cost of one complication related event, could easily surpass the yearly healthcare cost of a diabetic patient with no complications or additional comorbidities.[30]

ICU Stay and Mechanical Ventilation in Diabetic Patients

The management of diabetic patients in the ICU has remained a persistent problem for healthcare professionals for the last 20 years.[32] Dysglycemia, a term that encompasses both hypoglycemia and hyperglycemia, during an ICU stay, has been correlated with increased prevalence of hospital complications and mortality among the diabetic population.[32,33] Development of recent clinical practices promotes the use moderate glucose control, to maintain levels around 140 mg/dl.[32] Previous practices suggested utilizing tight control, keeping glucose levels between 80 to110 mg/dl.[32] Tight glucose control stemmed from lack of available knowledge as well as the absence of technology that now allows for the continual or rapid monitoring of glucose levels in the ICU.[32,33] Before hospitals were able to perform instant glucose monitoring, fear of causing a medically induced hyperglycemic event may have caused patients to experience poorly maintained glucose levels.

A recent meta-analysis of 141 studies by Siegelaar et al. indicated that purely having a diagnosis of diabetes in the ICU does not directly lead to increased mortality, until the addition of other risk factors is incorporated.[31,32,34] Diabetes leads to a higher incidence of nearly all comorbidities including renal, cardiovascular, and neuropathic disease.[31,32] The onset of diabetic complications can directly impact mortality rates of critically ill patients. A prevalent risk factor of mortality in diabetic patients was the development of ICU bloodstream infections.[31,32] However, the most significant predictor of mortality was the initiation of mechanical ventilation.[32] Mechanical ventilation is believed to play a role in the poor glycemic control of diabetic patients in the ICU, due to the continuous tube feeding that must occur while a patient is intubated. [32,34] Daily nutrition regimens are utilized to ensure that patients are not being be overfeed, but the administration of a liquid diet directly into the stomach increases gastrointestinal absorption.[32] This mechanism causes blood glucose levels to elevate more rapidly than the traditional eating and digesting process.[33,34] If the mechanically ventilated diabetic patient has impaired glucose function, a hyperglycemic event can ensue.[33] The use of propofol for sedation is also associated elevated blood glucose levels due to the caloric and lipid content of the drug.[32] Severe hyper glycemia was also found to be more prevalent in diabetics receiving post-operative care in the ICU, as opposed to care for a medical illness.[32,34] The greatest severity of issues was observed in cardiac surgery patients due to the traumatic impact of open chest surgery on the body.[31,32,33] Any traumatic event, whether it was planned or unplanned caused diabetic patients to experience higher rates of wound infection, UTI, pneumonia, cardiac arrest, MI, ARDS, and emergency intubations during their stay in the hospital.[31,32] Increased mortality in diabetic patients in the ICU is observed to is a multifactorial issue that is affected by the severity of the disease, quality of care, infections, and other complications.[32]

CHAPTER III

METHODS

The research questions for this study are as follows:

1. What is the prevalence of diabetes among patients involved in motor vehicle accidents in a Level-1 trauma center?
2. Are there differences in length of stay between diabetic and non-diabetic patients involved in motor vehicle accidents?
3. Are there differences in mechanical ventilation duration between diabetic and non-diabetic patients involved in motor vehicle accidents?
4. What is the prevalence of diabetic patients involved in motor vehicle accidents that also have other comorbidities?

Data was collected at a level-one trauma center located in Atlanta, GA (n = 2802). This sample size was inclusive of all patients who were intubated and mechanically ventilated and admitted into the intensive care unit (ICU) in this trauma center following a motor vehicle accident between January 2011 and September 2015. The trauma center is part of a 623-bed public hospital. This retrospective study was approved by the university institutional review board. The requirement for informed consent was waived due to data being previously obtained from records of former patients who were discharged from the hospital prior to this study. All identifying factors were removed from patient records. Furthermore, all ethical considerations for this study are in accordance with the World Medical Association Declaration of Helsinki.

All the patients in this study were either directly admitted to the ICU or admitted following surgery. Patients in this analysis were admitted between January 2011 and

September 2015. In the current study, motor vehicle accident (MVA) is defined as any collision involving an automobile, motorcycle, motor scooter, or all-terrain vehicle. Patients were identified using a trauma registry, a database containing demographic, injury and outcome information from the scene of the accident through hospital discharge. Patient characteristics by diabetic classification is presented in Table1. Medical records were searched and compiled into a deidentified dataset for analysis. Patient age, sex, height, weight, injury severity, time on mechanical ventilation, and whether the patient lived or died were collected from the trauma registry, and electronic medical records. Injury severity was assessed using the standard injury severity score (ISS).

Statistical Analysis

Subgroup analyses were conducted on the following: diabetic vs. non diabetics, and male vs. female. Independent samples t-tests were conducted to determine whether statistically significant differences were present in all included parameters between diabetic and non-diabetics patients. Mann Whitney-U tests were used to determine median LOS in the ICU, LOS in the hospital, number of days on a ventilator, number of comorbidities, as well as number of complications experienced. Chi-Square tests were utilized to assess the prevalence of diabetes within gender groups, as well as within the various race/ethnic groups including African Americans, Caucasian, and Asian/other patients. All statistical analysis of the data was conducted using the Statistical Package for Social Science software (version 25.0, SPSS Inc. Chicago, IL). A confidence interval of 95% ($p \leq 0.05$) will be recognized as statistically significant.

CHAPTER IV

RESULTS

The research questions for this study are as follows:

1. What is the prevalence of diabetes among patients involved in motor vehicle accidents in a level-1 trauma center?
2. Are there differences in length of stay between diabetic and non-diabetic patients involved in motor vehicle accidents?
3. Are there differences in mechanical ventilation duration between diabetic and non-diabetic patients involved in motor vehicle accidents?

   What is the prevalence of diabetic patients involved in motor vehicle accidents that also have other comorbidities?

A total of 2802 patients were recorded in the motor vehicle accident registry of a Level-1 trauma center (Table 1). Over the course of the study, the hospital treated (50.0 ± 9.7) vehicular accident patients per month. Among all the 2802 patients included in the sample, 247 (8.8%) were confirmed to have Diabetes Mellitus (DM). The remaining 2,555 (91.2%) of patients were absent of DM. Of the 247 diabetic patients, women account for 73 (29.5%) of DM patients, and men accounted 174 (70%) of diabetic patients. Men amounted to 1,866 (66.6%) of the total number of patients, while women made up 936 (33.4%) of the total sample. In this particular sample, men substantially outnumbered the women, leading to a higher prevalence of diabetes within male sub-group. Out of the 936 women included, 73 (7.8%) had DM, compared to the 863 (92.2%) of women who did not present with diabetes. Out of the 1,866 male participants, 174 (9.9%) had diabetes mellitus, and 1672 (90.1%) of men did not have DM. Although the prevalence of diabetic males was greater, there was no significant difference (p=0.179) between the number of males and females effected by DM.

Table 1. Patient Characteristics by Diabetic Classification

	Diabetes= No N=2,555 (91.2%)	Diabetes= Yes N=247 (8.8%)	Total N=2,802	Statistical Test, P-value
Gender [a]				
Female	863 (92.2%)	73 (7.8%)	936 (33.4%)	1.805, (*1*), p=0.179
Male	1,692 (90.1%)	174 (9.9%)	1,866 (66.6%)	
Age, Mean (SD) [b]	39.04 (17.08)	58.14 (14.45)	40.73 (17.71)	-19.50, (*316*), p<0.001
Race [a]				
African-American	1,299 (91.3%)	124 (8.7%)	1,423 (50.8%)	1.94, (*2*), p=0.380
Caucasian	1,008 (90.6%)	105 (9.4%)	1,113 (39.7%)	
Asian/Other	248 (93.2%)	18 (6.8%)	266 (9.5%)	
Ethnicity [a]				
Non-Hispanic	2,421 (91.5%)	238 (8.5%)	2,659 (94.9%)	1.19, (*1*), p=0.275
Hispanic	134 (93.7%)	9 (6.3%)	143 (5.1%)	
Total LOS in ICU Median (IQR) [c]	3 (5)	4 (6)	3 (5)	P=0.008
Total LOS in hospital Median (IQR) [c]	7 (13)	10 (15)	7 (13)	P=0.009
Total length on ventilator Median (IQR) [c]	0 (3)	0 (3)	0 (3)	P=0.020
Number of comorbidities, Median (IQR) [c]	0 (1)	2 (1)	1 (1)	P<0.001
Number of complications, Median (IQR) [c]	0 (0)	0 (1)	0 (0)	P=0.215
Injury severity score (ISS), Mean (SD) [b]	18.17 (11.71)	15.04 (9.46)	17.89 (11.56)	4.85, (*324*), p<0.001

[a]= Chi-Square test; [b]=Independent samples t-test; [c]=Mann-Whitney U Test

The mean age difference of non-diabetic and diabetic patients was found to be statistically significant (p<0.001). The mean age of the total population sample was (40.73 ± 17.71) years. The mean age for the diabetic patients was 58.14 ± 14.45 years, and the mean age for nondiabetic patients was nearly half of the diabetic patients at 39.04 ±17.08. Race (p=0.380) was indicated to be not significantly different. Out of a total of 2802 MVA, patients African

Americans made up the majority the total sample population representing 1423 (50.8%) of patients. Caucasians accounted for 1113 (39.7%) of patients and Asians/other only accounted for 266 (9.5%) of patients. Within the group of the 1,423 African Americans, 124 (8.7%) had diabetes mellitus. Out of 1113 Caucasians, 105 (9.4%) were diabetic patients. Although African Americans made up a majority of the patient population, Caucasians still had a higher prevalence of diabetes within their sub-group. Out of the 266 Asian/Other patient, only 18 (6.8%) were confirmed to have DM.

When comparing the number of diabetic patients by race/ethnic group to the total number of diabetic cases (n=247), African Americans amounted to nearly 50.2% of the diabetic patients. Caucasians accounted for 42.5% of the diabetic patients and Asians accounted for only 7% of diabetic patients. Out of 2802, 143 patients associated with Hispanic descent making up (5.1%) of the patient population. Out of the 247 diabetic cases only 9 Hispanic relating patients had diabetes, accounting for 3.6%. Total length of stay in the ICU (p=0.008) did show to be statistically significant between diabetics and non-diabetics patients. Diabetic patient's median amount was 4 days (Figure 2) in the ICU compared to 3 days (Figure 3) for that of non-diabetics. Total length of stay in the hospital (p=0.009) was statistically significant as well, with a median of 10 days for diabetic patients and 7 days for non-diabetics. Total length of stay on a mechanical ventilator (p=0.02) was also found to be statistically significant, with diabetic patients spending a greater number of days on the ventilator compared to non-diabetic patients (Figure 4).

Figure 2. Number of total ventilator days for diabetics

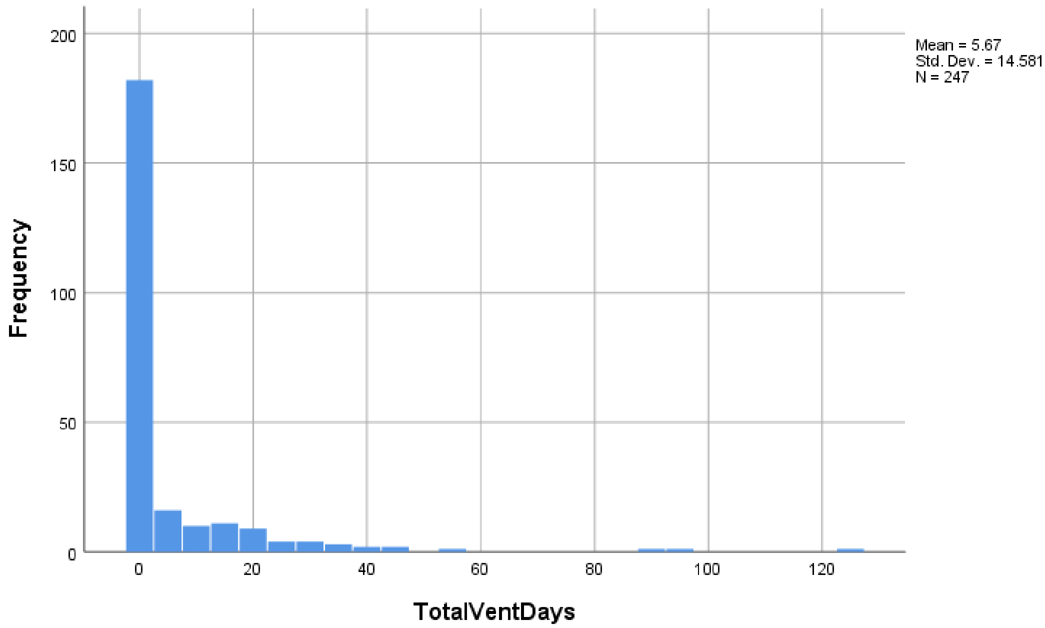


Figure 3. Number of total ventilator days for non-diabetics

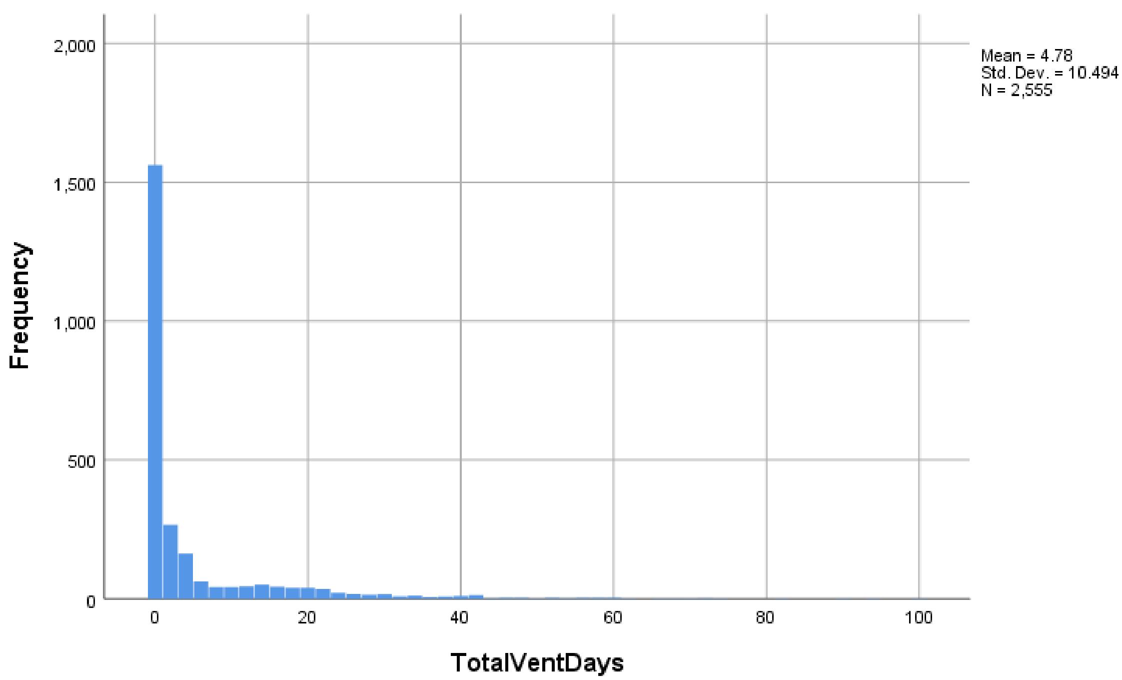
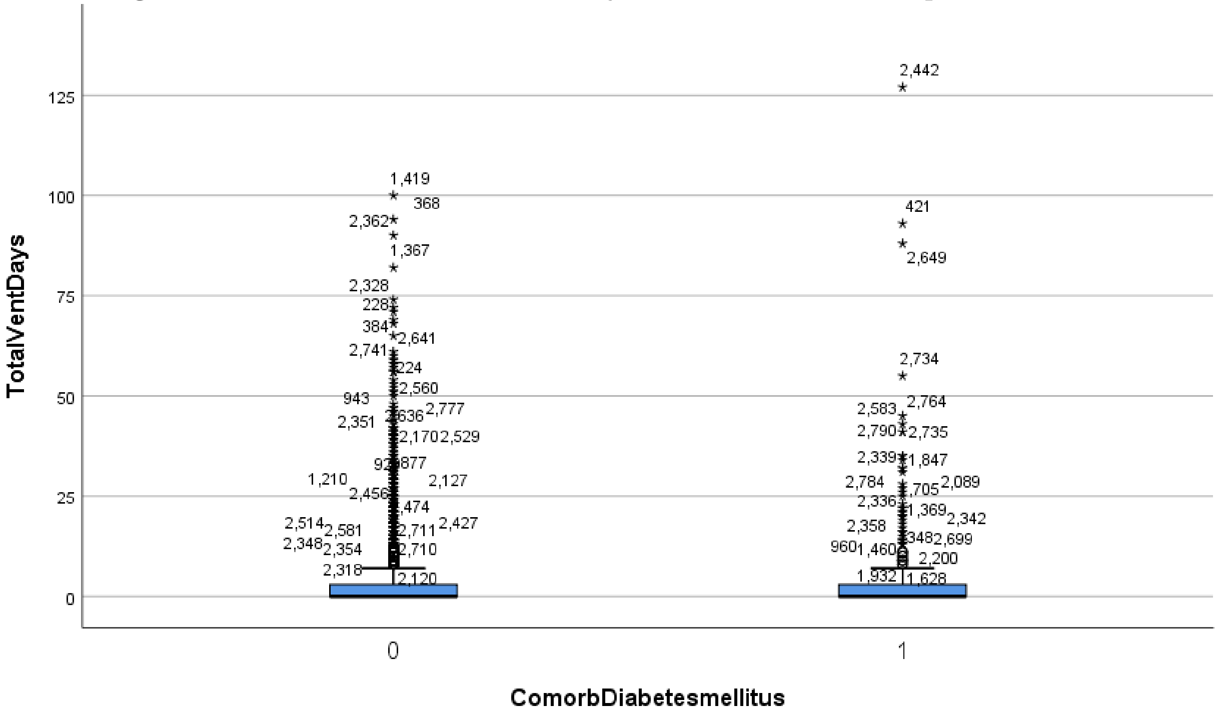


Figure 4. Number of total ventilator days for non-diabetics compared to diabetics



Note. 0 indicates non-diabetic patients and 1 indicates diabetic patients.

The presence of comorbidities between diabetic and non-diabetic patients was statistically significantly ($p<0.001$) with diabetic patients experiencing a median of 2 comorbidities but patients without diabetes did not indicate any. The number of complications experienced in diabetics versus non diabetics was found to have no statistical significance difference ($p=0.215$). Injury severity score was found to be statistically significant ($p < 0.001$) with diabetes reporting a mean of (15.04 ±9.46), and non-diabetic patients reporting a mean of (18.17 ± 11.71). The ISS for the total population both diabetics and non-diabetics combined was (17.89 ± 11.56). According to the Injury Severity Scale, patients without diabetes had a “moderate” score between (9-15) while those without diabetes had a “serious” score between (16-24).

CHAPTER V

Discussion

In the current study there was a statistically significant relationship found between the presence of diabetes mellitus and total length of stay on the ventilator, total length of stay in the intensive care unit, and total length of stay in the hospital. Diabetes is a chronic disease that in itself requires strict lifetime management in order to maintain a sufficient quality of life. It requires daily monitoring in order to restrain the many complications that may arise if the disease becomes uncontrolled. However, when a diabetic patient experiences bodily trauma, such as that of a motor vehicle accident, maintenance becomes more difficult and other complications more easily arise. Studies suggest that management of diabetes in the ICU is critical for patients who have just experienced a traumatic event due to the many complications that diabetic patients are more suspectable to.[31,32]

Because of this, the diabetic trauma patients experienced significantly increased amount of time hospitalized due to the management of their disease, the injuries that they may have incurred, as well as treatment of the onset of other diabetes related complications. An analysis that evaluated data from a 2008 Healthcare Cost Utilization Project, discovered that diabetics experience increased hospital LOS when admitted for any medical procedure. It was indicated that diabetic related issues could arise increase the time and cost allocated to a patient. A Taiwanese study conducted in 2014, shared similar results, reporting that total medical costs, hospitalization costs, and hospitalizations all significantly increased with the number and severity of diabetes related comorbidities and complications.[30] A recent meta-analysis, indicated that purely having a diagnosis of diabetes in the ICU does not directly lead to increased complications and increased hospitalization, until the addition of other risk factors is incorporated.[31,32,34]

Limitations

The results of this study should not be interpreted as all-inclusive of critical patients in every ICU due to varying locations demographics. This study was a retrospective study design and may lead to misrepresentation of true associations. This study was also limited by the variables that were reported and made available in the trauma registry. All the data in the study from trauma patients and should be used with caution when comparing the noncritical patient population. Lastly, the prevalence of diabetes varies greatly around the nation and the world, making results difficult to generalize in other regions and countries.

Conclusion

This study found that motor vehicle trauma patients with diabetes mellitus were reported to have significantly more days on a ventilator, spent more time in the ICU, as well as more total days in the hospital. Diabetic patients require additional interventions during their ICU and hospital stay in order to address and manage the challenges presented by the disease. Patients with DM are more likely to develop any complication following a traumatic event over patients without. While in the ICU, the diabetic population presents with higher rates of wound infection, UTI, pneumonia, cardiac arrest, MI, ARDS, as well as unplanned intubations. Since the average age for diabetic patients is nearly 60 years, the development of multiple comorbidities such as obesity and various health issues is likely to occur. This may cause diabetic related complications to manifest, increasing patient mortality and making it difficult to properly maintain, especially following a traumatic event such as a motor vehicle accident.

References

1. Katsarou, A., Gudbjörnsdottir, S., Rawshani, A., Dabelea, D., Bonifacio, E., Anderson, B. J., Jacobsen, L. M., Schatz, D. A., & Lernmark, Å. (2017). Type 1 diabetes mellitus. *Nature Reviews Disease Primers*, *3*(1), 1–17. https://doi.org/10.1038/nrdp.2017.16

2. DeFronzo, R. A., Ferrannini, E., Groop, L., Henry, R. R., Herman, W. H., Holst, J. J., Hu, F. B., Kahn, C. R., Raz, I., Shulman, G. I., Simonson, D. C., Testa, M. A., & Weiss, R. (2015). Type 2 diabetes mellitus. *Nature Reviews Disease Primers*, *1*(1), 1–22. https://doi.org/10.1038/nrdp.2015.19

3. *Mechanisms of Insulin Action and Insulin Resistance | Physiological Reviews*. (n.d.). Retrieved April 15, 2021, from https://journals.physiology.org/doi/full/10.1152/physrev.00063.2017

4. Wondifraw, H. (2015). Classification, Pathophysiology, Diagnosis and Management of Diabetes Mellitus. *Journal of Diabetes & Metabolism*, *06*. https://doi.org/10.4172/2155-6156.1000541

5. CDC. (2020, March 24). *Diabetes Risk Factors*. Centers for Disease Control and Prevention. https://www.cdc.gov/diabetes/basics/risk-factors.html

6. Centers for Disease Control and Prevention. (2020). *National Diabetes Statistics Report 2020*. U.S. Department of Health and Human Services. Retrieved April 8, 2021, from https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf

7. *Diabetes | Georgia Department of Public Health*. (n.d.). Retrieved April 15, 2021, from https://dph.georgia.gov/diabetes

8. Enomoto, L. M., Shrestha, D. P., Rosenthal, M. B., Hollenbeak, C. S., & Gabbay, R. A. (2017). Risk factors associated with 30-day readmission and length of stay in patients with type 2 diabetes. *Journal of Diabetes and Its Complications*, *31*(1), 122–127. https://doi.org/10.1016/j.jdiacomp.2016.10.021

9. Songer, T. J., & Dorsey, R. R. (2006). High Risk Characteristics for Motor Vehicle Crashes in Persons with Diabetes by Age. *Annual Proceedings / Association for the Advancement of Automotive Medicine*, *50*, 335–351. Retrieved April 10, 2021, from High Risk Characteristics for Motor Vehicle Crashes in Persons with Diabetes by Age (nih.gov)

10. Almigbal, T. H., Alfaifi, A. A., Aleid, M. A., Billah, B., Alramadan, M. J., Sheshah, E., AlMogbel, T. A., Aldekhayel, G. A., & Batais, M. A. (2018). Safe driving practices and factors associated with motor-vehicle collisions among people with insulin-treated diabetes mellitus: Results from the Diabetes and Driving (DAD) study. *Journal of Safety Research*, *65*, 83–88. https://doi.org/10.1016/j.jsr.2018.03.003

11. *How are Diabetes and Car Accidents Related?* (n.d.). Retrieved April 10, 2021, from https://www.danflahertylaw.com/blog/how-are-diabetes-and-car-accidents-related

12. Philadelphia, P. A. (n.d.). *Diabetic Complications Lead to Increased Length of Stay Following Elective Surgeries*. EndocrineWeb. Retrieved April 10, 2021, from https://www.endocrineweb.com/professional/meetings/diabetic-complications-lead-increased-length-stay-following-elective-surgeries

13. Bommer, C., Heesemann, E., Sagalova, V., Manne-Goehler, J., Atun, R., Bärnighausen, T., & Vollmer, S. (2017). The global economic burden of diabetes in adults aged 20–79 years: A cost-of-illness study. *The Lancet Diabetes & Endocrinology*, *5*(6), 423–430. https://doi.org/10.1016/S2213-8587(17)30097-9

14. Liu, H. T., Rau, C. S., Wu, S. C., Chen, Y. C., Hsu, S. Y., Hsieh, H. Y., & Hsieh, C. H. (2016). Obese motorcycle riders have a different injury pattern and longer hospital length of stay than the normal-weight patients. *Scandinavian journal of trauma, resuscitation and emergency medicine*, *24*(1), 1-9. DOI10.1186/s13049-016-0241-4

15. Jehle, D., Gemme, S., & Jehle, C. (2012). Influence of obesity on mortality of drivers in severe motor vehicle crashes. *The American Journal of Emergency Medicine*, *30*(1), 191–195. https://doi.org/10.1016/j.ajem.2010.10.017

16. Wondifraw, H. (2015). Classification, Pathophysiology, Diagnosis and Management of Diabetes Mellitus. *Journal of Diabetes & Metabolism*, *06*. https://doi.org/10.4172/2155-6156.1000541

17. *DKA (Ketoacidosis) & Ketones | ADA*. (n.d.). Retrieved April 10, 2021, from https://www.diabetes.org/diabetes/complications/dka-ketoacidosis-ketones

18. O’Neal, K. S., Johnson, J. L., & Panak, R. L. (2016). Recognizing and Appropriately Treating Latent Autoimmune Diabetes in Adults. *Diabetes Spectrum*, *29*(4), 249–252. https://doi.org/10.2337/ds15-0047

19. Gallo de Moraes, A., & Surani, S. (2019). Effects of diabetic ketoacidosis in the respiratory system. *World Journal of Diabetes*, *10*(1), 16–22. https://doi.org/10.4239/wjd.v10.i1.16

20. International Diabetes Federation. *Facts & figures*. (n.d.). Retrieved April 15, 2021, from https://www.idf.org/aboutdiabetes/what-is-diabetes/facts-figures.html

21. Saeedi, P., Petersohn, I., Salpea, P., Malanda, B., Karuranga, S., Unwin, N., Colagiuri, S., Guariguata, L., Motala, A. A., Ogurtsova, K., Shaw, J. E., Bright, D., & Williams, R. (2019). Global and regional diabetes prevalence estimates for 2019 and projections for 2030 and 2045: Results from the International Diabetes Federation Diabetes Atlas, 9th edition. *Diabetes Research and Clinical Practice*, *157*, 107843. https://doi.org/10.1016/j.diabres.2019.107843

22. *Metabolic Effects of Visceral Fat Accumulation in Type 2 Diabetes | The Journal of Clinical Endocrinology & Metabolism | Oxford Academic*. (n.d.). Retrieved April 15, 2021, from https://academic.oup.com/jcem/article/87/11/5098/2823317?login=true

23. Ma, S., Zhang, J., Zeng, X., Wu, C., Zhao, G., Lv, C., & Sun, X. (2020). Type 2 diabetes can undermine driving performance of middle-aged male drivers through its deterioration of perceptual and cognitive functions. *Accident Analysis & Prevention*, *134*, 105334. https://doi.org/10.1016/j.aap.2019.105334

24. Almigbal, T. H., Alfaifi, A. A., Aleid, M. A., Billah, B., Alramadan, M. J., Sheshah, E., & Batais, M. A. (2018). Safe driving practices and factors associated with motor-vehicle collisions among people with insulin-treated diabetes mellitus: results from the Diabetes and Driving (DAD) study. *Journal of Safety Research*, *65*, 83-88. Retrieved from Safe driving practices and factors associated with motor-vehicle collisions among people with insulin-treated diabetes mellitus: Results from the Diabetes and Driving (DAD) study (sciencedirectassets.com)

25. Meyr, A. J., & Spiess, K. E. (2017). Diabetic Driving Studies—Part 1: Brake Response Time in Diabetic Drivers With Lower Extremity Neuropathy. *The Journal of Foot and Ankle Surgery*, *56*(3), 568–572. https://doi.org/10.1053/j.jfas.2017.01.042

26. Spiess, K. E., Sansosti, L. E., & Meyr, A. J. (2017). Diabetic Driving Studies—Part 2: A Comparison of Brake Response Time Between Drivers With Diabetes With and Without Lower Extremity Sensorimotor Neuropathy. *The Journal of Foot and Ankle Surgery*, *56*(3), 573–576. https://doi.org/10.1053/j.jfas.2017.01.043

27. Zhang, X.-X., Kong, J., & Yun, K. (2020). Prevalence of Diabetic Nephropathy among Patients with Type 2 Diabetes Mellitus in China: A Meta-Analysis of Observational Studies. *Journal of Diabetes Research*, *2020*, e2315607. https://doi.org/10.1155/2020/2315607

28. Perazzolo, M., Reeves, N. D., Bowling, F. L., Boulton, A. J. M., Raffi, M., & Marple-Horvat, D. E. (2020). Altered accelerator pedal control in a driving simulator in people with diabetic peripheral neuropathy. *Diabetic Medicine*, *37*(2), 335–342. https://doi.org/10.1111/dme.13957

29. Cheng, S.-W., Wang, C.-Y., & Ko, Y. (2019). Costs and Length of Stay of Hospitalizations due to Diabetes-Related Complications. *Journal of Diabetes Research*, *2019*, e2363292. https://doi.org/10.1155/2019/2363292

30. Chen, H.-L., & Hsiao, F.-Y. (2014). Risk of hospitalization and healthcare cost associated with Diabetes Complication Severity Index in Taiwan's National Health Insurance Research Database. *Journal of Diabetes and Its Complications*, *28*(5), 612–616. https://doi.org/10.1016/j.jdiacomp.2014.05.011

31. Petrosyan, Y., Kuluski, K., Barnsley, J., Liu, B., & Wodchis, W. P. (2020). Evaluating quality of overall care among older adults with diabetes with comorbidities in Ontario, Canada: A retrospective cohort study. *BMJ Open*, *10*(2), e033291. https://doi.org/10.1136/bmjopen-2019-033291

32. Anand, R. S., Stey, P., Jain, S., Biron, D. R., Bhatt, H., Monteiro, K., Feller, E., Ranney, M. L., Sarkar, I. N., & Chen, E. S. (2018). Predicting Mortality in Diabetic ICU Patients Using Machine Learning and Severity Indices. *AMIA Summits on Translational Science Proceedings*, *2018*, 310–319. Retrieved April 9, 2021, from Predicting Mortality in Diabetic ICU Patients Using Machine Learning and Severity Indices (nih.gov)

33. Pasquel, F. J., Lansang, M. C., Dhatariya, K., & Umpierrez, G. E. (2021). Management of diabetes and hyperglycaemia in the hospital. *The Lancet Diabetes & Endocrinology*, *9*(3), 174–188. https://doi.org/10.1016/S2213-8587(20)30381-8

34. Monnier, L., & Colette, C. (2011). Glycemic Variability: Can We Bridge the Divide Between Controversies? *Diabetes Care*, *34*(4), 1058–1059. https://doi.org/10.2337/dc11-0071