EMERGENCY MEDICAL STRETCHER REDESIGN: THE CANOPY

An Interactive Qualifying Project

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By

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Abstract

The ambulatory medical stretcher is important for patient stabilization, transportation and administering quality centric care. The structure of the stretcher is configured in such a way that it can carry patients of all kinds regardless of the patient’s weight or injuries. This project investigated the efforts that have been made to improve paramedics and patient safety. We focus on the types of canopies that have been used to shield patients from rain, snow or high temperature exposures. The project team engaged with local EMS practitioners to understand how any canopy can help to improve EMS safety. A framework for designing a canopy is established, and account for its incorporation on ambulatory stretcher is presented.
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UMass Memorial Paramedics
CHAPTER 1. EMS AND LIFE SAVING PRACTICES

1. Introduction

Emergency Medical Services, commonly abbreviated EMS, provide acute out-of-hospital care to people in a medical emergency. The goal of EMS is to provide effective and immediate care to patients in need while simultaneously transporting him or her to an alternate place of care. The overall goal is to get the patient to the place of care as quickly as possible in order to treat their ailment. Emergency Medical Services help save thousands of lives each year by quickly and effectively treating and transporting numerous different patients.

Currently, citizens can reach EMS personnel by calling the emergency contact number 9-1-1. Upon dialing the number the citizen will be connected with a dispatcher in their area who will ask questions to gather information about the accident and/or emergency. After the dispatcher has gathered significant information about the problem, the appropriate ambulance crew will be sent out to address the situation. EMS personnel work to stabilize the patient immediately when they arrive at the scene. Next, they evaluate the patient’s condition and decide what particular hospital to transport the patient to. For example, a patient who has been evaluated as having a severe heart attack will be transported to the nearest hospital with an adequate cardiology program to treat that person.

During their time on the scene, EMS must follow a set of steps and protocols. These rules are set by national and state laws to ensure the safety of both the patient and the EMS technician.
Depending on the situation, different steps and protocols need to be followed to ensure everyone’s safety and to give EMTs the best chance to save the patient’s life. For instance, the EMTs may arrive on the scene and identify the patient as having a spinal cord injury. As a result, they will immediately take the particular steps necessary for spinal chord injuries in order to prevent further injury. An example of a step would be to stabilize the neck and spinal column by placing the patient on a backboard and conducting a C-spine. This will prevent the patient’s neck and back from moving which helps eliminate any further injury to the patient.

Whatever type of situation that EMTs respond to, their goal remains the same. They must treat and provide as much care as possible to the patient while keeping themselves safe as well. To help aid them in this task, EMTs have a specific set of equipment that they take with them on every call. Included in this list are a first aid kit, gloves, a medical stretcher, etc. The first aid kit is filled with supplies such as bandages and scissors, while the gloves are used to prevent the spread of pathogens from patient to EMT. Perhaps one of the most important items is the medical stretcher, which is standard in all medical ambulances.

Despite the vast improvements in medical care over the past several years, little has been done to improve the design and functionality of the basic medical stretcher. The goal of our project is to design a canopy to protect the patient from various weather conditions. The canopy will be used to replace the numerous blankets and other devices that EMTs currently use to protect patients from the adverse effects of the weather.
CHAPTER 2. EMS AND PATIENT-CENTRIC QUALITY CARE

2. Introduction

The emergency medical stretcher is a medical device used to carry and transport a patient from one place to another. The design of the stretcher is very simplistic and has not evolved much over the past several years. The modern medical stretcher has durable wheels which makes the transport of patients much easier, regardless of the environment. The stretcher is basically a type of hospital gurney, or narrow bed, on a wheeled metal frame that is usually adjustable in height. Most models are typically collapsible making it easier to transport between the scene of an accident and the ambulance. They are also equipped with straps, or tie-downs, that are used to secure the patient to the stretcher. The straps help to prevent the patient from moving and further aggravating any injuries. The main objective of the stretcher is to prevent further injury and facilitate safe movement of the patient to a fixed hospital bed or examination table in the surgical ward, emergency room, or wherever the patient’s final destination may be. During any movement or transport of an emergency medical stretcher, two people are required: one at the head and the second at the foot of the stretcher.

Without the use of a dependable medical stretcher, the potential for injury to both the patient and caregiver drastically increases during patient transport. Stretchers are generally used when a person is unable to walk by him or herself, however other means of transportation are often needed. For example, transporting a stretcher down a set of stairs is impractical and extremely
dangerous so other measures must be taken. Stairchairs, which look similar to wheelchairs, or backboards are often used to carry a patient down a set of stairs. Two people are also required during the use of stairchairs or backboards.

"Normalized" stretchers, or folding stretchers, are the simplest kind of stretcher. They are made of two poles and two transversal-hinged bars with a cloth stretched between the poles. The bars can be folded for ease of storage. Today, normalized stretchers are rarely used by modern emergency services. However, they are still widely used by organizations in which storage space is an important factor. For example, many first-aid organizations, such as the Red Cross, use normalized stretchers in order to maximize space. A similar type of simple stretcher is a disaster stretcher. These stretchers are often used as beds in disaster scenarios because of their ease of storage and transport. Disaster stretchers consist of a tubular aluminum structure with a washable cloth attached. They cannot be folded like a normalized stretcher, but they are able to be easily stacked on top of one another. Both normalized and disaster stretchers have no wheels, and therefore must be carried by three or four people. In a situation where only two people are forced to carry one of the stretchers, the straps must be tied to the poles of the stretcher. This is to make the weight of the stretcher more supported by the shoulders of the carriers and not simply by their hands.

2.1 How EMTs Handle Patients and Medical Stretchers
Current patient care and EMT practices are of the utmost importance in today’s medical environment. The ability of EMS personnel to complete their job properly and swiftly can result in the difference between life and death. The job of EMTs can be both physically and emotionally taxing. The primary concern when arriving on an emergency scene is for the EMS team to first secure their own safety. They must make sure neither the EMT nor the patient is exposed to an increase risk of disturbance. EMTs must perform their jobs with only the equipment they carry on them and in the ambulance. They must be able to rely upon all the members of their particular emergency response team in any circumstance. Not every emergency call is going to involve massive trauma, but it is the EMTs job to assess the patient’s health and send them to the necessary medical facility for care.

Each ambulance is stocked with certain supplies and a certain amount of equipment depending on the population density, economic condition and the certification level of the EMTs provided on the ambulance. There are typically two types of ambulances, one that can provide basic life support and one that can provide advanced life support. There are medical kits for EMTs in all ambulances regardless of whether it is a basic or advanced life support ambulance. The medical kit is brought with the EMT when they are leaving the ambulance to tend to a patient. The kit has all the necessary tools and supplies needed to treat the patient. These medical kits usually contain bandages, fluids, scissors, tape, needles, gloves, wound dressings, and other supplies for day-to-day treatment. The medical kit is also used in conjunction with the airway management
The airway management kit is used on people who are unconscious and cannot breathe, or are having difficulty breathing, on their own. Generally, the airway management kit is used on patients with head injuries, drug overdoses, or drowning incidents. Other devices such as the oxygen tanks are normally left in the ambulances until they are needed. Oxygen tanks come in several different sizes and can be used to treat patients with a variety of injuries. In addition, many medications and IV fluids are kept on the ambulance and are listed in Table 1.

Table 1: Critical Care Transport List

<table>
<thead>
<tr>
<th>Table 1A: Medications</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Generic Name</th>
<th>Trade Name</th>
<th>Concentration</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated Charcoal</td>
<td>Actidose</td>
<td>(50 g)</td>
<td>2</td>
</tr>
<tr>
<td>Adenosine</td>
<td>Adenocard</td>
<td>(6 mg vial)</td>
<td>4</td>
</tr>
<tr>
<td>Albuterol</td>
<td>Ventolin</td>
<td>(0.5 mL in premix)</td>
<td>3</td>
</tr>
<tr>
<td>Aminophylline</td>
<td>Somophylline</td>
<td>(250 mg vial)</td>
<td>2</td>
</tr>
<tr>
<td>Aspirin</td>
<td>Bufferin</td>
<td>(325 mg tabs)</td>
<td>1</td>
</tr>
<tr>
<td>Atropine Sulfate</td>
<td>-</td>
<td>(1.0 mg syringe)</td>
<td>6</td>
</tr>
<tr>
<td>Bretylium tosylate</td>
<td>Bretylol</td>
<td>(500 milligram vial)</td>
<td>2</td>
</tr>
<tr>
<td>Calcium Chloride</td>
<td>-</td>
<td>(1 g syringe)</td>
<td>2</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>Decadron</td>
<td>(4 mg vial)</td>
<td>2</td>
</tr>
<tr>
<td>Dextrose, 50%</td>
<td>-</td>
<td>(25 grams syringe)</td>
<td>4</td>
</tr>
<tr>
<td>Diazepam</td>
<td>Valium</td>
<td>(10 mg syringe)</td>
<td>2</td>
</tr>
<tr>
<td>Diloxin</td>
<td>Lanoxin</td>
<td>(0.5 mg ampule)</td>
<td>1</td>
</tr>
<tr>
<td>Diltiazem</td>
<td>Cardizem</td>
<td>(25 mg vial)</td>
<td>1</td>
</tr>
<tr>
<td>Dimenhydrinate</td>
<td>Dramamine</td>
<td>(50 mg vial)</td>
<td>2</td>
</tr>
<tr>
<td>Diphenhydramine</td>
<td>Benadryl</td>
<td>(50 mg vial)</td>
<td>2</td>
</tr>
<tr>
<td>Dobutamine</td>
<td>Dobutrex</td>
<td>(250 mg vial)</td>
<td>2</td>
</tr>
<tr>
<td>Dopamine</td>
<td>Intropin</td>
<td>(800 mg pre-mix)</td>
<td>2</td>
</tr>
<tr>
<td>Epinephrine 1:1,000</td>
<td>Adrenalin</td>
<td>(1.0 mg ampule)</td>
<td>4</td>
</tr>
<tr>
<td>Epinephrine 1:10,000</td>
<td>Adrenalin</td>
<td>(1.0 mg syringe)</td>
<td>8</td>
</tr>
<tr>
<td>Flumazenil</td>
<td>Romazicon</td>
<td>(0.5 mg vial)</td>
<td>2</td>
</tr>
<tr>
<td>Furosemide</td>
<td>Lasix</td>
<td>(40 mg vial)</td>
<td>4</td>
</tr>
<tr>
<td>Glucagon</td>
<td>-</td>
<td>(1 mg vial)</td>
<td>1</td>
</tr>
<tr>
<td>Haloperidol</td>
<td>Haldol</td>
<td>(5 mg vial)</td>
<td>2</td>
</tr>
</tbody>
</table>
Heparin (5,000 IU)  2
Hydroxyzine Vistaril (50 mg vial)  2
Insulin-regular Humulin R (1 vial)  1
Ipatropium Atrovent (2.5 ml prefll)  4
Isoetharine Bronkosol (1% nebulizer solution)  4
Ketorolac Toradol (60 mg vial)  2
Labetalol Normodyne (200 mg vial)  2
Lidocaine Xylocaigne (100 mg syringe)  4
Lidocaine Xylocaigne (2 grams pre-mix)  2
Magnesium Sulfate - (1 gram vial)  2
Manntitol Osmotrol (25% solution vial)  2
Methylprednisolone Solu-Medrol (125 mg vial)  2
Methylprednisolone Solu-Medrol (1 gram vial)  2
Midazolam Versed (5 mg vial)  2
Morphine - (10 mg syringe)  4
Nalbuphine Nubain (10 mg vial)  2
Naloxone Narcan (2 mg vial)  2
Nifedipine Procardia (10 mg capsules)  4
Nitroglycerin drip Tridil (50 mg vial)  2
Nitroglycerin spray Nitrolingual (0.4 mg)  1
Nitroglycerin paste Nitro-Dur (1 tube)  1
Norepinephrine Levophed (4 mg vial)  2
Phenytoin Dilantin (1 gram vial)  1
Procaainamide Pronestyl (1,000 mg)  1
Prochlorperazine Compazine (10 mg vial)  2
Promethazine Phenergan (25 mg vial)  2
Racemic Epinephrine VapoNefrin (2.25% solution)  2
Sodium Bicarbonate - (50 mEq)  2
Succinylcholine Anectine (200 mg)  2
Tetracaine Tetracaine (1 mL unit dose)  2
Thiamine Vitamin B1 (100 mg)  1
Torsemide Demadex (20 mg)  2
Vecuronium Norcuron (10 mg)  3
Verapamil Isoptin (10 mg)  2

Table 1B: IV Fluids

<table>
<thead>
<tr>
<th>Name</th>
<th>Volume</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>lactated Ringer's</td>
<td>(1,000 mL)</td>
<td>8</td>
</tr>
<tr>
<td>0.9% sodium chloride</td>
<td>(1,000 mL)</td>
<td>4</td>
</tr>
<tr>
<td>dextrose, 5% in water</td>
<td>(500 mL)</td>
<td>2</td>
</tr>
<tr>
<td>dextrose, 5% in 0.25% NaCl</td>
<td>(500 mL)</td>
<td>2</td>
</tr>
</tbody>
</table>
Another extremely important instrument that every ambulance carries is a monitor, or better known as a defibrillator. An AED, or automated external defibrillator, can save someone’s life that is going into cardiac arrest or suffering from chest pains. The defibrillator can also be used on children, and alternate paddles for children are available. Immobilization devices such as cervical collars, head immobilization devices, and backboards are also located in the ambulance. The collars and head immobilization devices are typically attached to the backboard for immediate accessibility at an emergency scene. Advanced life support ambulances will often carry more sophisticated equipment to deal with more complicated patients. For example, some additional equipment in the ALS ambulances may include pacemakers, nebulizers, more types of medications, and other equipment for vascular access.

Before arriving at the scene of the accident, EMTs are provided with an emergency medical dispatch (EMD) that gives them information about the situation they are heading to. This allows the team to prepare while they are en-route to the scene. An effective EMD will include traffic delays, the safest routes to take, pre-arrival instructions for taking care of the patient, and any specific weather information the team should be informed of. The dispatch will also include a description of the scene as best as possible so that the EMT is able to determine whether it is a trauma or medical call. These dispatches help EMTs decide if special rescue equipment, multiple vehicles, more personnel, or a medical helicopter is necessary. For example, any calls involving cardiac or respiratory problems or motor vehicles will generally require extra personnel. If there
has been reported violence at the scene of the call, the EMTs are not supposed to enter the scene until police are on the scene and any potential threats have been secured. Also, for accidents involving hazardous materials, special units are dispatched at the same time as EMS.

As previously stated, when EMTs first arrive on the scene, they must first make sure the scene is safe. The nature of the injuries, the number of people involved, and any other safety issues must be identified. For example, if there was a weapon involved, the EMT should know the location of the given weapon. Once the EMT assesses the scene they must then establish a danger zone. There are many different parameters for the danger zone depending on the type of accident that took place. For example, there is a 100 square foot zone for fuel spills and car fires, whereas a “regular” scene with no apparent hazards is designated as 50 square feet.

During this time at the scene, EMS personnel must also find out about the patient’s medical history. An acronym that EMTs use to get the most accurate medical history is SAMPLE. “S” stands for sign and symptoms, “A” for allergies, “M” for medication, “P” for pertinent medical history, “L” for last meal, and “E” for events that lead to EMS being called. One important difference in patient care is the difference between signs and symptoms. Signs can be seen, heard, or felt by the EMT whereas symptoms are more subjective and cannot be measured by the EMTs. Symptoms are more relative to the patient. If there are several patients, the EMTs must identify life-threatening problems and prioritize patients by the severity of their injuries. Once the scene is secured, it is the EMTs job to determine whether to treat the patient on scene or to
transport them immediately. Some of the more high priority injuries or illnesses that an EMT will experience are unresponsive patients. Unresponsive patients include those with difficulty breathing, chest pains, large amounts of bleeding, or patients in shock. EMTs also use a method to find out the status of the patient by using a checklist. The checklist is based on a list of the most life threatening symptoms. This checklist is known as the ABC’s and are as follows: A – airway, B – breathing or ventilation, C – circulation or perfusion, D – disability or mental function, E – expose the patient to a detailed examination then protect the patient from weather and surrounding environment. EMTs use another acronym to check the mental status of patients. This acronym is AVUP which stand for: A – alert and awake, V – responds to verbal stimuli, P – responds to painful stimuli but does not respond to verbal stimuli and U – unconscious, does not respond to verbal or painful stimuli.

EMS must be able to handle many different patient types, terrains, and types of weather. One of the most integral parts of an EMT’s job is lifting and transporting a patient. Many EMTs are injured each year while trying to move patients improperly. Some EMT injuries are attributed to the size of the particular patients and to the mechanics of the EMT doing the lifting. The most effective way lift the stretcher is to stay as close to the patient as possible and create leverage to maintain balance. It is necessary for EMTs to know their limitations and if they do not think they can handle the weight of the patient then they should wait for help. EMTs are taught many
different techniques to move, carry, and drag patients that will ensure the safety of the patient and EMT themselves.

2.2 An Emergency Medical Stretcher’s Purpose

The purpose of a stretcher is to provide a safe, stable means of transporting a patient from one area to another. If a patient is unable to move on his or her own, a stretcher is particularly helpful in allowing the EMT to move them. Stretchers have existed since antiquity and, in their simplest forms, consisted of two poles with canvas in-between to support a person. This type of stretcher is best used in wartime or disaster situations where speed of response is a large factor. In such situations, a wheeled vehicle would not be suited to quickly transport someone in need, so this stretcher serves as the quickest most efficient solution.

As technology evolved over time, so did the shape and function of the medical stretcher. Simple sling stretchers still exist and serve their purpose in wartime and disaster situations where quick evacuation over rough terrain is necessary. However, these simple stretchers are no longer the main means of transporting an injured patient to a place of care. Now, stretchers are primarily used in tandem with ambulances to quickly and effectively move a patient from the scene of an accident to a place of treatment. These stretchers are much different than the sling stretchers used in earlier times. Unlike the sling stretchers, they have wheels and a solid base allowing the EMT to have the patient at many different levels during transport. The stretchers are now
foldable which allow the patient to sit-up at different angles. These stretchers are configured to fit inside an ambulance and provide EMTs with a stable work area once they are secured inside the vehicle. This significantly increases how much an EMT can do to help a patient in need before they even reach the hospital.

Not only have stretchers evolved to work together with ambulances in transporting patients, but they have also evolved to suit the different places where they are used. For example, a stretcher used in the water by lifeguards would not be the same as one used by rescue skiers to assist people who are hurt on a mountain. No matter where you are in the world or what type of situation you are in, there will be a stretcher to fit your needs and safely transport you to a place of treatment. This versatility is why the stretcher is such an effective and widely used medical tool.

2.3 Old Medical Stretcher Designs

From cavemen thousands of years ago, to ancient Roman times, to the most technologically advanced militaries in the world today, the oldest form of the medical stretcher is still in use. It is also still carried in virtually every medical emergency ambulance to date. Figure 1 shows the average United States’ military backboard. Backboards have been made of practically every material from wood, to canvas and rope, to high-tech plastics. It has provided support and structure for those who lay helplessly upon it each and every day.
Regardless of the material it is made of, the backboard’s primary focus is to allow emergency personnel to quickly and efficiently transport the patient from the accident scene to wherever help is located. In today’s society, medical professionals use the backboard to transport patients from scenes where ambulances, as well as their own emergency medical stretcher, cannot reach. The board is able to stabilize the patient’s spine and head, by the use of safety belts that keep the patient in place as well as foam cushions used to stabilize the patient’s head. Once all strapped in, the backboard can be completely upside-down and the patient will remain securely in place, shown in Figure 2. The backboard is only used as means of transporting the patient between the
scene and the actual emergency medical stretcher. Once reaching the stretcher, the patient will either be slid onto the stretcher or will remain on the backboard which will then be placed on the stretcher and strapped down.

As technology progressed through time, focus was shifted from the overall safety of the patients to that of the patient as well as the medical personnel. In order to more easily transport patients, wheels were added to stretchers to enable them to be pushed by the EMTs rather than carried. Collapsible rods were ultimately added between the bed of the stretcher and wheels to allow for easy transport directly between the road and the emergency ambulance. The rods retract and fold compact allowing for the stretcher to take up less room inside the ambulance. Original
backboards were stiff and were uncomfortable for the patient. As a result pads were ultimately added to cushion the patient and provide for more comfortable ride. Sidebars were then added to keep the patient contained and protect them from potentially falling off while being transported on the road or within the ambulance itself; Figure 3 represents an older-style medical stretcher. The material of the stretcher frame has also changed throughout the years from simple aluminum in older stretchers to titanium in the advanced newer models.

![Figure 3. Older Medical Stretcher. (Image adopted from: http://2.bp.blogspot.com_/RXJv3UQOBBM/...)](image)

Locking mechanisms were installed in the ambulance to physically lock the stretcher in place once inside. This would keep the stretcher securely in place during the ride to the hospital and protect against further injury to the patient due to excess movement of the stretcher. Older stretchers and backboards did not contain such mechanisms and relied upon friction to remain in place.
With these new technological advances to stretchers, critical problems arose. The overall design of the stretcher was unreliable and unsafe for the patient as well as the EMT. Stretchers would often tip over if just one wheel encountered an object on the ground, such as a rock. A statistic showed that 54% of all reported medical accidents were the result of a collapsing stretcher (Wang et al., 3009). The cross bars would often collapse resulting in harm being done to the patient, as well as the responders. Responders’ hands and fingers would frequently get caught in the crossbars resulting in dislocation and broken bones.

2.4 Current Stretcher Deficiencies

The current ambulance stretcher has various functional deficiencies that decrease the safety of the patients as well as the EMS personnel. Additionally, the comfort of the patient is also compromised with the current stretcher designs. The stretcher is composed of several parts: the mattress, the cover sheet, and the skeletal mechanical structure, there is significant room for improvement in all three of these components.

Ferno and Stryker are two of the largest manufacturers of emergency medical equipment in the United States (JEMS, 2010). Each company is constantly working to improve on the overall design and functionality of their stretchers. Stryker, for example, has one of the most technological advanced medical stretchers in the entire industry. In their Power-PRO XT model,
EMTs only have to exert little effort in controlling the stretcher’s. By simply pressing a button, the stretcher can hydraulically lower and rise without the use of exerting the EMTs’ own muscular force. A diagram of Stryker’s Power-PRO XT is shown in Figure 4 below (Stryker, 2010).

Figure 4. Stryker’s Power-PRO XT Emergency Stretcher: a technologically advanced emergency medical stretcher.
Over time, this technology can be beneficial to EMS personnel; the accumulated muscular strains due to ordinary, and non-Stryker technology, stretcher movement can cause them permanent bodily injuries. The price of the automated stretcher, however, is several times larger than the price of an ordinary stretcher. Due to tight budgets of many hospitals and EMS companies, they are not able to make the investment to purchase the latest most technologically advanced stretchers. Due to this fact the sales of these specific Stryker stretchers are not meeting their expectations; in which case the product is not fulfilling the important task of repaying for the effort, cost, and time that was put in to manufacture it. The sales can improve over time, only if Stryker can reduce its sale price while maintaining the core technological advances that were added. Another way to rescue this version of the stretcher is to reduce its level of advancement and balance it with a reduction of the price. In one way, this stretcher could contribute to making the EMS personnel’s job easier but this must be confronted by the realities of the market. There are still several areas of improvement in this technologically advanced stretcher including: ways to improve sterility, as well as how to dampen vibrations through the stretcher to allow for a smoother ride for the patient as well as a steady workbench for the EMTs and paramedics.

The transfer of contaminants from one patient to another or even to an EMT or paramedic is a major concern of those in the medical field (Bradshaw, 2007). If bodily fluids are present within the ambulance, it takes several hours for the inside of the ambulance as well as all the equipment to be disinfected. The substances excreted by one patient are contained as much as possible to
prevent contamination of the work place and the possibility of infecting a future patient. Not all the excretions transfer disease, but the proper safety precautions must be taken. The 2010-11 WPI Ambulance Biosensor IQP/MQP team is thoroughly researching the excretions that are transferrable and contagious by their nature. Through a larger effort, the aspiration to design a sensor against contagious bacteria and viruses would be underway.

Thus far, linen cover sheets are used as the proposed barrier against the excretions. These cover sheets are reusable, and are continuously rewashed. Some viruses and bacteria are still present after washing, and are potentially transferrable. Moreover, the cover sheet is not sufficient to contain certain excretions. The contamination can spread to the mattress and to surrounding parts of the ambulance. The 2010-11 WPI Surgical Sponge MQP team is working toward properly containing these contaminants through a multi-layer design. A combination of reusability and disposability in the design can help in reducing the cost of sterile maintenance and minimize the spread of disease to other patients and EMS personnel.

The physical mattress pad is another very important component of the stretcher. The mattress should offer the most amount of comfort to the patient as possible. One of the biggest reasons that UMass Medical Center does not use Stryker’s stretchers is the low level of comfort of the mattress (Haynes, 2011). Mustafa Fofana, professor of Mechanical Engineering – WPI, proposes
that a simple rearrangement of the order and organization of supports within the mattress can increase the comfort level tremendously. Also, changing the material that the core of the mattress is made from will improve the ability to reduce vibrations and absorb shock. Moreover, the cover of the mattress is crucial in preventing the spread of contaminants. The cover should be bacteria-resistant, and mechanically capable of being reused and cleaned over a long period of time.

Currently, the conventional stretcher contains additional deficiencies that should be improved for the safety and comfort of the patients and the EMS personnel. Poor vibration dampening, potential tipping and collapsing of the stretcher, height and size accommodation, and minimal protection from various weather conditions are some of these problems (Wange et al., 2009). Changes to the overall skeletal structure of the stretcher are necessary for improvement.

Figure 5. The process of loading the stretcher into the ambulance (Wang et al., 2009).
Stretcher collapse can cause serious damage to the patient especially if the patient is already in a critical health condition. A study has shown that 54% of stretcher related injuries are caused by stretcher collapse (Wang et al., 2009). Such collapses can lead to injuries such as sprains, fractures, traumatic brain injuries, or even death. A stretcher’s collapse can be caused by failure of the joints and parts to withhold the stress applied on it by the patient and the EMS personnel as it goes through the various stages of handling and usage as shown in Figure 5.

A tipped stretcher is another major problem in the current stretcher design; 30% of reported injuries are a result of tipped stretcher (Wang et al., 2009). A stretcher tipping can be attributed to inherently existing problems. The relatively small base area compared to the upper portion of the stretcher doesn’t render resistance to tipping due to the nature of the momentum formed, which can be ultimately favorable of tipping. A stretcher is used in emergency situations and this resistance should be increased to cope with the varying forces and motions applied on it by the patients and EMS personnel. Moreover, the stretcher’s wheels, which are non-deformable, give little flexibility to accommodate various angles of loads. Also, the volume of the wheels, specifically, the surface area of the interaction between the wheels and the ground is small. A twofold approach can be applied on the wheels, by increasing the area of interaction and the wheel flexibility to prevent tipping.
The current stretcher doesn’t have the ability to properly and safely accommodate tall and obese patients. The current stretcher doesn’t have an efficient mechanism to increase and decrease the length of the stretcher as desired. Similarly, it doesn’t have an efficient mechanism to adjust the width of the stretcher to support the full body of obese patients. Bodily parts unsupported by the stretcher compromise the safety of patients, and increase the risk of further injury for both the patient and EMTs.

Another deficiency of the stretcher is its large weight. The weight of the stretcher can preferably be reduced, while still maintaining functional support of the loads it must hold. By researching in the flourishing materials science field, a composite material, which can bear the necessary loads while being relatively light, can be found. The weight is extremely important especially when carrying patients on stretcher down and upstairs. EMS personnel have repeatedly complained about the weight of the stretcher in this regard (Haynes, 2010). Furthermore, a more efficient mechanism must be developed in the current stretcher to make it easier for EMS personnel to transfer patients down and upstairs. Many EMS personnel suffer from back pain, which is directly related to these activities.

Another deficiency of the current stretcher is its inability to dampen vibration and shock. Vibration is an undesired complication when patients with fractured bones and with other critical
health conditions are transferred via the ambulance’s stretcher. Vibration not only is uncomfortable, but it can aggravate the already adverse condition of the patient. The WPI Ambulance Project has attempted to minimize vibrations allowed by the ambulance. A 2009 WPI PhD study investigated this problem and was capable of minimizing vibration to less than 1.5 Hz by applying a multi-system of springs on the structure of the ambulance, while complying with state and federal regulations. However, 1.5 Hz is still a significant level of vibration that can be further reduced. The WPI Ambulance Surgical Sponge team is integrating into their design a layer that will help with vibration dampening. It is crucial that the vibration dampening mechanism is applied on the stretcher as well. This will create a three-filter layer vibration dampening system, and will minimize vibrations to levels that will not affect the health of the patient. Potential modifications to the type of wheels used in the stretcher, and the integration of a shock absorbent system into the design can dampen vibrations. Many patients complain about the painful experience of feeling the rough surfaces and curbs as they are being transferred so more research must be done to reduce this problem.

Another serious deficiency of the current stretcher is the absence of an effective shield to protect the patient from various weather conditions. In the event of snow, rain, cold, and other adverse weather conditions the patient is simply covered with blankets (Haynes, 2010). This is not
sufficient to protect the patient who is already in a vulnerable state. Further exposure to such weather conditions without proper protection can advance health conditions to a dangerous level.

2.5 Existing Medical Stretcher Shields

There are few products in existence that are designed to protect patients from various weather conditions while being transported to and from an ambulance on a stretcher. Ferno, a global leader in the manufacture and distribution of professional emergency healthcare products, offers two particular products to cover patients while on the stretcher. Ferno currently has operations in twelve countries worldwide, which includes the United States, Canada, Mexico, Latin America, United Kingdom, Europe, Africa, Middle East, Russia, Asia, Australia, and Japan. Although Ferno is a highly successful company, the two products currently offered for shielding and protecting a patient from weather leave significant room for improvement.

Figure 6. Ferno’s Weather Shield.(Image adopted from: http://www.ferno.com)
The two products currently offered by *Ferno* are the Weather Shield and the Patient Shield. The Weather Shield is intended to keep the patient, equipment, and bedding dry during inclement weather. The shield is similar to that of a body bag with a zipper down the center and fits around the patient much like a sleeping bag. In order to access equipment or any part of the patient’s body, the shield must be unzipped. When the shield is removed it must be taken off the patient, folded up, and placed in a pouch that attaches to the foot-end on the main frame of the stretcher. The weather shield is shown in Figure 6.

![Figure 6. Ferno’s Weather Shield](http://www.ferno.com)

The second product offered by *Ferno* is the Patient Shield. The Patient Shield is designed to prevent the transfer of pathogens from the patient to the EMTs and the surrounding environment during transport. The shield is attached to the stretcher by hook-and-loop fasteners that are
attached to the backrest frame of the stretcher. The shield comes down over the patient’s head and upper body much like the top of a baby stroller, except it completely encloses the patient. The patient shield is shown in Figure 7.

The shields can be improved by focusing more on the comfort of the patient and the functionality and the storage of the shield. For example, the body bag-like design of the weather shield may be unsettling or claustrophobic to the patient. Also, both shields take time to place on the stretcher and to be removed and stored. The shields should be altered in a way that allows them to be placed on the stretcher and over the patient in a quicker and simpler fashion. This would save time and eliminate extra work for EMT’s. The design of our canopy seeks to accomplish the goals of the Weather Shield, using a refined design of the Patient Shield as well as a newly designed shield to protect the body of the patient.

2.6 The Ambulance and Bacterial Contamination

United States hospitals have high standards of sterility and cleanliness (NHS, 2010). A significant portion of the hospitals’ budget is dedicated toward maintaining maximum cleanliness. The hospitals has strict rules to ensure that the medical staff take the necessary hygiene precautions, such as consistently washing the hands and changing gloves (Figure 8, below). The medical tools are carefully thoroughly cleaned after each uses to prevent the spread
of harmful pathogens. The hospitals use of disposable products serves as a safety precaution to prevent the transfer of contaminants from patient to patient or from a patient to the medical staff. Moreover, hospitals are pressured by federal health agencies to maintain high sterility or their license of operation could be revoked. Hospitals are afraid of lawsuits that could cause them a loss of money and most importantly their reputation. Ideally, the ambulance should be viewed under the same light to keep from spreading contaminants. Technically, it is the first line of medical treatment, and patient-medical staff interaction. One potential problem in the ambulance is the accumulation of bacteria, and its potential spread from patient to patient, and from patient to EMT.

Figure 8. Sterility in US hospitals is highly emphasized. (Image adopted from: http://www.msnbc.msn.com/id/27633551/ns/health-health_care/)
Bacteria are a basic element of life. They are prokaryote-type cells, less complex than the eukaryotic human cells. They contain a genome that is made from DNA, and it defines the shape and activity of each bacterium. Bacteria have many shapes, but most common are rod and sphere shapes. Their shapes also play a role in determining their reactivity. Bacteria exist in all habitats of earth, including the human body. The majority of bacteria that exist in the body are harmless, and some in fact, are beneficial to the human body (UCMP, 2008). Some bacteria in the body help in producing important vitamins such as B12 (Albert, Mathan, & Baker, 1980). It is clearly inaccurate to label all bacteria as harmful. However, from the large variety and diversity of bacteria, some cause serious infection and disease. As hospitals ensure a bacteria-free environment, ambulances should aim to reach the same standard.

Examples of disease-causing bacteria that are widely and easily spread include Staphylococci, Streptococci, Haemophilus influenza, Escherichia coli. Staphylococci can cause serious skin infection. Streptococcus causes infections that occur in the respiratory tract; pneumonia occurs as a result of this bacteria. Haemophilus is a bacteriaum that results in respiratory infections as well. E. coli prefers to live in the digestive system and may results in diarrhea and food poisoning. Helicobacter pyroli are bacterial agents that cause stomach ulcers. Mycobacterium
leprae, which resides in the immune system, causes leprosy and skin rashes, and is shown in Figure 9 (Misch, Vary, & Hawn, 2010).

![Microscopic image of the Mycobacterium leprae.](image)

Figure 9. Microscopic image of the Mycobacterium *leprae*.

Our biggest concern is to prevent the spread of such bacteria from the patient via the ambulance to another person. Most of the bacteria listed above are contagious; they are directly communicable between people, or they indirectly spread via a medium. The ambulance and stretcher carry patients in their most vulnerable moments, many which may have contagious bacteria. The ambulance and the stretcher must not act as a medium of such transfer.

A better understanding of the contagious activity of bacteria will assist us in seeing the scope of the problem. Each Bacteria type has a preference to inhabit and infect certain parts of the body.
Streptococci bacteria prefer the respiratory tract and are spread to other persons via the respiratory tract, they reside in the skin and is transferrable upon the direct contact with the infected skin. Mycobacterium leprae inhabits the immune system. However, the bacteria can trigger the nervous system to render skin rashes (Misch, Vary, & Hawn, 2010). The bacteria do not transfer upon contact with the skin because the bacteria reside in the immune system and not the skin. However, a non-symptomatic person has the ability to transfer this bacterial infection upon contact with his immune system related excretions. Such complications make identifying and avoiding bacterial spread a more difficult task.

2.7 Ambulances: Crashes and Injuries

Almost all of us have heard the sirens of the ambulance. Some react by quickly parking their car to allow the ambulance to pass, others cause more of an obstruction than anything else. As the ambulance is racing to the hospital, one can ask a valid question: What is the scope and what type of injuries occurs in ambulances as EMS are transporting the patients to save their lives? Based on the available studies, a detailed analysis is provided. The data is based on two national databases: General Estimates System (GES), and the National Highway Traffic Safety Administration’s Fatality Analysis Reporting System (FARS).

Ambulance crashes have received much attention, and it is an issue of significance importance to the safety of EMS personnel and their patients. Interestingly, ambulances experience higher
fatal crashes that lead to death of its occupants compared to police cars and fire trucks (Becker & Zaloshinja, 2003). The data is analyzed in a fashion to distinguish between the varying types of crashes, the different kinds of perceived injuries, and the relationship of that to the location of the EMTs in the ambulance. Also, there is an indication to the effect of the restraint while in the ambulance.

The number of fatal crashes involving an ambulance is 305, more surprisingly the number of non-fatal crashes is 36,693. Others indicate pedestrians or occupants of other vehicles on the road (shown below in Tables 2A-D). The fatal injuries within the ambulances are inclusive of both patients and EMTs. The non-fatal injuries are 10,398. Non-fatal injuries can range from simple bruises to severe wounds and fractures.

If we draw attention to the specificity and location of the injury within the ambulance, we see that there is a statistical difference in injury and location in the ambulance. On an emergency call, when seated in the front and restrained, the total of all types of injuries is 12% from total occupant of the ambulance (Table 3). When seated in the front and unrestrained, the total of all types of injuries is 20% from total occupant of the ambulance (Table 3). Notice that it is higher amongst unrestrained occupants. When seated in the back and restrained, the total of all types of injuries is 14% from total occupant of the ambulance (Table 3). When seated in the back and unrestrained, the total of all types of injuries is 34% from total occupant of the ambulance.
(Table3). Also, it is higher amongst unrestrained occupants sitting in the back. Moreover, from the following data, it is clear that, the back of ambulance is more dangerous.

**Table 2. Number of Emergency Vehicle Crashes and Persons Involved:**

**Table 2A.**

<table>
<thead>
<tr>
<th></th>
<th>Number of Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fatal</td>
</tr>
<tr>
<td>Ambulances</td>
<td>305</td>
</tr>
<tr>
<td>Fire Trucks</td>
<td>166</td>
</tr>
<tr>
<td>Police Cars</td>
<td>1,113</td>
</tr>
</tbody>
</table>

**Table 2B.**

<table>
<thead>
<tr>
<th></th>
<th>Fatal Injury Victims</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Emergency Vehicle Occupants</td>
</tr>
<tr>
<td>Ambulances</td>
<td>74</td>
</tr>
<tr>
<td>Fire Trucks</td>
<td>43</td>
</tr>
<tr>
<td>Police Cars</td>
<td>228</td>
</tr>
</tbody>
</table>

**Table 2C.**

<table>
<thead>
<tr>
<th></th>
<th>Non-Fatal Injury Victims</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Emergency Vehicle Occupants</td>
</tr>
<tr>
<td>Ambulances</td>
<td>10,398</td>
</tr>
<tr>
<td>Fire Trucks</td>
<td>3,660</td>
</tr>
<tr>
<td>Police Cars</td>
<td>49,950</td>
</tr>
</tbody>
</table>

**Table 2D.**

<table>
<thead>
<tr>
<th></th>
<th>No Injuries Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Emergency Vehicle Occupants</td>
</tr>
<tr>
<td>Ambulances</td>
<td>54,123</td>
</tr>
<tr>
<td>Fire Trucks</td>
<td>45,831</td>
</tr>
<tr>
<td>Police Cars</td>
<td>152,013</td>
</tr>
</tbody>
</table>

(Adopted from Table 1 from Becker et al.)
### Table 3. Types of Injuries and Locations of Occupants from Ambulance Crashes

<table>
<thead>
<tr>
<th></th>
<th>Injury Severity (Frequency)</th>
<th>Total Occupants</th>
<th>Total Vehicles Involved in Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Injury</td>
<td>Possible/non-incapacitating</td>
<td>Incapacitating</td>
</tr>
<tr>
<td><strong>Emergency Call</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front-seat</td>
<td>Restrained</td>
<td>27,873</td>
<td>3,305</td>
</tr>
<tr>
<td></td>
<td>Unrestrained</td>
<td>2,479</td>
<td>607</td>
</tr>
<tr>
<td>Seated in</td>
<td>Restrained</td>
<td>3,0771</td>
<td>475</td>
</tr>
<tr>
<td>the back</td>
<td>Unrestrained</td>
<td>3,044</td>
<td>882</td>
</tr>
<tr>
<td><strong>Routine Trip</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Front-seat</td>
<td>Restrained</td>
<td>11,585</td>
<td>1,562</td>
</tr>
<tr>
<td></td>
<td>Unrestrained</td>
<td>829</td>
<td>198</td>
</tr>
<tr>
<td>Seated in</td>
<td>Restrained</td>
<td>1,600</td>
<td>26</td>
</tr>
<tr>
<td>the back</td>
<td>Unrestrained</td>
<td>1,717</td>
<td>741</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>52,248</td>
<td>7,796</td>
<td>1,669</td>
</tr>
</tbody>
</table>

Emergency Medical Ambulance: crash data of type of injuries perceived and location of occupants in ambulance (adopted from Table 2 from Becker et al.).

This should be a sufficient indicator to induce changes to the back of the ambulance. In the event of a crash, the possibility of injury increases in the back of the ambulance. There is more equipment in the back and sharp edges, in which the occupants can potentially hit. Also, the seat belts are rarely used by the EMTs because there is great inconvenience in attending to the patient while keeping the seatbelt on. The WPI ambulance project is implementing such changes to provide safety to EMTs, and care to patients.
2.8 Ambulances: Transportation Speed and Time

One of the major causes for accidents in ambulances is the speeding. Significant speeds increase the risk of collision. Decreasing the ambulance’s speed could have prevented many of the fatalities and injuries caused above. Some studies have been conducted to monitor the time difference between the control and emergency ambulance run time. The effectiveness that the time saved at rescuing lives is discussed. It should also be mentioned that the injuries and fatalities that occur against the other parties of the collision, such as pedestrians and other cars, are even higher. The findings are shown in Tables 2 above under “Others”.

The concentration of hospitals containing large units with specified acute care for the patients increases the transportation distance and time. Jansson and Petzall conducted a comparison study and retrieved data concerning the mean speed difference between normal driving and emergency transportation on the same roads (Jansson & Petzall, 2010). The speed difference between the two types of transportation is 19.8 km/hour in urban areas (Table 4). Also, the speed difference between the two types of transportation is 23.2 km/hour in rural areas (Table 4). There is a significance difference between the emergency mean transportation speed and the normal mean transportation speed. The urban and rural areas have different data due to the varying traffic and road conditions. Although there are more cars in urban areas, the speed
difference (between emergency and normal transportation) is only slightly lower than the rural area. The speed increase decreases the time to get to the hospital.

**Table 4. The mean speed and speed differences (km/h) during emergency transportation and experimental driving in urban and rural areas**

<table>
<thead>
<tr>
<th>Areas</th>
<th>Emergency transportation</th>
<th>Experimental driving</th>
<th>Speed difference</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Urban area</td>
<td>67.0</td>
<td>23.1</td>
<td>47.2</td>
<td>18.2</td>
</tr>
<tr>
<td>Rural area</td>
<td>100.2</td>
<td>12.4</td>
<td>77.0</td>
<td>7.1</td>
</tr>
</tbody>
</table>

(adopted from Table 3 from Petzall et al).

The time saved in the urban areas when comparing the two types of transportations is 2.9 minutes (Table 5). The time saved in the rural areas when comparing the two types of transportation is 8.9 minutes (Table 5). Increasing the number of test-drives can enhance the results of the experiments. It would be important to determine if the time is saved.

**Table 5. Duration and time saved (min) between emergency transportation and normal driving in urban and rural areas.**

<table>
<thead>
<tr>
<th>Areas</th>
<th>Emergency transportation</th>
<th>Experimental driving</th>
<th>Time saved</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Urban area</td>
<td>8.0</td>
<td>4.3</td>
<td>10.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Rural area</td>
<td>28.7</td>
<td>9.8</td>
<td>37.6</td>
<td>14.4</td>
</tr>
</tbody>
</table>

(Adopted from Table 4 from Petzall et al).
It is interesting to note that ambulances drive with similar emergency speeds at the varying patient injury types. An increase of speed increases the number of collisions, and causes the fatalities and injuries discussed above. Furthermore, extremely urgent cases take precedence and the difference is important to save the patients’ lives. There should be a balance between increased speed to save the patient’s lives, and moderate speeding to prevent collisions and further fatalities. One possible solution is if the patient’s case is diagnosed before the driving speed is determined. It is preferred if the ambulance drives at elevated speeds if the patient’s health condition is urgent, and at normal speeds if the patient’s condition is relatively minor. Moreover, U.S. ambulances are equipped and trained to both transport and to stabilize the patient. Further training for EMS personnel can be helpful to provide the health stability to the patient while maintaining the safety standards. Additionally, using the engineering expertise to redesign the ambulance and offer a safer ambulance is the most sufficient solution.

2.9 A Safety-Based Perspective on Ambulance Redesign

The compartmentization of the ambulance is a very important consideration if we want to provide a more patient-centered ambulatory service. The paramedics are an integral part of this health service. Special care should be taken to provide the paramedics maximum efficiency and comfort when they are performing their job. Ferreira and Hignett performed a study that observed paramedics over a period of 130 hours. The most-performed tasks were checking blood
oxygen levels, oxygen administration, monitoring blood pressure, and observing the patient’s heart condition. The paramedic must have an efficient way to obtain the tools to perform these tasks. The distance between them and the tools should be shorter, in a way that they could easily reach them. The current ambulance design could be improved in such a way to emphasize the efficiency and readily available convenience of the paramedic’s supplies while examining the patients and offering emergency treatment.

Paramedics suffer from high incidences of musculoskeletal problems. This is mainly due to the handling of loads (Boocock, Gray, & Williams, 2002). A survey has reported that the ambulance staff manually handles and carries excessive loads at a rate of 18% (Boocock, Gray, & Williams, 2002). This presents an 18% risk of musculoskeletal injury. The injuries that the ambulance workers are exposed to are mainly due to the following: heavy lifting and force exertion, improper working posture, body vibration, and physical exhaustion. Doormaal, Driessen, and Landerweerd observed that in non-emergency calls, 24% of monitored postures of paramedics is improper and leads to injury. This percentage went up to 56% in emergency calls (Doormaal, Driessen, & Landerweerd, 1995). Letendre and Robinson reported that the most difficult tasks, that require the most physical force, are performing cardiopulmonary resuscitation (CPR), accessing the patient, accessing the needed equipment, loading the stretcher, and working from the provided seats within the ambulance (Letendre & Robinson, 2000).
Paramedics respond to various calls, some which are non-emergency and others that are highly urgent. The type of injuries that they have to deal with on daily basis differs, but one can categorize the different injuries and their frequency. One does not expect to make the ambulance design ideal and efficient for every task. However, using the collected data, one can prioritize and rate the different features, so that the ambulance’s limited space is designed to be in optimum at providing clinical efficiency and paramedic’s safety. Louis-Smith suggested that the design priorities should be the following (Louis-Smith, 1986):

1. Facilitate CPR by providing proper restraints for equipment and paramedics and provide easy access to equipment.

2. Improve the comfort of ambulance by providing better seats and reducing noise levels.

3. Reduce obstructions and clutter

4. Make equipment locations easy to access.

Ferreira conducted a study to get details about the nature of calls, the treatment given, and the frequency of the different clinical tasks. In an average shift of eight hours, the paramedic responds to about 5 calls, and spends about 25% of the shift giving treatment to the patient. The paramedic is giving treatment to the patient 30% while the ambulance is stationary and 70% while the ambulance is moving (Ferreira & Hignett, 2005). The rating of the frequency of the clinical tasks is provided in Table 6 below.
Table 6. The Distribution of the Frequency of Various Clinical Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Percentage of Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check pulse/blood oxygen saturation</td>
<td>51</td>
</tr>
<tr>
<td>Administer oxygen</td>
<td>27</td>
</tr>
<tr>
<td>Monitor ECG pattern/use cardiac monitor</td>
<td>23</td>
</tr>
<tr>
<td>Check blood pressure</td>
<td>21</td>
</tr>
<tr>
<td>Administer drugs/IV fluids</td>
<td>18</td>
</tr>
<tr>
<td>Patient transfer from chair to stretcher</td>
<td>16</td>
</tr>
<tr>
<td>Check blood glucose concentration</td>
<td>16</td>
</tr>
<tr>
<td>Frst aid treatment (clean wounds)</td>
<td>7</td>
</tr>
</tbody>
</table>

(adopted from Table 2 from Ferreira et al.)

This data can act as an excellent starting point to set up an optimum ambulance design.

Moreover, it is important to know the different interactions that occur between the paramedics and the patient, all relative to the location in the ambulance. Seat B was used 71% of the time. The paramedics treated the patients by sitting on the stretcher 14% of the time. Seat A was used 11% of the time. The paramedic box was used 2% of the time. The criteria that determine which location to be used depended on the type of call, the number of patients transported, and the patient’s injury type and its location (Ferreira & Hignett, 2005).

The clinical tasks frequency, and their relationship to the improper postures of the paramedic are represented below in Table 7.
Table 7. Clinical tasks conducted by EMS that affects their posture.

<table>
<thead>
<tr>
<th>Task</th>
<th>N</th>
<th>AC=1 (%)</th>
<th>AC=2 (%)</th>
<th>AC=3 (%)</th>
<th>AC=4 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing on clipboard</td>
<td>297</td>
<td>94</td>
<td>6</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Interaction with patient</td>
<td>292</td>
<td>70</td>
<td>30</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Idle</td>
<td>194</td>
<td>100</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Interaction with carer</td>
<td>74</td>
<td>82</td>
<td>16</td>
<td>—</td>
<td>2</td>
</tr>
<tr>
<td>Accessing equipment&lt;sup&gt;a&lt;/sup&gt;</td>
<td>56</td>
<td>41</td>
<td>54</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Using cardiac monitor&lt;sup&gt;a&lt;/sup&gt;</td>
<td>55</td>
<td>60</td>
<td>40</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Using pulse-oximeter</td>
<td>51</td>
<td>67</td>
<td>27</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Loading/unloading patient</td>
<td>45</td>
<td>62</td>
<td>27</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Other&lt;sup&gt;a&lt;/sup&gt;</td>
<td>38</td>
<td>47</td>
<td>50</td>
<td>3</td>
<td>—</td>
</tr>
<tr>
<td>Cannulation/drug administration&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31</td>
<td>32</td>
<td>68</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Blood pressure check&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30</td>
<td>57</td>
<td>43</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Blood glucose check&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26</td>
<td>58</td>
<td>42</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Rubbish/sharps disposal&lt;sup&gt;a&lt;/sup&gt;</td>
<td>23</td>
<td>9</td>
<td>91</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Oxygen administration&lt;sup&gt;a&lt;/sup&gt;</td>
<td>17</td>
<td>59</td>
<td>41</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Non-specific motion</td>
<td>16</td>
<td>75</td>
<td>25</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Talking to driver/ on phone&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12</td>
<td>25</td>
<td>75</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>First aid treatment&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11</td>
<td>57</td>
<td>43</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Transferring patient&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9</td>
<td>11</td>
<td>22</td>
<td>56</td>
<td>11</td>
</tr>
<tr>
<td>Listening with stethoscope&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8</td>
<td>50</td>
<td>50</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

<sup>a</sup> Indicates tasks with at least 40% of paramedics’ improper postures.
Detail of clinical tasks done by paramedics, and their influence on the paramedics’ injury (adopted from Table 5 from Ferreira et al).

The incidence of the improper paramedic posture, which can lead to injury, in emergency calls is higher than in non-emergency calls. Also, the incidence of improper paramedic posture is higher in a moving ambulance than in a stationary ambulance (Ferreira & Hignett, 2005). The data presented above is important at helping us shape the best ambulance design. We want to meet our objective of providing patient and paramedic safety while enhancing efficiency. A redesign of the ambulance is an integral part of a better transition.

2.10 Fast Rescue Stretcher

In response to catastrophic disasters, much like the 2008 earthquake that shook China, especially Wenchuan, simple yet innovative stretchers have been created for disaster relief. In many devastated areas, emergency medical ambulances are unable to respond to provide immediate relief and further measures must be taken to aid the injured survivors. Chinese engineers from the Nanchang Institute of Technology developed a bicycle, which unfolds into a fast rescue medical stretcher, shown in Figure 10 (Cao, 2010). With the development of such bicycle, only one first responder is needed in the rescue process saving manpower and human resources in the disaster area as well providing time effective services when medical vehicles are unable to assist. The overall design is simple, economical, and easy to produce (Cao, 2010).
Transforming the bike (Figure 11) into a stretcher is uncomplicated and rather quick making the rescue time short and extremely effective in devastated regions. A few, easy-to-remove nuts and screws allow the cushion to be removed and the handle bar rods to rotate. Both wheels rotate and lay evenly on the ground allowing the side rods to fall into place. The final look of the stretcher is represented in Figure 10. Each screw and nut removed is placed back into the rods maintain the stretcher’s formation. The stretcher can regain its original formation as a bicycle as quickly as it is set a stretcher (Cao, 2010).
With the development of this patent-pending fast rescue stretcher, emergency response teams will be able to assist patients more rapidly in catastrophic areas much like the Wenchuan earthquake and most recently the earthquake and tsunami in Japan. Its progress also cuts spending and is cost-effective.

### 2.11 Examples of Stretcher Improvement Opportunities

There have been many ideas for stretcher improvements. Teams at WPI are researching and developing potential solutions for numerous problems associated with the transfer of patients in regard to the stretcher. Examples include reducing patient vibrations while in transport, shielding the patient from various weather conditions. Also, it has a role in absorbing bodily fluids lost by the patient, creating a stretcher for people of all sizes (including infants), protecting stretcher
patients during an ambulance crash, and so on. Members of the Tokyo Medical and Dental University Graduate School of Japan introduced one particular idea. The authors (Kumiko Ohashi, Yosuke Kurihara, Kajiro Watanabe, and Hiroshi Tanaka) suggest the implementation of what is called a “smart stretcher.”

The “smart stretcher” is a wireless system that is able to continuously monitor the vital signs of a patient while they are being transported on a stretcher. The system is aimed at preventing common medical errors such as the overlooking of a patient’s emergency status. The device is also designed to alert apnea of the patient to medical staff during transport. The three main measurement devices used in the smart stretcher are a device that measures vital signs, a device that provides automatic patient ID recognition, and a device that tells the location of the patient in the hospital. The three types of information provided by the devices are transmitted using a wireless network system. All these devices help to monitor the overall status of the patient, and when an emergency is detected, the information is sent to an alert system that notifies medical personnel. The smart stretcher system is shown below in Figure 12.
Although the smart stretcher system was made to be used in a hospital setting and not during transport from the scene of an accident, it is an example of the many opportunities for the improvement of the stretcher and the overall safety of patients (Ohashi, 2008).

Another example of possible improvements to the stretcher is the implementation of a scale beneath the wheels of the stretcher. Anthony M. Niosi owns a patent for such a device. In emergency situations it is often necessary for EMS personnel to have to treat the patient on-site or in the ambulance. Immediate treatment is often critical to the survival of the patient, therefore it is very important to apply proper treatment. The dosage of such treatments is often based on
the weight of the particular patient. Because EMS personnel have no device that is able to weigh the patient, they are forced to estimate his or her weight on the spot. EMS personnel are often off by several pounds, especially when estimating small children or overweight individuals. An inaccurate estimation of the weight leads to an inaccurate dosage, which could significantly affect the effectiveness of the medication on the patient. Also, an over dosage could adversely affect the patients’ health. Niosi suggests that pads should be placed on the floor of the ambulance underneath the wheels where the stretcher is secured. The pads are able to weigh anything that is placed on the stretcher, and digitally display the weight of the patient on the stretcher (Niosi, 2000).
CHAPTER 3. OUR DESIGN

3. Introduction

After examining past and current medical practices and protocols for the operation and use of medical stretchers, it became clear that something big was missing from the equation. A patient in an accident was completely exposed to the elements while being transported on the stretcher into the ambulance as well as when they were transported from the ambulance into the hospital. The current method for protecting the patient from the elements was to cover them with blankets. This current method leads to many unnecessary problems from the patients as well as the EMTs caring for them. If there are too many blankets on the patient they can become hot and uncomfortable. If it is raining or snowing the blankets can easily become wet which can cause the patient to become cold and possibly hypothermic. Also if the patient is bleeding or excreting and fluids the blankets need to be washed and sanitized after every accident response. This costs the EMTs valuable time and money.

To solve this problem our group has designed a retractable canopy to attach to existing stretcher models which would protect the patient from all weather conditions as well as keep them warm. Our canopy design is lightweight and compact so it will not affect how the stretcher is handled by the EMTs. After surveying several EMTs asking them what they would like in a canopy attachment their largest concern was that the canopy would get in the way of them doing their everyday job. They did not want their normal functions to be hindered because of a bulky
attachment on the stretcher. This meant that we had to incorporate our design into the overall functionality and design of the existing stretcher so it did not interfere with the EMTs doing their duty. Doing this was easier said than done and our group went through several design iterations before we settled on one that would provide the patient the protection from the elements that they needed as well as stay out of the way of the EMT until it was needed.

Our final design utilizes a shade rolling system so that the fabric used to cover the patient quickly and easily rolls out of the way when it is not in use. The roll of fabric rests at the foot of the stretcher out of the way from the EMTs doing work on the patient or maneuvering the stretcher. The cloth is pulled out evenly over the patient using a rail system attached directly to the sides of the stretcher so there is nothing hanging off the stretcher. The rail system allows the cloth to slide back and forth and be easily adjusted to the desired height of the patient and the EMT.

The shade itself will be made out of gortex. We chose this material because it is water and wind proof so it will effectively shield the patient from all the elements while remaining lightweight and breathable. Also gortex is easily cleaned which makes the sanitation process quick and easy. It is fully adjustable in height to fit any size patient and allow them to be comfortable.
3.1 How We Arrived at Our Design

When first presented with the task of improving the modern stretcher, we had many different ideas and knew we could take this in many directions. Although today’s stretchers are more advanced there are still some aspects of the stretcher that can be improved upon and help improve the patient and EMTs’ experience. There were ideas that could help with storage of equipment for the EMTs to changing the mechanics of the lift of the stretcher. Some of our goals to start were to make the stretcher more comfortable, to make tools more accessible, make the stretcher easier to use, and to make it easier to load and unload on and off the ambulance. We wanted to meet these goals while meeting the health standards provided by federal and state law.

One of our first ideas on how to improve the design of the stretcher started from the ground up. We looked at the design of the tires and how they could be improved upon. One thing we noticed is that on many designs the wheels are rather small and not ideal for pushing through rougher terrain and could easily be caught up on smaller debris. We also thought the current wheel placement lent itself to easily tipping over. Therefore, we discussed moving the placement of the wheels as well. Our initial ideas to improve the wheels of the stretcher led us to consider using larger wheels. The stretcher will then be more stable and travel smoothly through rough terrain. The prospect of using a type of gel to inflate the tires so they would not pop easily was also discussed. These described tires would help with the absorption of shock on the rough terrain as.
The wheels are the only part of the stretcher touching the ground so it is important that they function properly.

The other idea considered was to add or improve a shock or suspension system for the stretcher. Often the stretcher is brought out into the field away from the ambulance and will encounter different terrains which can make the ride uncomfortable for the patient. By reducing the shock, it will improve the health and well-being of the patient. Some of the ideas for the stretcher shocks involved adding some form of hydraulics to the stretcher. Another independent suspension system was also talked about. One of the problems with changing the suspension and shock absorption of medical equipment is that it must still meet standards. Also, it cannot be designed only for a specific weight since there will be a range of different size people using the stretcher.

Continuing with the theme of shock absorption we also looked into the design of a pad or type of blanket that goes under the stretcher mattress. This described pad not only helps increase the shock absorption but also can be used to collect any bodily fluids or unwanted material from the patient. The pad would be soft and comfortable. Also, it would be washable or made from a cheap material so that it was possible to discard of and replace easily. We looked into materials that would act as a type of diaper, letting materials and fluids seep through it but keeping the patient dry and comfortable. There were many different materials and substances that allowed
the type of action we wanted. However, we struggled with how they would be put into place on the stretcher and how the sponge-like material would connect to the stretcher. Another IQP group at WPI actually took on this task and came up with some great designs similar to what we had planned. The sponge idea is nice because it helps increase comfort for the patient, helps the EMTs keep the stretchers clean. It also helps suppress vibrations at the same time.

Another task that was presented to the group was to increase the access to tools by EMTs. This is to make it possible for the EMTs to bring more equipment on the scene without having to carry a big bag with them as they pushed the stretcher along too. The idea was discussed to make the stretcher a mini ambulance and have everything that would be needed stored on a part of the stretcher. We first looked at having the tools connected to the stretcher by a recoiling wire so when they were finished being used. They would then snap back into place on the stretcher but this presented the problem of tools sticking out of the stretcher and making patients and EMTs vulnerable to being poked or stabbed by the free standing tools. Thereafter, we looked at adding a storage container into some of the empty space areas under the stretcher which could hold everything needed. This idea was feasible but again it was not able to be executed as well because adding the storage area underneath the stretcher took away the functionality of the stretcher, not allowing it to collapse as easily. Another problem was that stretchers need to be light so they can be easily lifted and moved. Adding storage to the stretcher only increased the weight and would also make it difficult to meet the necessary, stringent medical standards.
The next thing we looked at didn’t involve the stretcher so much as it did how the stretcher was loaded and latched into place once on the ambulance. The current setup in the ambulance has rods sticking up from the floor of the ambulance that the stretcher snaps into to lock into place. This design is suspect to problems because it is dangerous to the patient because if there was ever an accident the pole could possibly go through the stretcher and impale the patient or hurt an EMT as well. The rods also make it inconvenient for the EMTs to move around the ambulance. We looked at designs such as using clips, or guided rail system, or using magnets to hold the stretcher in place. The magnets were ruled out because they can be harmful to patients with pacemakers and other heart conditions. The rail system was effective because we wanted it to just be grooves in the ground that the stretcher could slide into and be secure but this was also tough to do because of the placement of the wheels. It was also possible that this system could be jammed more easily. It is important that the stretcher is securely in place so that the EMTs can perform their job safely and easily.

Some other ideas we had were incorporating existing tools and equipment into the current stretcher to save more space, similar to the storage ideas. We thought of attaching the oxygen tanks that are often used, somewhere on the stretcher so that they would not simply be sitting on the patients lap as is common procedure. This did not help decrease the weight of the stretcher though which was counterproductive to one of our goals. Also the many different sizes of
oxygen tanks used made it hard to come up with a standard design. We also tried to incorporate the tubing of the oxygen and IV’s by having them built into the railings and metal work of the stretcher so that they ran along the inside of the framework so the wires and tubes would not be floating around. This was problematic because it is rather important to be able to see the tubes to make sure they are working properly and can be moved easily. It is also tough to fix any problems with them if they are built into the actual framework of the stretcher.

We settled on the idea for the weather retardant canopy because this helps EMTs do their job better, increases comfort of the patient and also won’t add too much weight to the stretcher. There is also many different ways in which we can go about designing and applying this idea to the stretcher. We also hope to incorporate as many previously discussed goals as possible into this design as well so that the benefits of this design can be maximized.

3.2 Alternative Designs

3.2.1 Alternative Designs: The Two-Sided Retractable Canopy Design

The process to our final design led us to consider many alternative designs. As our understanding of the objectives and goals of the project became more clear, our project design evolved to reach the best product. The constraints and the process of prioritization used helped the group to refine the design.
The ambulance stretcher canopy design is a novel idea. It has not yet been integrated into the US ambulance stretchers. One of the canopy designs considered by the group is the two-sided retractable design. The group initiated an effort to use it as a potential model. The group discussed the dimensional and design details, the pros and cons of this design, the materials to be used, and a cost analysis.

The two-sided retractable canopy works via a mechanism that allows for the whole stretcher to be covered. The right side of the canopy gets pulled to a maximum height covering the right half of the patient’s body, creating a half circle-shape cover. Similarly, the left side of the canopy gets pulled to a maximum height covering the left half of the patient’s body. Moreover, there would be a spring material within the core material which gives strength and support to the overall structure. Also, it would contribute to the retractable ability of the canopy. Attachment methods for the canopy parts have been devised. The right side of the canopy would be attached to the stretcher via five circular adjustable attachment parts. The attachment parts clip to the outmost outer rails of the stretcher allowing the right side of the canopy to hold firmly to the stretcher. The left canopy side will be designed in the same fashion as the right canopy side.

This design has several pros. The discussion above partly emphasized the pros. This design demonstrated above will satisfy the objective of covering and protecting the patient from some weather conditions. This design’s shape will be able to accommodate for the various patients’
weight and size. The overall structure is durable and can last for a long time. Moreover, it will be easy to use and install by the EMS.

This design has several cons. The integration of extra flaps in both the head and foot region of the stretcher becomes necessary to protect the patient against the wind and the cold. The attachment of the flaps on the two-sided canopy is difficult. The flaps have to be installed on the stretcher separately. Another disadvantage of this design is that it would not allow the EMS to use the IV when it is opened. The ideas in this design were not completely abandoned. By learning the deficiencies and advantages of this design the group was able to enhance the final design’s functionality.

3.2.2 Alternative Designs: The Two-Section Retractable Canopy Design

We passed by several designs before we derived to the final design. We learned from each process, and we studied the cons and pros of each design. We took the pros and tried to include them in the next designs. At the same time, we tried to eliminate the cons of the previous designs. After the two-sided retractable canopy, the group introduced the two-section retractable canopy.

The two-section retractable canopy corrected some of the problems that existed in the two-sided retractable canopy. One of the cons discussed earlier with the two-sided retractable canopy is the
difficulty of giving IV therapy to the patient while the canopy is fully assembled. IV therapy is an important procedure that cannot be compromised. The two-section retractable therapy will solve this problem. This canopy is divided into two sections. One of the sections cover the head and chest region, and the other section will cover the legs region.

This canopy is a one unit device, divided into two sections allowing, and each section is to be used independently. The first section will cover the area from the stretcher vertical midline to the end of the stretcher at the legs. The second section will cover the area from the stretcher vertical midline to the end of the stretcher at the head. The stretcher vertical midline represents the line at which the stretcher upper part is mechanically leaned forward or backward (Figure 13). This position was chosen in order that the two-section canopy design is in harmony with the stretcher design, and so that no hindrance to the stretcher occurs. The two sections are independent of each other. For example, if the patient needs an IV therapy, or his head and chest region needs to be exposed, the first section can be opened and the second section remains unopened. The second section functions in a similar fashion to the first section. The canopy is pulled from the left side of the stretcher creating a curve cover and it is locked at the right side rail of the stretcher.
There are several pros to this design. The two-section retractable design will protect the patient from many weather conditions. It is easier to use and install. Moreover, the design’s flexibility allows for medical procedures such as IV therapy to be used while the canopy is in use. This canopy design will present minimal hindrance to the stretcher, and has the potential to make a smooth transition if it is added to the stretcher.

Despite these improvements, there remain some cons that should be evaluated. Additional flaps will have to be added to the design to prevent wind from penetrating into the head region. Also,
a method should be developed to close the small gap at the vertical stretcher midline. Moreover, this design can present claustrophobic effects to the patient. The two-section retractable canopy design was an improvement from the previous designs. The final design includes many aspects of this design. This design was a necessary step toward the development of a better canopy design which satisfies the objectives in the best way.
3.3 The Final Design

The final design for our stretcher canopy will be comprised of three main parts. First is the roll of Gortex fabric that is used to cover the patient. The Gortex is lightweight, windproof and waterproof this will enable the cover to keep the patient cool and dry in any weather conditions. The next component of our final design is the rail system that the Gortex roll is attached to. The rails are attached directly to the metal side rails of the stretcher which will allow the Gortex roll to be drawn out to a desired length over the patient. The last component of our design is the roller itself on which the Gortex fabric is rolled. The roller will have a similar internal mechanism as a window shade. This will enable the Gortex fabric to automatically roll back onto the roll when the rails are retracted. These three components working together will comprise the final stretcher canopy.

The first step in modeling our final design was to obtain measurements of a stretcher. Since there are hundreds of varieties and models of stretchers all of which are different in some way, we chose a single model to base our model dimensions. The stretcher we used was a standard model found in ambulances at U-Mass Memorial Medical center in Worcester MA.
From the dimensions obtained on our visits to U-Mass Medical Center we were able to construct a 3-D solid works model to the exact scale of the actual stretcher. The stretcher is represented by a simple rectangle. The model did not need to show all of the intricacies of the stretcher because all we needed to model our canopy were the rough outer dimensions to attach our canopy to. Since the canopy attaches directly to the foot and side rails of the stretcher the two main dimensions that we need are the width and length of the stretcher.

The roll of fabric is designed to be as wide as possible in relation to the stretcher to give the maximum coverage of the patient. To prevent the canopy from possibly blowing to the side during harsh weather conditions we plan to have a fastening system that enables the fabric to be secured to the rails of the stretcher for any length it is drawn out. The simplest system we came up with was to put a Velcro edge on the side of the Goretex fabric. This Velcro edge could be secured to an opposing Velcro edge located on the top of the rail on the side of the stretcher. The Velcro can easily be torn away if the EMT needs access to the patient which allows for easy access while still shielding the patient. This would allow the canopy to be secured around the patient and prevent any wind or elements from getting underneath it and possibly make the patient uncomfortable.

The roll itself that the fabric sits on will be spring loaded like a window shade; a schematic of this is displayed in Figure 18 below.
The internal spring mechanism will allow the fabric to be automatically drawn back onto the roll when it is retracted. This ensures that the fabric is tightly wound around the roll and will also save the EMT the work of having to roll the fabric back onto the roll when the canopy is not in use. The ratchet mechanism inside the roll allows the fabric to be drawn out to a certain point and stay at that desired point until the user wishes to move it. At which point the EMT can simply pull forward on the top portion of the canopy causing the ratchet to release and the spring to unwind the roll.

To solve the problem of how tall to make the canopy we decided to make both the roller portion and head of the canopy adjustable in height. This would allow the canopy to be used on any sized patient and would ensure the correct fit every time. If we had not made the canopy adjustable in height then it would not be able to be used on all patients. This would mean that if someone was too big for the canopy and it was not able to be used it would be a waste of space and more importantly weight which is all important on the stretcher. Also, by making the height adjustable the EMTs can control how close the canopy is in relation to the patient so they will feel more like they are wrapped in a blanket and not trapped in a small tent. Below are the two adjustable brackets which the canopy is attached to.
Figure 14. Bracket #1.

Figure 15. Bracket #2.
The holes in each allow for the head and foot portion of the canopy to be adjusted independent of one another to fit any body shape. So if someone has large feet but a skinny torso the foot portion can be raised while the upper portion is lowered to obtain a snug fit.

After solving the problem of how to fit a variety of patients we needed to determine how exactly the canopy would move back and forth on the stretcher on the same plane. To fix this we decided to use two rails located on either side of the stretcher. These rails would be secured to the bars on the side of the stretcher. This would make them completely out of the way and would help streamline our design so there was no big bulky protrusions from the sides of the stretcher which would affect the EMT’s ability to maneuver around and do their job. The rails were designed so that the bracket shown above on the right would be able to slide back and forth freely in it. The cylinder located at the bottom of the bracket would rest inside the track on the rails. The rail, pictures below, has a groove in which the cylinder will rest, enable it to slide back and forth freely, making for simpler ease of operation.
All of these components combined work in turn with each other to form the functioning final design for our canopy. The final design modeled below, Figure 17, will significantly improve upon the current canopy designs and eliminate the need to carry excess blankets and sheets to cover a patient. Our design will keep the patient cool and dry in all weather conditions. The last and most important design feature of the canopy is that it will easily detach from the stretcher allowing it to be cleaned and sanitized in case of contamination. All of these features will help to make the EMT’s job easier as well as keep the patient shielded from the elements and safe.
3.4 Materials Used for the Design

One of the most important aspects of the design of the canopy for the stretcher is what materials will make up the weather resistant canopy. Every part of the canopy must be taken into great consideration. Because it is going to be part of a medical stretcher there are many different factors that must be taken into account in order to meet the standards of not only government rules but it must also meet the standards of the hospitals, EMT’s, and patients.

While thinking about the many uses of the canopy there are many things that materials must be able to do to make the design work to its highest capability. First, the material must be waterproof. The main reason the canopy has been designed is for the purpose of protecting patients from inclement weather among other situations. The current procedure for EMT’s to
protect patients from weather is to cover them in towels or blankets (Haynes, 2011). This procedure is not only ineffective because it makes the patient uncomfortable and can lead to further complications or sickness but it also makes it difficult for the EMT to continue to work on the patient if necessary. A waterproof material would be able to keep the patient dry and it would also take away from the unnecessary weight of the wet towels. The material would allow for the water to runoff the stretcher onto the ground not affecting the patient and leaving the stretcher and any tools the EMT might be using unharmed. The canopy is only meant to be used outside of the ambulance as the patient is being transported from the scene to the ambulance for treatment, by keeping the patient dry during this period of time which can range from a few seconds to many minutes depending on the scene, the EMT will be able to perform their job more effectively and the patient will remain comfortable once inside the ambulance. Appendix I shows the sketch of the canopy folding over the head of the stretcher.

The material to be used must also be able to protect patients from ultraviolet (UV) rays. Many different injuries can be intensified by exposure to too much sunlight, such as burn victims (Nasar, 1999) and any type of injury involving trauma to patients’ eyes (UCMC, 2010). Not only does it help with these certain types of patients but it also provides a certain level of comfort to patients on an especially sunny day. It is easier to make the part of the canopy covering the body UV resistant because it can be an opaque material, but as for the part of the canopy covering the head and upper body of the patient, this part must be transparent so that the EMT
can better monitor the patient as they are being transported and tend to them immediately if necessary.

Being able to maintain the body heat of a patient can be especially important when dealing with certain trauma patients. The material must be able to provide the ability to keep in body heat and keep the patient warm if necessary. If a patient is suffering from hypothermia or has just been rescued from a cold lake it is necessary to keep the patient warm and be able to treat them properly. By using the stretcher with the canopy attached, it allows for the canopy to do the job of or help with the job of keeping the patient warm and protect them from the elements. There are many instances where that patients body temperature can immediately affect their health (Haynes, 2011) and by having this feature on the stretcher, the EMT’s can better regulate this aspect of the patient and have less to worry about while treating the other symptoms of the patient.

The material to be used must also be able to be movable and not stiff in any way. First, it must be movable in order to fit on the rail system that will be attached to the stretcher and roll freely on the ratchet mechanism. The material must also be able to be moved so that it can stretch and retract so that it can cover any necessary parts of the patient. There was concern that due to the rail system, the whole body of the patient would not be covered, mainly the sides of the patient, which could make for a drafty design, but in order to remedy this our material will be able to
extend over the sides in order to cover this region and if necessary Velcro can be used in order to hold the material securely in place. On top of the material being movable it must also be light, one of the biggest concerns of EMT’s with adding objects onto the stretcher is that it is only an increase in weight that they must deal with every time they have to lift the stretcher. This not only applies to the material used to cover the patient but also the rail system that will be attached to the stretcher to make use of the canopy possible.

Figure 18. The design of the mechanism that will be attached at the foot of the stretcher. As you can see it is necessary for the material to be able to move freely on this mechanism and to be able to cover the patient as necessary.

In dealing with anything to do with medical standards or health standards it is obvious that each time a stretcher is to be used, it should be clean and free from any type of residue from the previous patient (Haynes, 2011). This brings up the fact that whatever material is to be used
should be inexpensive. Inexpensive materials allows for parts to be easily replaced if broken and/or replaced completely if soiled and unwashable. Because the canopy will be in close contact with the patient so that it can best serve its purpose, it is necessary that it can be removed if it becomes infected with any blood, disease, or any type of bodily fluid. The material to be used should not be reactive in any way either, in order to protect the safety of the patient. By making the canopy material independent of the stretcher, it also makes it much easier to simply replace the material rather than having to deal with replacing the whole stretcher if it does become infected.

On top of all the requirements that the material must meet, it should also simply be comfortable for the patient. Generally patients being treated on a stretcher are not too thrilled about being there in the first place so it helps if their experience is as pleasant as possible, and by simply increasing their comfort this can improve their attitude and at times their health. So although it is important that the material meet the functioning standards it is equally important that the patient
will be comfortable using the canopy because after all the design will not be worth it, if the patient simply doesn’t want to use the canopy.

As far as materials go, there are many different materials that our group has looked into to satisfy our needs that have been previously discussed. One of the first materials that we looked into is Polyvinyl Chloride (PVC), a type of plastic. There are many different types of PVC, the most common one is it’s use for tubing but we are looking at the clear more flexible type of this plastic. This material would be used for the retractable headpiece of the canopy design because it is transparent and unreactive. The material is very workable and can easily fit any design shape necessary (CSC Textiles, 2011). PVC has the ability to be flexible at many different thicknesses as well, so it can be made thick enough so that it is waterproof, windproof, and still able to be used in the retractable design. In regards to UV protection, there are types of PVC that have different levels of UV protection as well, and it also has the ability to have a darker tint added to it to increase the comfort and UV protection. Another appealing aspect of PVC is that its rather cheap to use and easy to obtain. There are many different properties of PVC that can be adjusted as well in order to meet any specific needs or requirements.
Figure 20. Roll of clear Polyvinyl Chloride that is the ideal material for the retractable head part of the canopy design.

In looking for the material that best suits the body-cover portion of the canopy design, we first looked at many commonly used materials that are used in similar ways as our design would be. We came up with the idea of looking at things such as boat covers, Under Armour, Gore-Textex, and even the covering used on jeep wranglers. All of these materials are UV resistant, weather resistant, durable, windproof, and waterproof. They meet all the needs that would be important for the material to be a part of the canopy design.

Under Armour, which is commonly used as sports apparel to keep athletes warm and protect them from the elements. There are different brands that provide protection from the cold and the heat. We thought that it would be possible to outfit the stretchers with this material as part of the design of the stretcher depending on the seasons. The only problem with this material is that it is rather expensive and instead of repelling the water away from the patient, it sometimes becomes
more of an absorbent material that could leave the patient feeling uncomfortable. Gore-Tex is also used in sports and clothing apparel as well as for camping equipment so it is also built to deal with tough weather conditions. Gore-Tex works by sealing their specially made material in between an outer lining and an inner lining of fabric that allows the material to be breathable but the Gore-Tex material which has pores 20,000 times smaller than a drop of water, does the work in keeping the inner material and user dry (W.L. Gore-Tex & Associates, 2011). Gore-Tex and Under Armour also have a steeper price because the material is a brand name. They both have the possibility of being effective; although Gore-Tex may be more effective than Under Armour because of its durability.

Figure 21. The technology and fibers behind Gore-Textex (left) and Under Armour (right).
These two materials, Under Armour and Gore-Tex both possess the properties necessary for the canopy design that will be outfitted on the stretchers. Their current uses as outdoor materials that are supposed to protect the users from the elements shows that they are suitable for this type of job. They are both brand names that make use of the material a little more tricky and possibly a little more expensive.

We found that the material used for this purpose is known as 100% Solution Dyed Satura (Lee Sail Covers, 2011). This material seems almost too good to be true. It is a polymer that has been engineered for outdoor use. It is not only UV resistant and waterproof but it’s highly breathable. This material is very durable and can be used for a long time because of its resistance to stress. Another great property of the 100% Solution Dyed Satura is that it can be easily cleaned so that it can be reused over and over. Although the cost of this material is a little more expensive, it is well worth it because it does not need to be replaced as often but simply washed. This material comes in many different colors too and is 100% recyclable. The 100% Solution Dyed Satura also offers different weights, ranging from 6.5 (oz./ sq. yd) to 8 (oz./ sq. yd.). This material seems to be the perfect fit for the canopy design piece responsible for covering the body of the patient.
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### 3.5 Meeting with UMass Paramedics Regarding Our Design

To get a more in-depth analysis of the medical stretcher, we arranged to meet with the University of Massachusetts Medical Center (UMass). The meeting place that was decided on was the garage that housed the ambulances that were not being used. These vehicles were still fully equipped and ready to use which was beneficial to us because we were able to see the inside of an ambulance exactly the way it would be when transporting a patient. The only difference between this visit and the actual thing is that no one in the group had to suffer through a medical emergency.

At first, we walked around examining the different types of ambulances and the way things were arranged inside. Although there were different models and makes of vehicles, the insides were made to special specifications. Everything was either fastened to the walls and floor or
contained within locked drawers that could be opened if need be. Having never been in an ambulance before, the tight space was quite a surprise for all of us. Everything in the vehicle was strategically arranged in space saving techniques. Such things as oxygen and IV tubes came down from the ceiling, just above where the head would be. This is an important factor that will later be expressed in more vivid detail.

The parameters for both size and safety were our main concerns during this visit. When designing the inclement weather canopy, several design requirements were put forth to ensure that nothing interfered with any emergency procedure taught today. When the patient is brought into the ambulance, the arms and face must be readily available to receive oxygen or an IV. Because of this, the canopy must allow access to the face and be transparent. To adhere to these requirements, the material was made to be transparent and canopy cloth placed at the feet of the patient so it may be pulled over the body. As mentioned earlier, oxygen is provided to the patient from the ceiling; however this is not always the case. If oxygen needs to be administered to the patient before entering the ambulance, it is administered via oxygen mask and tank. The tank is then placed somewhere near the feet of the patient and cannot be interfered with when placing the canopy over the body.
Another part of our visit that surprised us was how small the stretchers were. In length, the average stretcher is about 78 inches and only 21.5 inches wide. The dimensions are so small due to the limited space within the ambulance. This means that the frame of the canopy we design can’t expand any further than these parameters. This does not apply for every stretcher though. Some stretchers displayed were much wider than others to accommodate the larger patients and some were longer than others to accommodate the taller patients.

The canopy’s attachments can be put on any type of stretcher that has support beams on the side, no matter what the size of the stretcher might be. The brackets, shown in Figure 22, can attach and contour to any stretcher despite any change in dimension.
As previously mentioned the dimensions of the stretcher and canopy must be held to strict
guidelines. This does not only apply to length and width. The weight of the canopy fixture, and
the entire stretcher for that matter, must be as light weight as possible. We needed to think of a
way to attach the canopy without adding bulk to the stretcher. The professionals at UMass
suggested that the group attach the canopy where there is empty space on the stretcher.
Obviously the canopy has to be attached to some part of the frame but the fastening pieces could
occupy empty spaces between bars and under the bed, just as long as it didn’t interfere with the
compressing of the stretcher’s support beams.

The next step in the procedure, after figuring out where the canopy would be connected, was
how the canopy would be put over the patient. One idea we came up with was an accordion style
for the material that would unfold from the feet of the patient to the designated length over the
body. This method didn’t last long because this canopy would be hard to clean and would need
to contain some sort of support system throughout to keep the accordion shape. Another reason
why this wasn’t chosen was due to the fact that it would be very hard to reuse. The next idea we
came up with was to place the canopy on the side of the stretcher and pull it over the patient
where it would attach to the other side. This was a successful method until we realized that the
patient would sometimes need to be sitting up in the stretcher and the canopy was along the side
rail when the stretcher was positioned up, it wouldn’t be able to contour the upper body of the
patient. The third and final idea for the mechanism we chose was the rail system currently being
used. The canopy would be rolled up into a cylinder at the end of the stretcher, just beyond the feet. It would then be connected to a rail system that would be able to slide along the sides of the stretcher to any point of the body. Once covered to the proper body part, the canopy would then be fastened via Velcro to each of the side rails to prevent any form of weather getting in.

The material of the canopy was the next topic we discussed with the paramedics from UMass. The method of covering the patient in blankets is used because of the low cost and ease of simply placing a couple blankets on the patient and being done with it. Most blankets are not reusable but they are so cheap that it is still the most cost effective method. The canopy we’ve created is made from a very durable and waterproof material called Gore-Tex. Gore-Tex is also very easy to clean. The cost of the canopy is obviously more expensive than a blanket but the goal is for it to be reused enough times to bridge that gap of cost efficiency. The Gore-Tex’s durability can easily withstand the elements that would be affecting it. The only concern would be keeping the canopy continuously uncontaminated before every reuse.

### 3.6 Benefits of “The Canopy”

The main goal of our team’s project is to design a retractable canopy that bolts externally onto an existing Striker emergency medical stretcher that protects the patient from various weather conditions. The canopy consists of two parts, one part at the head of the stretcher and that
second part at the foot. The device at the foot can be pulled out over the patient’s lower half and up to their chest, while the device at the top can be pulled over the patients head. Our team believes there are many benefits of creating the canopy. The potential benefits include: protecting the patient from various weather conditions, keeping the patient warm, and making the process of covering a patient more convenient for EMT’s.

The first major benefit of the canopy is it will protect the patient from various weather conditions. The material for the canopy will be Gore-Tex. Gore-Tex is a waterproof material that is breathable and is effective at shielding wind. Gore-Tex is used in jackets, gloves, tents, sleeping bags, and much more. The layers of the material are shown below.

It is important to protect the patient from rain, sleet, or snow because these conditions can adversely affect the health of the patient. Also, there are many instances in which it is important to keep the patient warm. For example, if the patient is suffering from hypothermia or other related conditions, it is crucial that the patient is warm. The canopy will also protect the patient from the sun. This is important for patients who are suffering from heat exhaustion or have suffered severe burns or other situations where it is crucial to protect the skin or body temperature of the patient. As mentioned above, Gore-Tex is used in jackets and tents so the material will also help to shield the patient from high winds.
Another potential benefit to the canopy is its ease of use. Currently, emergency response technicians use blankets or body bag-like covers that can be a hassle to put on the patient and must be exposed of after. The canopy will allow the EMT to simply pull the cover over the patient from the bottom and top of the stretcher to whatever position is necessary. When the EMT is ready to remove the canopy, it can simply be slid back into its original positions at the top and bottom of the stretcher. Also, because the canopy lies above the patient and does not rest on the patient’s body like a blanket or cover does, it may not have to be disposed of after every use. The design of the canopy is made to allow the patient not feel like they are congested especially if the patient is claustrophobic.

3.7 Other IQP/MQP Stretcher-Related Projects

There are many ongoing projects currently taking place at Worcester Poly-tech in regard to various emergency response procedures. The majority of these projects involve the potential for improving the overall function and safety of the ambulance. The projects include improvements to the Coast Guard’s ambulance boat, the setup of the interior of ambulance vehicles, the process of letting cars know an ambulance is in the area, a specially designed suit for emergency response technicians, and a surgical sponge for the bed of the stretcher.
The WPI group that is working on the improvements to the Coast Guard ambulance boat is attempting to create a faster boat that can hold more patients than the current ambulance boat models. They have been focusing on the base of the boat and how to create the most stability for the boat, while at the same time increasing its overall speed. The group has looked into the differences between catamaran and trimaran boats, and which will create the most stable environment for the patients inside the boat. However, their main goal is to increase the overall speed, and therefore have put more of an emphasis on how to make a faster boat. The faster the ambulance boat is, the sooner they can arrive at the scene of an accident. Therefore, the ambulance boat improvements could have a major impact on the amount of lives saved during emergencies at sea. An example of a current ambulance boat can be seen below.

![Ambulance Boat](http://www.workboatsinternational.com/ibf151.html)

Figure 23. This ambulance boat model can only hold 6 people and travel up to 30 knots. (Image adopted from: http://www.workboatsinternational.com/ibf151.html)
Another group is working on improving the setup of the interior of an ambulance motor vehicle. The main reason for doing this project is because of the current dangers to patients and emergency response technicians during patient transfer. When an ambulance gets into a car accident, often times the patient or emergency response technicians are seriously injured because of the setup of the interior of the ambulance. For example one potential improvement, as you can see in the picture below, can be made to the single seat located on the left side in this particular ambulance. When the ambulance is in an accident or stops short, the EMT that is located in the seat on the left is exposed to potential a potential head injury due to the location of the circled part in the picture. This is only one example of how the interior of the ambulance can be improved. The goal of the group is to make as many adjustments as possible to better insure the safety of both the patient and emergency response technicians on board.

Figure 24. This is the inside of a 1999 Braun ambulance. The red circled part of the ambulance is one safety concern with this particular model. (Image adopted from: http://used-firetrucks.com/fire_trucks_for_sale/used_ambulances.htm)
The next opportunity for improvement is in the process by which the ambulance notifies other vehicles on the road that it is in the area. Currently, the ambulance uses sirens and flashing lights to let drivers know that it is approaching. However, this is not always effective and other vehicles often get in the way or cause accidents. Although this could partially be due to the lack of attention of the other drivers, there is still potential to improve the methods. The group working on this project is focusing on finding a way to make sure the other drivers on the road are aware of the approaching ambulance. The group is exploring the possibility of using different colored lights, which grasp the attention of drivers more effectively. They are also experimenting with the possibility of having some device placed in all vehicles that can signal the approach of an ambulance inside the actual car. The potential improvements could allow the ambulance to get to its destination faster and decrease the amount of car accidents during patient transfer.

There is another WPI group that is focusing on improving the suits worn by emergency response technicians. EMTs work long hours and are constantly lifting patients onto backboards and stretchers and are always bending over to attend to patients. As a result, a common complaint of EMTs is back pain. This particular group is working on a suit that implements some sort of back support to reduce back pain and injuries of EMTs. Also, other potential improvements are being considered such as using a more breathable fabric, creating pockets in more convenient places
for medical tools, and also adding padding in some areas. Improving the EMT suit could improve the comfort, safety, and overall effectiveness of the EMT.

Another major opportunity for improving the ambulance is finding a way to reduce the vibrations of the patient while the vehicle is moving. The first idea attempted by WPI project teams was to put a force plate in the bottom of the ambulance below the floor. However, this was not implemented because of certain ambulance regulations which prohibited its use. The next idea was to reduce the vibrations by putting shock absorbers in the legs of the stretcher. However, this did not completely suppress the vibrations, so further measures had to be taken. As a result, WPI teams are now experimenting with the mattress of the stretcher that the patient lies on. The team has named their project the “surgical sponge.” Not only are they attempting to suppress vibrations with the sponge, but they are also trying to make it be able to absorb any bodily fluids that are lost from the patient. They are planning on having this sponge lay on top of the stretcher mattress, which would prevent the mattress from being soiled and would make the stretcher easier to clean. If the team was able to accomplish both suppressing the vibrations and absorbing fluids from the patient, it would be very beneficial for the work of EMTs and those responsible for cleaning the stretcher.
These projects are some of the many ways in which WPI teams are seeking opportunities for improvements to emergency response practices, devices, and vehicles. Again, the main goal of the projects is to improve the safety and comfort of both the patient and the EMT.

3.8 The Canopy in Harmony with the Stretcher

The main objective of this project is to create a stretcher canopy to protect the patient against the various weather conditions while he is on the stretcher. However, our design should incur minimal hindrance on the other functionalities of the stretcher. Accordingly, the installment positions of the front and back side canopy were chosen. Moreover, important considerations such as canopy disassembly place and storage were determined.

Figure 1 displays the inner ambulance compartment. The stretcher canopy use will end in the position shown by the arrows on Figure 25. This position was chosen for one main reason. It is that so the canopy can offer the patient maximal protection from adverse weather conditions until other coverage is available. The inner ambulance compartment would serve this job at this point, and the use of our canopy becomes unnecessary. In fact, we strongly recommend that the EMS not leave the canopy assembled within the ambulance as it will create unwanted hindrance.
Some parts of the canopy should be stored in the ambulance before and after use. It might not be necessary to use the canopy all the time, but only when it adds to the comfort and safety of the patient. However, we expect that the canopy will be used most of the times because of the universal protection that it offers. In the meantime, some parts of the canopy can be stored in the designated storage area in the inner ambulance compartment shown in Figure 26. The storage of these parts will not cause hindrance due to their small size.
The group’s thought process of the installation of the canopy has taken careful consideration of the stretcher dynamic functionality. Our design was continuously improvised upon this basis. A crucial part of this part was to understand in what ways can the stretcher transform, or how the different parts move relative to each other. Figure 27 represents the stretcher at a completely stretched position. This is the most common and used stretcher position. Also, this was the easiest position to accommodate when the group determined how the canopy will be in harmony with the stretcher at each given position.
Figure 27. The completely stretcher position, the most common stretcher position. Picture was taken on a visit to Umass EMS on April 1, 2011.

Figure 28 represent the ambulance stretcher at an elevated lower part position. This part of the stretcher is elevated independent of the upper part. The lower canopy part will be installed where the green arrows are shown. A component which allows vertical movement of the canopy was integrated in this part of the design. The black arrows highlight the stretcher midline. The lower canopy coverage will terminate at that line. This was decided for design considerations. If the lower canopy exceeds the midline, the up and down movement of that part of the stretcher will be hindered by the canopy and vise versa. However, this will not compromise the coverage of the patient. The upper canopy part functioning in conjunction with the lower canopy part will cover any areas not reached by the lower canopy.
Figure 28. The ambulance stretcher at an elevated lower part position, and lower canopy part installation position represented by green arrows. Picture was taken on a visit to Umass EMS on April 1, 2011.

Figure 29 represents the upper stretcher part at an elevated position. The elevation of the upper part of the stretcher is also independent of the lower part discussed earlier. This was the most difficult part of the canopy design process. This part can move to almost 90°, and the canopy design has to accommodate all this range of movement. Upon this basis, the upper canopy part was made adjustable to the various elevations of this part of the stretcher. The yellow arrows in Figure 39 represent the positions at which the upper part of the stretcher will be installed. The upper canopy part will reach up to the midline discussed and shown in Figure 28.
In order to reinforce the firmness of the canopy, so that it can withstand strong winds for example, a mobile railing system was integrated into the canopy design. This should also help in the horizontal movement of the canopy. The blue arrows in Figure 30 show the position at which this system will be attached. Moreover, in some of the alternative designs discussed earlier this part of the stretcher was used to firmly attach some of the canopy parts.
Figure 30. The right side of the stretcher, where the railing system of the canopy will be attached. Picture was taken on a visit to Umass EMS on April 1, 2011.

Thoroughly understanding the dynamics and the functionalities of the stretcher was an integral part to the success of the canopy design project. The group aimed at creating the best protective ambulance stretcher canopy while causing minimal hindrance to the stretcher and ambulance. Properly considering both objectives allowed the group to apply a balanced approach toward an effective stretcher canopy design.
CHAPTER 4. CONCLUDING REMARKS

The design process of the “canopy” was simple, but the functionality of it had to be practical and maintain the strenuous day-to-day wear-and-tear. UMass Memorial paramedics really gave us their input as far as whether the project appeared to be useful or not. Their opinions truly mattered and played a key role in the development of our design.

Our model’s design is simple; the structure is plain, but proves to be very functional and effective, the material’s are cost effective, yet durable and practical for any emergency situation without any potential for harming the patient. The design’s concept is an on-take of Ferno’s weather and patient shields, but our immense modifications to their shields allows for a better-quality and purposeful design.

Regardless of the overall concept, modifications can always be made. Our “Canopy” prototype hopes to pave the way for a more precise and practical designs that will protect patients from various weather conditions. Materials can easily be altered, and there is always room for improvement upon the structural design of the canopy. Only consistent use of the device will tell of the design’s overall functionality. The design can even be altered to hold other medical equipment such as oxygen tanks, IV fluids, and other necessary items needed in an emergency situation.
REFERENCES


