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Degree of Bachelor of Science

Ambulatory Resuscitative Care and Surgery (RECAS)

By

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Abstract

Ambulances in the United States act as transportation vessels with the ability to sustain a patient's life until they reach the hospital. Ambulance transport time can be a matter of life and death, and current overcrowding problems in emergency rooms add to the time a patient must wait before receiving critical care. This project aims to create a pre-hospital vehicle in which patient diagnosis and both minor and time-sensitive surgeries can be performed at the scene of the injury, preceding transportation to a hospital. Information was gathered by compiling case studies on survival rates and response times relating to trauma injuries; interviewing EMTs and hospital personnel; and researching medical equipment and devices, personnel, and procedures to treat patients with time-sensitive injuries. Analysis and unification of this data resulted in engineering design sketches of a new, mobile critical care ambulance that – intends to improve the overall quality of care in the pre-hospital environment, saving lives overall. Specific implications, constraints, and costs encountered while designing the surgical ambulance were elaborated on.

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Chapter 1: Ambulatory Resuscitative Care and Surgery

1.1 Project Overview

The Ambulatory Resuscitative Care and Surgery team (RECAS) aims to improve the current pre-hospital environment. In the United States today, ambulances transport patients to the hospital, but that is basically all they are: a transportation vessel with the ability to sustain a patient's life until they reach the hospital. Today, Emergency Rooms and Intensive Care Units operate at critical capacity. This overcrowding in hospitals has dire consequences. In many cases, the time an ambulance spends transporting the patients to the hospital can be a matter of life and death, never mind the time spent waiting for ER and ICU space to clear. While current ambulances can transport patients from the scene of an incident to a hospital, they are unable to perform any surgeries and more in-depth procedures. This motivation will result in the creation a pre-hospital vehicle in which time sensitive surgeries can be taken care of on the scene. Transportation to the hospital would not be required until after the completion of the minor surgery, whether it is for conditions such as respiratory failure, cardiac arrest, blunt trauma, burns, or aneurysms.

Time is critical in responding to an emergency medical situation. In transporting patients from their home or other location to the hospital, there is always a risk that the patient might not survive the trip. Non-life-threatening situations do not require such immediate medical attention, but patients in critical condition must be transported as quickly and effectively to the hospital as possible. In responding to emergencies, there are many factors that emergency personnel cannot control. In instances where immediate treatment is necessary for patient survival, like those aforementioned, the ability to perform surgery on scene is essential.

1.2 Project Objective

The objective for this project is to create a surgery vehicle, not just an ambulance. This will be done by (1) revising current surgical and resuscitative procedures already performed in ambulance, (2) researching and implementing new biomedical technologies, and (3) redesigning an ambulance interior for surgical purposes. Implementing new, compact technology would allow for maximization of space within the cabin, and make a safer and overall more efficient environment for both the patients and the ambulance personnel. This project will take the environment into consideration throughout, by reducing weight within the cabin in order to save space, to using eco-friendly materials wherever possible.

1.3 Constraints and Obstacles

Many constraints and obstacles come into play when working towards these goals. Implementing new technologies, especially ones that have not been on the market for long periods of time, can become expensive. America's healthcare system offers another constraint. Health insurance companies make upwards of a thousand dollars just for transporting a patient to the hospital. Would they be willing to pay for pre-hospital surgeries if they could make more money for in-hospital surgeries? Another concern arises in the surgery process itself – EMTs and Paramedics are not qualified to perform some types of surgeries. There is also the problem of maintaining a vehicle with high-risk medications, such as sedatives, that would be required in this surgical vehicle. The goal of this project is to create an Emergency Room vehicle, containing all the supplies and equipment required while staying sanitary, safe, energy efficient, and environmentally conscious.

1.4 Contents

In order to make this project a success, many aspects of surgery need to be researched.

Chapter two – Justification, Inspiration, and Types of Trauma – will contain literature background with respect to surgical and resuscitative tools, ambulance response time, specifications, and personnel along with any other information relevant to our project, including types of trauma as well as how to determine level of trauma.

Chapter three will contain engineering design sketches of the surgical ambulance, as well as SolidWorks drawings of redesigned surgical and resuscitative tools. The research from Chapter two will be applied in order to design all properties of the cabin – from interior storage to electronic and computer equipment used. The chapter includes list of qualified personnel required to work in this vehicle, and the tasks expected to be performed by them. In addition, a detailed list of all supplies and equipment will also be provided in this chapter. Research on what time-sensitive surgeries would be beneficial to implement in the pre-hospital environment will also be listed here. This chapter will also include background information on the necessary types of surgical tools and equipment for these surgeries. New biomedical devices, such as advances in surgical tools that make the ambulance workers job easier and safer, as well as new imaging technology is discussed in this chapter.

Chapter four, the final chapter of our report, contains conclusions drawn from research and analysis in chapters two and three. This chapter will sum up literature research, and explain how this project could be implemented into the modern medical field. Specific implications, constraints, and costs encountered while designing the surgical ambulance will also be discussed in this chapter. Recommendations will be made on how future students could improve upon and expand this project in further research.

Chapter 2: Justification, Inspiration, and Types of Trauma

2.1 Why would a RECAS unit be necessary?

2.1.1 Economical impacts of time sensitive Injuries

In the article *Global Trends in Trauma* author A. K. Leppaniemi complains that only recently have global trends for injuries increased in comparison to global trends in other areas, such as pollution, disease and malnutrition. There is a need for research in the effects of a war on injuries as well as during peacetime. The deterioration of resources coupled with population growth and a few other factors has led to a declining standard of living in most of mankind. With these issues combining with some countries failing or close to failure, trauma prevention and care will be a struggle unless the world as a whole will help in these weaker countries (Lappaniemi, 2004).

One of the main objectives of the RECAS unit would be to respond to incidents of trauma where time is sensitive in nature, and where death from injury is only preventable in light of a rapid response (serious head trauma, car accident, and gunshot/stab wounds). A study performed in 1990 showed that in that year alone, 10.1% of all deaths were from injuries. Road traffic accidents remain the 9th most common cause of death via injuries, self-inflicted injuries the 12th, violence the 17th and war injuries the 21st. It is predicted that by 2020, these rankings will change to 6th, 10th, 14th and 15th respectively. The annual incidence of assault with a gun in Finland was 9.1/100000, Sweden at 2.3/100000, and in 22/100000 in the US (Lappaniemi, 2004).

A study between three cities has also shown that, in patients with an Injury Severity Score of at least 9 or dead on arrival, mortality decreases with income, and mortality rates also decreases with lower mean arrival times. The objective of our unit is to provide care in congested cities where arrival time may be thwarted due to unforeseen circumstances, and to also provide care in rural areas where transport to a hospital is limited due to cost, distance, and the lack of a means of transportation.

Shifting to traffic accidents, the World Health Organization and World Bank claim that around 12 million people die every year on the roadways, which should increase to about 20 million within the next twenty years. Drunk driving, speeding, and not wearing a seatbelt are among the reasons that roadway injuries. In the United States, the cost of trauma is approximately 3.8 times the cost of Cancer, and 6.6 times the cost of cardiovascular diseases. “The reduction of death and disability from injuries would have a major economic benefit worldwide” (Leppaniemi 2004). In incidents that cannot be directly prevented, RECAS will respond in attempts to reduce the death and disability, if the injury itself cannot be prevented (i.e. construction accidents, household traumas, and, again, car accidents).

The WHO showed that, in 2000, more than 1.6 million people died due to violence. Roughly half of those deaths were suicides, a third from homicides, and a fifth were armed conflict. The rate of violent deaths is 32.1/100000 in low- to middle-income countries, whereas 14.4/100000 occurs in middle-income countries. 57000 children were killed as a result of child abuse that same year. A survey showed between 10 and 69% of women have been assaulted by an intimate male partner in their life. In response to the survey, Dr. Krug of WHO supported that “in some countries up to 5% of the GDP is spent on treating the effects of violence” and fought that violence is predictable, preventable and prevention plans should be implemented (Lappaniemi, 2004).

During the 1990’s there were fifty-seven armed conflicts in 45 different places, only 15 of which having more than 100 casualties. Those 15 were all intrastate conflicts over territory or government, and eleven of them directly affected the countries around them with refugees and weapons deals. The first and second world wars were highly dependent on industrial production capacity and were won by wearing down each other's populations with very high casualties. Now such wars are very low casualty and are much more dependent on technology, culture, politics, economics and diplomacy than just military, and often times involves drug lords or professional mercenary groups (Leppaniemi, 2004).

Terrorism, the author continues, is not a new thing, and, from 1980 to 1987, there were 3,856 different terrorist incidents, the majority of which were in Western Europe (37%) and the Middle East (26%) and consisting most commonly of explosions (35%) and assassinations (12%) (Leppaniemi, 2004). The 9/11 attacks on the US showed that terrorism can confuse even the most powerful country in the world and change the political climate very swiftly. Instant deaths seemed to correlate with the magnitude of explosion, building collapse and if it occurred indoors. In light of the event, a decade later, the RECAS unit would be dispatched, in addition to smaller scale incidents of multiple injuries (e.g. car accidents, gang shootings, etc.), to larger scale traumatic events such as these, in attempts to minimize resulting casualties. Recently a new scoring pattern has been realized for explosion injuries and awaits further development. Designated trauma facilities classified by level of trauma care in one system have proven effective in the US.

> *"The essential elements of regionalized trauma care include the classification of all hospitals in the region according to the level of trauma care they can provide, designation of tertiary (level I) trauma centres as the hospitals where patients with major trauma should be treated, establishment of emergency medical services that provide prehospital trauma care to trauma patients, implementation of triage protocols for the transport of trauma patients to the appropriate trauma hospitals, and centralized co-ordination of pre-hospital and in-hospital care (Sampalis et al.,*

1999)." (Leppaniemi, 2004)

The assumption in regionalization is that fewer, more specialized facilities aimed at trauma will prove more effective than spreading patients thin throughout all the medical facilities that exist. In addition to responding to trauma on scene, there is potential for the RECAS unit to respond to a non-trauma specified medical facility, as a means of eliminating transport, during which the patient is susceptible to re-arrest. A study in Seattle showed that trauma hospitals with more than 650 patients annually would have improved mortality rates and in-patient times (Leppaniemi, 2004).

A growing concern in North America is that the decreasing trauma volume as well as the increased frequency for non-operative management is going to lead to less experienced trauma surgeons in the future. One option would be to increase an individual trauma surgeon's responsibilities so they will get more operative experience. A second choice, as suggested in the reading, would be to "add emergency surgery to the trauma service," which is where RECAS hopes to expand trauma response (Leppaniemi, 2004). A Philadelphia study showed this was a valid method to get trauma surgeons more operating time. A few doctors in 2004 spoke about merging emergency general surgeons with emergency trauma surgeons. They felt this was a great idea because manifestations that imply emergency surgery are very similar between the two fields and a surgeon who knows both fields will obtain as much operative experience as they can handle, not to mention that with experience this surgeon could oversee most other specialists and consult in the design of future trauma/emergency surgical units.

While space is limited for trainees in the RECAS unit, a definite teaching possibility would be the inclusion of general trauma surgeons as ride-along team members for more specific training in trauma surgery. Conclusively, there is plenty of data being collected through unconventional means in order to show correlations in how trauma occurs in our world and how we can maximize efficiency to save lives. Similarly, the RECAS unit presents as a somewhat unconventional means of response to this trauma, a warrior medic unit in the civilian realm**.**

2.1.2 Critical events during prolonged transport of ambulance patients

In a study by Hartke, et al. in 2009, the incidence of re-arrest and critical events during prolonged transport of post-cardiac arrest patients was observed. They hypothesized that the transport of post-cardiac arrest patients by critical care transport team (CCTT) is feasible, and the duration of transport is not associated with adverse events (Hartke, et al., 2010).

To perform the study, the team retrospectively reviewed charts of cardiac arrest patients. They planned to determine the frequency of repeat cardiac arrest and critical events during transport. All patients were transported by CCTT between January 1, 2001 and May 31, 2009 to a single urban academic medical center that serves as a referral center for over four million people. Two authors in the study assessed CCTT charts for factors such as demographic information, critical events during transport – such as re-arrest, hypotension, and hypoxia – Glasgow Coma Score, transport time, and CCTT procedures. Hospitals record for post-cardiac arrest therapy techniques such as coronary angiography, percutaneous coronary intervention, therapeutic hypothermia usage, IABP usage, automated implantable cardioverter-defibrillator placement (AICD), hospital length of stay (LOS), and discharge disposition (Hartke, et al., 2010).

Re-arrest, in terms of this study, was defined as "a loss of loss of central pulses requiring cardiopulmonary resuscitation (CPR) and/or defibrillation at any time while the patient was under the flight crew's care." Critical events were defined as "hypotension, hypoxia, or both at any time while the patient was under the CCTT's care (Hartke, et al., 2010).

In this study, three hundred eighteen patients with a diagnosis of post cardiac arrest were identified in the CCTT database. Seventy patients were excluded because they had expired prior to transport, suffered traumatic cardiac arrest, arrested secondary to a surgical etiology, or had incomplete in-hospital data. The remaining 248 were analyzed, 153 (61%) of which were males, with a mean age of 58 +/- 17 years. Figure 1 shows a complete break down on patients included within the study (Hartke, et al., 2010).

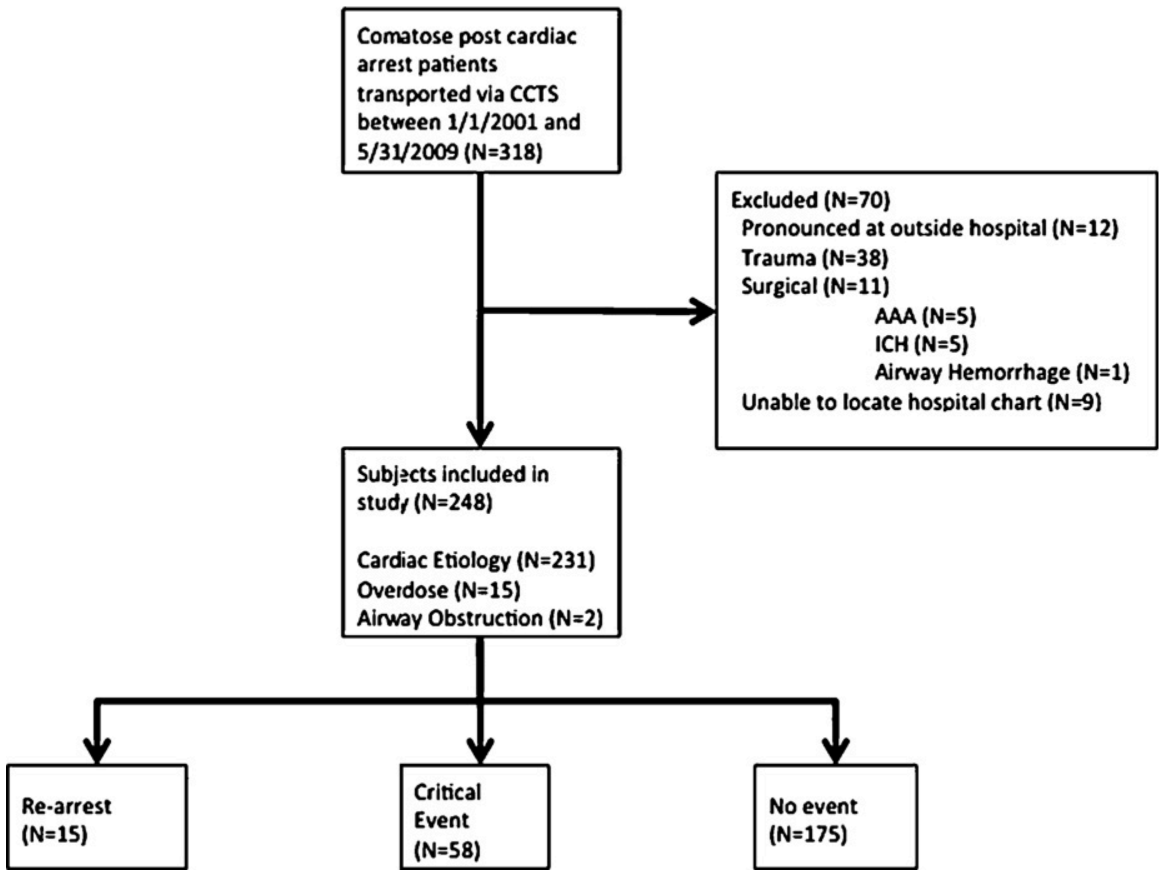

Figure 1: Charts reviewed for inclusion in study (Hartke et. al., 2010)

The median duration of patient care was sixty-three minutes, during which most patients required at least one continuous infusion during transport. Figure 2 shows the average time to re-arrest or critical event versus the percent of patients who experience each event. With an average time of transport of sixty-three minutes, you can see from Figure 2 that a significant number of patients will experience another incident during transport (Hartke et al., 2010)

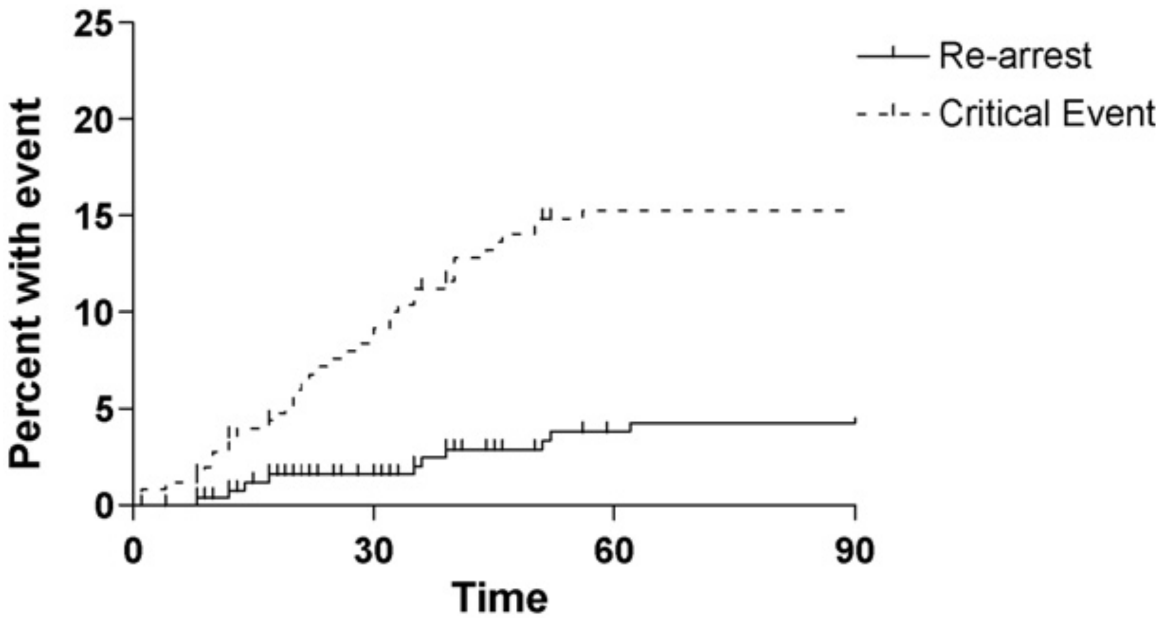

Figure 2: Time to re-arrest or critical event. (Hartke et. al, 2010)

As seen in Table 1, critical events were common, and they affected 58 (23%) of patients during transport. Most re-arrests and critical events were found to occur during the first hour of transport. 27% of critical events occurred at the referring facility prior to departure. Overall, 46% of patients survived. 29% had a "good" outcome. Survival and good neurologic outcomes were higher in patients who did not suffer any re-arrests or critical events even during transport and received care earlier. Also seen in Table 1, only 20% of patients who suffered re-arrest during transport survived, and only 13% was shown to have good neurologic outcome (Hartke, et al., 2010).

Table 1: Critical events, re-arrests, and outcomes during transport (Hartke et al, 2010)

	Occurred at referred facility	Survival	Good Outcome
No Event	-	92 (53%)	58 (33%)
Any Event	17 (23%)	21 (29%)	13 (18%)
Hypotension	11 (22%)	16 (32%)	10 (20%)
Hypoxemia	1 (14%)	2 (29%)	1 (14%)
Both	1 (100%)	0 (0%)	0 (0%)
Re-arrest	4 (27%)	3 (20%)	2 (13%)

In conclusion, 30% of patients necessitated more aggressive critical care during transport in order to prevent decomposition. With a pre-hospital transport vehicle such the one designed in this project, more effective treatment comparable to hospital care would be able to be applied sooner with the hope of decreasing the percentage of re-arrest and other pre-hospital complications.

2.1.3 The golden hour of trauma: a need for mobile surgery

The concept of the golden hour of trauma was created from the principle that severely injured patients have a better likelihood of survival with quick, appropriate resuscitation and treatment. The article "Mobile Surgical Transport Team" explains the development of a mobile surgical transport team (MSTT), with the concept of the golden hour of trauma in mind. Some trauma patients, even after given advanced life support treatment from paramedics, remain too unstable for transport to a nearby hospital for more treatment. Therefore, these patients who have potentially survivable injuries die without access to surgical resources. Implementing a MSTT can change patients' fates. Referring back to the golden hour concept, it highlights the significance of early resuscitation and treatment of trauma patients in reducing their mortality rate (Datena 1998).

At the publication of this article in 1998, trauma was the leading cause of death between the ages of one and 36. In the United States, about 160,000 people die from injuries each year; 50,000 of these are related to automobile accidents and 30,000 to ballistic weapons, mainly primarily handguns. The results from over 50 studies, taking place between the years 1988 to 1998, showed that approximately 19.3% of injury related deaths in hospitals were preventable. This means that about 32,000 lives each year could be saved with an improvement in medical care. The most common cause of the preventable deaths was a delay in or failure to perform emergency surgery (Datena 1998).

There are three types of trauma deaths: immediate, early, and late. Immediate trauma means that the patient dies instantly or within a few minutes of suffering the injury. They make up 50% of all trauma deaths, and there is essentially no hope to save these patients. Early trauma deaths constitute death with two or three hours of sustaining a trauma injury. They constitute about 30% of trauma deaths, and the ability to survive heavily depends on the quality of their initial assessment and resuscitation, and how quickly they can be transported to a hospital. Late deaths therefore occur after more than three hours since the time of a patient receiving the injury, and they make up 20% of all trauma deaths. These deaths are not as preventable as early deaths, but more appropriate initial surgical treatment and intensive care after surgery. As the result, the main goal of this MSTT is to prevent early and late trauma deaths. A MSTT team would use MICA or an airplane/helicopter depending on weather or distance. Personnel on this team communicate with the hospital that the patient would end up being transported to, giving them continual updates on the patients progress. The document so far mentions that the MSTT would consist of a surgeon, a nurse, and a certified RN anesthetist (Datena 1998). Instead of a mobile surgical team, our project creates a supplied ambulance for that team to work in.

2.1.4 Hospital overcrowding

When emergency departments of hospitals are overcrowded, they divert ambulances to other hospitals even if that hospital is the closest. The article, published in 2003 in the Evening Sun, states that emergency departments divert ambulances 20-50% of the time. When all hospitals in a given area bypass ambulances, the emergency medical services crew has the power to override this bypass. Hospitals diverting ambulances puts patients at danger because their injuries are typically time-sensitive and these patients require emergency care (Gale, 2006).

2.2 Mobile Intensive Care Units – A Basis for RECAS

2.2.1 Types of Mobile Intensive Care Units in Germany

"There are three kinds of road ambulances in Germany: The "mobile intensive care unit" or "Rettungswagen" (MICU or RTW) is designed and equipped for the transport, advanced treatment, and monitoring of emergency patients. The "patient transport ambulance" or "Krankentransportwagen" (PTA or KTW) is designed and equipped only for the transport of non-emergency patients (e.g. chronically and terminally ill patients) who are not expected to become emergency patients" (Backe, 2009). The third type of land ambulance that is part of the German EMS system is the Notarzteinsatzgahrseug (NEF), which is a station wagon or small van. There is no equivalent in America, currently, and it is most similar to what the RECAS vehicle hopes to be. NEF's purpose is to bring the emergency doctor to the scene of the emergency, when required. Below, in Figure 4, is the interior of a Notarzteinsatzgharseug.

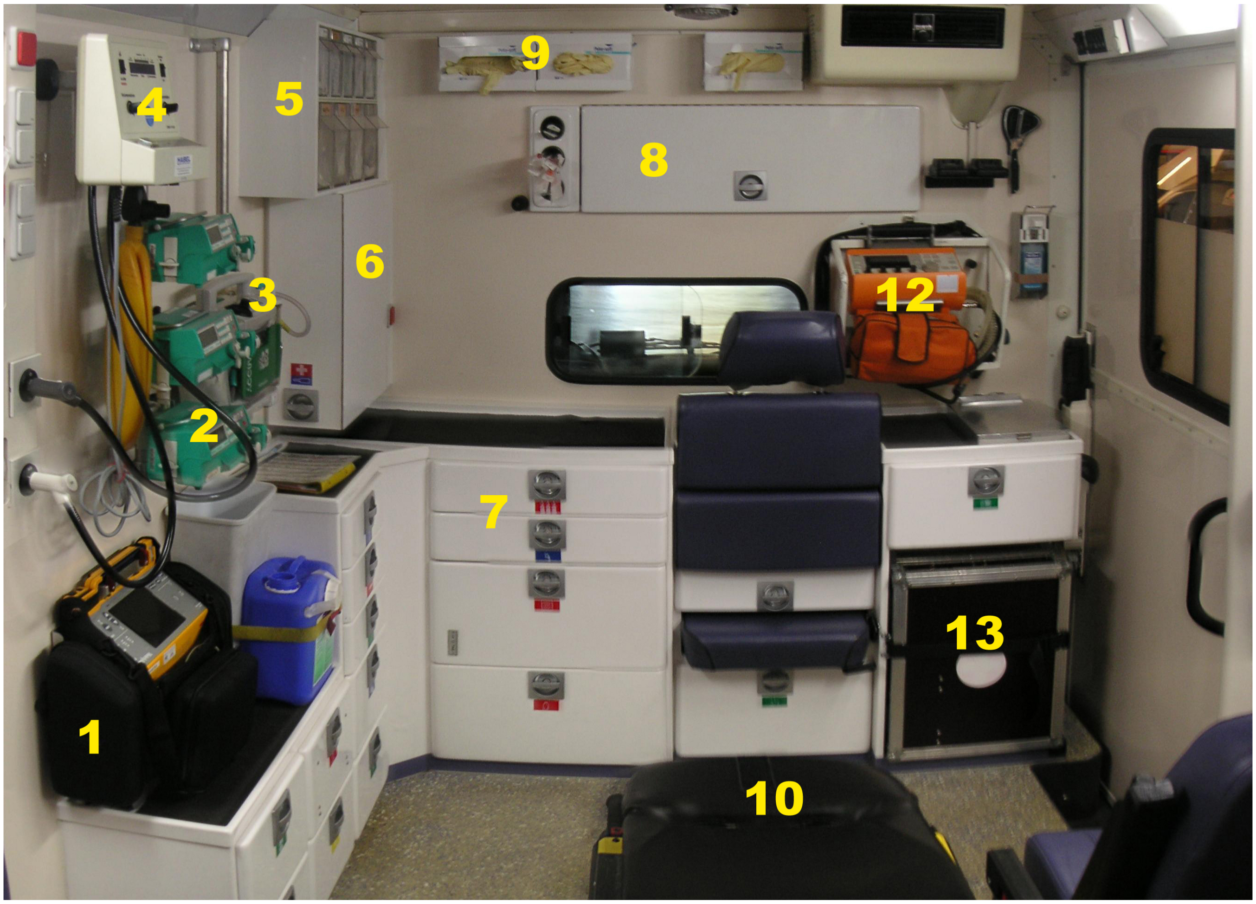

Figure 3: Interior cabin of the German Notarzteinsatzgharseug

Table 2 shows the inventory list of the Notarzteinsatzgharseug.

Number	Description
1	Defibrillator/Monitor
2	Syringe driver
3	Suction unit
4	High flow CPAP (used only for specific patients who are transported between hospitals)
5	Syringes and Needles
6	Drugs
7	Additional equipment, e.g. infusions, intubation equipment
8	Additional equipment, e.g. CPAP-Helmet, Immobilization equipment
9	Medical gloves
10	Stretcher
11	Not shown
12	Ozylog 3000 ventilator
13	Emergency suitcase and backpack

2.2.2 Mobile Intensive Care Units in the United States

A 1977 article in the Washington Post announced that two Mobile Intensive Care Ambulances (MICA) were put into serve in the District of Columbia towards the end of the year. There are the first implemented in this area. The units are linked by radio to a university medical center and a hospital. This allowed the paramedics to speak with doctors in those emergency rooms. They also had equipment to relay electrocardiograms to the hospital. These paramedics are allowed to administer certain drugs, in particular those given to heart attack patients. They are also allowed to administer electric shock treatment that can bring hearts back to their normal rhythm (Colen, 1977).

2.2.3 Additional Ambulance Equipment that could save lives

An article entitled “Heartfelt Call on Ambulance Equipment” published in the beginning of 2001 in an Australian newspaper explains the recent findings of the Heart Foundation. The Foundation claims that hundreds of Victorian lives could be saved if better equipment was put in local ambulances, specifically heart monitors and blood clot dissolving drugs. Unlike the United States, Australia uses MICA ambulances. The Foundation said that all of these types of ambulances should be equipped with 12-lead ECG machines. Studies show that the information provided by these devices can cut down patient treatment time. They also wanted paramedics to be able to administer thrombolysis to patients experiencing a heart attack because it not only reduced the risk of damaging the muscle, but saved patient’s lives. “The chief executive of the foundation's Victorian branch, Kathy Bell, said the treatment was relatively easy to administer and could be done by trained paramedics.” In 2008, Queensland ambulance service became the first to administer thrombolytic drugs in Australia. Within the first four months this initiative saved the lives of 20 heart attack patients," she said (Medew, 2011).

2.2.4 MICU: A hospital on wheels

An article in The Evening Sun calls the MICU a hospital on wheels, and it describes on implemented in Pennsylvania. Before, medic units transport personnel and equipment normally used in a hospital to the patient, and then basic ambulances transport, equipment, and personnel to the hospital. The MICU eliminates the need for two response vehicles. It is staffed with a paramedic and a registered nurse. By the MCU unit handling the more serious calls, the basic ambulance is freed up and can therefore handle a lot more calls. The article claims that having the MICU unit has significantly reduced patient waiting time for those who need transport to another medical facility; this oftentimes required the use of a helicopter (Gale, 2006???)

A newspaper article from 2006 in the Albany Times Union stated that a national study on the issue of emergency room overcrowding claims that on average, every minute an ambulance is diverted to a different hospital in the United States.

2.3 Trauma – What qualifies as a traumatic injury?

2.3.1 Measuring trauma: Glasgow Coma Scale (GCS) and Revised Trauma Scale (RTS)

Trauma as defined in *Trauma Operative Procedures* by L. A. Van Camp and H. Delooz is the "consequence of an external cause of injury that results in tissue damage or destruction produced by intentional or unintentional exposure to thermal, mechanical, electrical, or chemical energy, or by the absence of heat or oxygen" (Van Camp and Delooz, 1999). In responding to and treating trauma, time is obviously of the essence. Equally important, however, is the actual identification of type of trauma and severity. The sooner trauma is identified, the sooner it may be treated.

Injury, according to Van Camp and Delooz, is "currently responsible for 7% of world mortality" and constitutes, in the United States, the leading cause of death from childhood to late 30s (Van Camp and Delooz, 1999). Traumatic injuries "result in an important financial and productivity loss while inflicting a tremendous personal burden on the injured and their families" (Van Camp and Delooz, 1999). By creating a surgically operable ambulance, we sincerely hope to decrease the number of resulting deaths from such devastating injuries as well as trauma caused by cardiac arrest and stroke. Before we can do this, however, viable procedures that can be completed in our unit must be identified.

In identifying these procedures, it is important to not only understand various procedures and surgical tools, but to have an understanding or trauma scoring. Patients treated by the RECAS unit would be those who, as assessed and defined by trauma scores, are in extremely critical condition and require immediate surgical attention – cases where merely stabilizing vitals en route to a hospital is not enough to ensure a decent chance of survival.

Trauma scoring, in its current usage, serves 3 main purposes. First trauma scoring is used for triage, sometimes also utilized by paramedics (i.e. the Glasgow Coma Scale). Trauma scoring is also considered crucial in patient outcome evaluation, quality assessment, and resource allocation, and serves a purpose in trauma epidemiology, as it serves as a baseline from which to compare trauma cases (Van Camp and Delooz, 1999).

Injury or any other traumatic event, as earlier defined, will result in physiological changes to the body. These changes are reflected by changes in vitals and levels of consciousness. Two main classes of trauma scales exist. The first class of these is termed "physiological trauma scoring systems," which quantify these changes (Van Camp and Delooz, 1999). These scoring scales are later coupled with anatomical scores, more specifically oriented towards identifying site and type of injury. For example, the Abbreviated Injury Score (AIS) assesses trauma on a scale of 1 through 6 (1 being minor, 6 currently untreatable) in nine different body regions. The Injury Severity Score (ISS), along with other injury scoring systems, serve as adaptations of AIS; for instance, the ISS gives a score of 75 for any injury of magnitude 6, as determined by the AIS (Van Camp and Delooz, 1999; Cornwell et al., 1998).

The best scales, however, according to Van Camp and Delooz, are "based on a limited number of valid parameters that are easy to measure" (Van Camp and Delooz, 1999). In our case, more concise scales are preferred, so long as accuracy is not compromised. Our prior concern, however, would be assessing if transport is an option. Besides in the obvious instances, such as a massive accident (automotive, train, or otherwise) or instance of fire/assault, our primary concern in using such scales is identifying severity and the need to operate on scene. In the specified instances, it is presumed that the majority of patients would treated on scene automatically (so long as the perimeter is considered secure) to avoid time spent travelling back and forth between the scene and the hospital.

According to multiple sources, the primary method of measuring level of consciousness and neurological stability is the Glasgow Coma Scale (GCS). Its measurable factors are considered reasonably reputable as far as observer reliability and its predictive use are concerned (Van Camp and Delooz, 1999). Meaning, the measurements are considered to be relatively simple and can reasonably be measured by an observer, such as a paramedic. The GCS assigns a score of 1 through 5 in the categories of Eye Response, Verbal Response, and Motor Response, totaling a score between 3 and 15 (Van Camp and Delooz, 1999).

Eye Response		
Spontaneous	4	Spontaneous
To voice/speech	3	To speech
To pain	2	To pain
None	1	None

Verbal Response		
Oriented	5	Cooing/babbling
Confused	4	Irritable cyring
Inappropriate	3	Crying in response to pain
Incomprehensible	2	Moans in response to pain
None	1	None

Motor Response		
Obeys command	6	Spontaneous/purposeful movement
Localization of pain	5	Withdraws to touch
Response to pain (withdrawl)	4	Response to pain (withdrawl)
Flexion (decorticate posturing)	3	Abnormal flexion
Extension (decerebrate)	2	Abnormal extension
None	1	None

Figure 4: Glasgow Coma Scale, the Three Paramaters

While it is understandable that a patient would not want a paramedic performing brain surgery on them on site (since neurosurgeons are specifically trained), the GCS is crucial for identifying cranial trauma and a lower score on the GCS could be the deciding factor to perform the surgery on site for better chance of survival. Typically, the longer the brain is under pressure, or without oxygen, the lower the chance for returning to full capacity and, in some cases, the lower the chance of survival outside a vegetative state. A low score on the GCS is often indicative of neurotrauma; however, it does not always indicate a neurotrauma that needs to be addressed only by a neurosurgeon (see previous definition of trauma). Other traumas can create an internal environment deprived of oxygen in the brain; in these cases, the GCS would indicate more the severity of the condition was in. In the case of an aneurism or direct trauma, however, new tools have made treatment of direct brain hemorrhaging minimally invasive, such as the Guggenheim coil. In a dire situation, these advances constitute treatment by an on-call general surgeon or medical officer as a more feasible option.

In assessing general trauma, the original Trauma Score was developed as an adaptation of the Triage Index. The Triage Index measured those mechanisms included by the GCS, as well as Capillary Refill and Respiratory Expansion; the adaptation of this included Respiratory Rate and Systolic Blood Pressure. The Trauma Score was later revised to eliminate Respiratory Expansion and Capillary Refill as these mechanisms were considered too difficult and unreliable to observe and measure externally. Currently the most commonly used trauma scoring system, the Revised Trauma Score, therefore, measures only Respiratory Rate, Systolic Blood Pressure, and the mechanisms observed by the Glasgow Coma Scale (Van Camp and Delooz, 1999).

“RTS = (0.9368 * GCG) +

(0.7326 * systolic blood pressure on admission) +

(0.2908 * respiratory rate on admission)"

(Cornwell et al., 1998)

2.3.2 Cardiac Trauma

In the article *Cardiac Trauma*, Asensio presents and describes a variety of general classifications for penetrating cardiac injuries, or injuries that physically intrude the heart. In evaluating an incoming patient, factors that contribute to matters of life or death include how soon a patient arrives at a trauma center, a patient's mental state, whether intrusions were made by gunshot, the amount of blood that a patient has lost, and whether cardiac arrest has occurred. The article demonstrates that a penetrating cardiac injury may be fatal to a patient in association to the consequences of pericardial tamponade, during which an intrusion to the heart causes bleeding into the Pericardium – a sac enveloping the heart. The Pericardium may not be able to accommodate such an event if bleeding occurs too fast because its expansion will not occur quick enough, and pressure inside the sac will rise. As a result, the right ventricle will be compressed, and its filling will be decreased. This lowers the left ventricle's ejection and filling as well, and thus, the heart's overall output will be lowered. Upon reception of a patient suffering a penetrating cardiac injury, the importance in assessing such an individual's potential for Pericardial Tamponade may be argued to be greater than assessing that patient's vitals in attempting to determine their survival, and authors provide some studies in this article that may support this argument (Asensio, G, P, W, V, & A, 2001).

In this article, techniques utilized by physicians in countering Pericardial Tamponade in a patient suffering a penetration to the heart are discussed. The original technique presented is to open the chest just below the sternum, and to create an incision into the Pericardium through which a tube would be inserted so that excess blood flow could exit the sac. A second technique described is for physicians to use an ultrasound to image the heart – a technique that is very convenient in determining whether or not there may be a problem, being that it is a non-invasive procedure, requiring no anesthesia. Setbacks to this procedure, however, are that it is not sensitive or specific to the event in which patients experience haemopneumothorax, or a puncture in the chest wall that will allow air or blood into the chest cavity. Emergency Department Thoracotomy is another technique described during which, to provide access the heart, an incision is made between the ribs, and the ribs are wedged apart. This procedure is challenging, and is mostly used for very specific injuries, for instance: blunt trauma leading to cardiac arrest or when a patient seems terminal (Asensio, G, P, W, V, & A, 2001).

There are several techniques that are all involved in operating on a penetrating pericardial wound. Incisions of choice are basically dependent on the few areas of the body that a doctor can cut open to properly reach the organ that is in need of care. Examples of such forms of incisions include Median Sternotomy, described as an incision just below the sternum that is followed by a cracking of the sternum that will allow access to the heart and lungs. A Left Anterolateral Thoracotomy is an incision that is made between the left ribs. It's a procedure requiring a rib spreader in order to access the heart, and this technique is used more specifically for patients arriving at near death, are haemodynamically unstable, require mechanical or pharmacological support to maintain a normal blood pressure, and whose injuries have reached the mediastinum (Asensio, G, P, W, V, & A, 2001).

The article further elaborates that techniques of cross-clamping vena cavae may be used to empty the heart and stop hemorrhaging. Although, the authors note that the procedure is only mentioned historically, usually results in cardiac arrest, is a difficult state to salvage in an individual after three minutes. Clamping of the pulmonary hilum is referred to as a valuable maneuver in stopping a hemorrhage. However, it increases afterload on the right ventricle of the heart, and requires declamping in order to prevent too much afterload – during which the heart is backed up and must work harder to catch up. Clamping the pulmonary hilum will stop hemorrhaging in the lung in order to prevent air from entering the bloodstream, but it should not be performed on patients with acidosis or ischaemia. This often causes fibrillation or arrest (Asensio, G, P, W, V, & A, 2001).

In general, atrial wounds should be treated with a partial occlusion clamping. A surgeon must work fast to repair the atria using a monofilament suture. Depending on how long it takes, unclamping may be necessary. In this article, it is mentioned that the walls of the atria are very thin, and they require delicacy to prevent further tearing. Repairing ventricular wounds is very similar, although gunshot wounds may highly complicate this task as a large amount of bleeding will occur and several sets of stitches will be needed just to control the accumulation of blood, let alone repair the walls. Since the heart continues to work after being injured, its contractions may sometimes cause further damage to the tissue. As a result of a bullet's ballistics and velocity, torque and compression deforms the heart slightly, further complicating the wound and their repair. Teflon bioprosthetic material can be used to close up the stitched portions of the ventricles (Asensio, G, P, W, V, & A, 2001).

Coronary artery injuries need to be monitored closely while putting in stitches because they are very easy to block off or squeeze when operating on the heart. Also, such injuries occasionally require cardiopulmonary bypass in order to be operated on when procedural proximity is high. Ligations are only performed on these arteries during final attempts made to save patients due to ligations on coronary arteries typically causing the heart to stop. Asensio continues in explaining that, although all of these types of injuries are very complex on their own, patients typically come in with more than one and they are prioritized by greatest to least blood loss (Asensio, G, P, W, V, & A, 2001).

Asensio lastly organizes information regarding cases of patients with multiple penetrating cardiac injuries. There are few cases that are observed and reported by each institution that offers such information, and most of these institutions treat "fewer than 15 such cases annually" (Asensio, G, P, W, V, & A, 2001). The author mentions that these institutions also decline to draw conclusions on their data. In addition, these cases are very complicated; there is no standardized method for dealing with these cases in a chronological order. Additionally, very few patients survive long enough to make it to the hospital. It is mentioned that many of the essential results that are reported and could offer useful information for study may reveal a bias to findings or outcomes in patients with much less severe conditions, not including all cases of penetrating cardiac injury. For instance, Asensio mentions that data that indicates the performance an Emergency Department Thoracotomy (EDT), mentioned earlier as the method in which a through-the-ribs incision is chosen, is shown to be missing from most pre-hospital data series.

Asensio argues that heart injuries can be more accurately determined with a cardiovascular respiratory score (CVRS), claiming that doing so may lead to greater predictability of mortality. Asensio provides support for this claim by presenting case studies, many of which he himself has undergone, and in doing so, attempts to demonstrate that CVRS ratings may reveal a correlating relationship to a mortality rate in penetrating cardiac injuries. Findings mentioned in this article are such that CVRS ratings predicted 96% of mortalities with a CVRS score of 0, 67% of mortality in patients with a CVRS score between 1 and 3, and 25% mortality in patients with a CVRS of 4+. Some of the data from one of Asensio's studies in 1998 includes mortality rates for the following injuries: Right atrial injuries at 62.5%; Left atrial injuries at 80%; Right ventricular injuries at 48.7%; Left ventricular injuries at 76.9% (Asensio, G, P, W, V, & A, 2001).

2.3.3 Thoracic Trauma

In the article *Thoracic Trauma*, author Gopinath explains the general event of throacic injuries. This form of trauma constitutes roughly 10% of all trauma cases, and it is sometimes associated with an orthopedic or head injury. Thoracic trauma is caused by either blunt trauma, a stab wound, or a gunshot wound. For communal disturbances, stab and gunshot wounds are most associated with outcomes of thoracic trauma. In urban settings these outcomes are associated with traffic and construction injuries that result in blunt trauma. Some of these injuries result in instant fatalities and in many cases no more than first aid is available before the patient expires. For this reason most facilities are ill prepared to aid patients suffering from these injuries. Patients must be brought to trauma care centers, which the author notes, are never very close to a highway. When left without proper care, patient health will diminish initially from respiratory dysfunction and secondarily from cardiac dysfunction. Patients sometimes develop adult respiratory distress syndrome, which is not normally recognized early if trauma occurs in a non-chest injury. In general, treatment for this injury involves restoring respiratory function, controlling bleeding and attempting to prevent sepsis. Many deaths are caused by airway obstruction, Hemothorax or Pneumothorax, and Hemopneumothorax is a life-saving surgery for these patients (Gopinath, 2004).

The author continues with more information about blunt trauma. He discusses that blunt trauma occurs more often in men than women because higher rates of men are involved in careers fields of construction and other dangerous jobs. However, the percent of women in these careers is increasing. Morbidity and mortality rates for blunt trauma are high when taking into account events in which groups of people are affected, such as a collapsed coal-mine. The second major cause of blunt trauma is assault, occurring mostly in individuals between ages 20 to 50. Automobile accidents are the third leading cause of instances of blunt trauma. In the field of thoracic trauma, 75-80% of trauma cases are consequences of blunt trauma and 50% of patients show injuries to other organs as well. The author states that enmity and murder attempts typically cause penetrating injuries and victims sometimes do not receive the care that they need out of fear of their attackers. Against thoracic trauma in general, cellphones may allow victims access to the help they need and some public vehicles carry first aid kits on them. In some cases, the public does not want to help due to the threat of being sued for worsening a patient's condition (Gopinath, 2004).

In managing a patient, they should be positioned face-down if they are spitting up blood, and individuals assisting such patients should attempt to get a victim’s identification from a wallet or purse: they may have a condition that paramedics will need to know about. The author also mentions that, when dealing with these patients, it will be important to splint any limbs where there are fractures and cover any wounds with sterile dressing (Gopinath, 2004). Once a patient has EMT support, medical professionals can speculate at a diagnosis and assess a patient’s overall condition. By taking blood pressure in both arms and comparing them, professionals can determine whether or not there is an injury to the aorta. If a patient's breathing is lessened or absent, they are likely suffering from a lung injury – hemothorax or pneumothorax. Intestinal injuries can be excluded if bowel sounds are present, and splenic injuries are present when there is bruising to the upper abdomen. The condition of a patient’s central nervous system can be assessed by examining the injury site, checking for bleeding from the ears, checking for unequal pupils, assessing consciousness, or by noting if there is any inability to move limbs. The spine should be checked for any injury, and swelling of the abdomen will require a Ryle's tube. A chest x-ray will show any fractured ribs, pneumothorax or hemothorax. The air level in the subdiaphragmatic area can indicate rupture of stomach or bowel, and it requires immediate surgery. It is suggested to start intravenous fluid therapy and to insert an intercostal drainage tube in case of pneumothorax or hemothorax. Monitoring blood loss twice every hour is also suggested, as is the transfusion of enough blood to cover the loss. Depending on how much blood loss per hour, a course of action can be formed for a patient. If hemoptysis leads to flooding of lungs consistently, ventilator support will be needed (Gopinath, 2004).

Flail chest is a condition in which parts of the chest move paradoxically as a result of broken ribs. It can be diagnosed when the patient shows signs of the following: 4+ anterior or posterior body fractures; bilateral anterior rib fractures; sternal and rib fractures; 7+ anterolateral rib fractures; or 4 to 5 costochondral rib fractures. Flail chest can cause paradoxical movement, hypotension, retained secretions, Atelectasis, or a mediastinal flutter and management includes strapping or sand bag support, external fixation with towel clips, pulley and traction, internal fixation with wires and plates, and positive pressure ventilation. In all chest injuries, general measures include: analgesics and antibiotics; an oxygen mask (or manual ventilation); appropriate intercostal drainage tubes; arterial blood gas measurements; intercostal block or epidural block; chest physiotherapy; repeated bronchoscopic suction; and mini tracheostomy. A patient will require ventilator support if they enter shock, develop tachypnoea, Cyanosis, if they have a PAO2 pressure below 60mm Hg or a PCO2 pressure above 50mm Hg. A patient will also require a ventilator upon experiences of lung contusion, hemo or pneumothorax, flail chest, falling blood pressure, increased pulse rate, low PO2 or rising PCO2, and during such cases, manual ventilation has some benefits (Gopinath, 2004).

Morbidity in patients is shown to be between 20 and 80 percent, mostly due to an associated injury, and depends on factors that include the severity of the injury, the condition of the lungs, any head injury, associated abdominal injury, and any long bone fractures or fat embolism. If the only injury is present in the chest, a patient should then be checked for cardiac tamponade, injury to great vessels, or an injury to the bronchi or oesophagus. If the patient is on a ventilator for an extended period of time, they may develop infection, bed sores, or deep vein thrombosis; baro trauma, or persistent pneumothorax; ventilator dependency and the need for tracheostomy; tracheal stenosis; or rare complications which include Tracheo innomolate or Tracheo oesophageal fistula. Several indicators of Cardiac Tamponade include low blood pressure, increasing pulse, muffled heart sound, or an x-ray showing an enlarged cardiac shadow. At least half of penetrating chest injuries will include hemo/hemopneumo/pneumothorax and the lungs. If an injury is close to the heart, surgical intervention is required as well as the removal of clotted blood from the pleural cavity or a clotted hemothorax and epyema. Emergency surgery indicators include an initial loss of >1500 ml blood, a continuous bleed of 200 ml/hr for 4 hours, a suspected tracheo bronchial tear or a suspected great vessel or oesophageal injury. The author concludes that chest injuries are common, and that upon witnessing an individual experiencing such an injury, bystanders must efficiently and promptly communicate for an ambulance as well as attempt to manage the wound with a first aid kit.

2.3.4 Vascular Trauma

The article *Vascular Trauma* discusses and explores the mechanisms, diagnosis, and treatment procedures involving Vascular Injury, and it can be summarized in the following paragraphs. The article begins by defining terminology associated with the various ways in which a patient may obtain a vascular injury. Following these definitions, methods for diagnosing vascular injuries are explored and the concluding portions of this article reflect upon procedural instructions for treating incoming patients with vascular injuries and for treating circumstantial consequences that result in vascular trauma.

A blunt injury, such as being hit by a car, is described as an injury that will disrupt veins locally and will irritate or hinder performance in the immediate vicinity of veins as well. Penetrating injuries can be caused by stab wounds or by gunshot wounds, and they either cause partial or complete vessel severs in the event that the foreign object is removed. Iatrogenic injuries are general blood vessel damage caused during surgery or other procedures, some of which are intentional. There are several different ways in which the arteries and blood vessels may be damaged. The most common injury is vessel disruption, in which a blood vessel is partially or completely severed, either causing ischemia as well as false aneurysms as a partial, or causing hemorrhage that decreases with clotting or a spasm. The second most common injury is an intimal injury, which may cause thrombosis or may develop into an intimal flap, and then into distal ischemia. Intimal flaps may also cause a dissection that slowly grows and will become apparent after some time. If a vessel and the vein to which it is attached are both injured, an arteriovenous fistula formation may occur. Lastly, there are arterial spasms, and the article only mentions that they are "rare and should not be considered as the cause of limb ischemia after trauma" (Davenport, Tai, & Walsh, 2009).

There are two major ways to diagnose vascular injuries. In Clinical diagnosis, the evaluation may be broken down into hard signs, requiring attention right away, and soft signs, which are symptoms that suggest the possibility of a vascular injury but that require further investigating. It is mentioned that 1 in 5 injuries within close proximity to a penetrating injury are occult, or not apparent in imaging or symptom diagnosis. There are three branches of imaging diagnosis. The first, Duplex ultrasonography, is 90% accurate, non-invasive, and will "detect arterial disruption, thrombosis, false aneurysms and arteriovenous fistulas" (Davenport, Tai, & Walsh, 2009). Second, Contrast-enhanced CT, may be utilized with hemodynamically stable patients and is the preferred method for evaluating thoracic aortic injuries and the other large vessels. Third, Digital subtraction angiography, is the final method explained in this article, which is described as being used for actively bleeding injuries as long as the bleeding is controlled (Davenport, Tai, & Walsh, 2009).

The authors mention numerous methods that may be used to manage cardiac injuries. The first method described is to monitor breathing before circulation. Hemorrhage control, performed by putting pressure on the wound, is important in all vascular injuries, and surgery would be required if the bleeding is not controlled. In most cases, tourniquets have proven effective in reducing blood flow to wounds in limbs of the body. The authors notes that survival improves with manufactured devices both in pre-hospital environments and before going into shock, and mentions that Nerve Palsy complication occurs around 1-2% of the time. The authors continue this portion of the article by noting that these are military statistics and that environments for the general public are much different, so these statistics should correlate but not be identical (Davenport, Tai, & Walsh, 2009).

In repairing arterial and venous injuries, the authors describe that there are ten methods and a general preparation that must be taken into account. The preparation includes repairing any fractures, clamping the aorta and exposing a healthy portion of the vein at each side of the wound. The vessel is then cleaned and trimmed, intimal flaps are stitched, on-table angiography is performed and "intra-arterial heparin is injected to prevent further thrombosis" (Davenport, Tai, & Walsh, 2009). A Lateral Suture is stitching to close wounds and used for medium and large vessels, as well as transverse lacerations in other arteries. If a vessel will likely narrow as a result of these stitches, a patch angioplasty is used, or a patch made from nearby tissue. An end-to-end anastomosis will repair two ends of severed artery with sutures, and the authors recommended oblique vessel-tip cuts and interrupted sutures to prevent stenosis (narrowing) and purse stringing (pull-tight results in vein collapse). An interposition graft is the method of creating extra vein in the event that the trimmed veins do not reach comfortably, and the solutions offered in this article include the use of a piece of the saphenous vein due to its size and durability, or otherwise using ePTFE (polymer) prosthetic grafts due to their resistance to infection (Davenport, Tai, & Walsh, 2009).

Bypass procedures are used when a major ligation of arteries occurs, and they are used in circumstances of complex injuries. Moderately contaminated wounds and major soft tissue loss will require a bypass in order to graft new arteries while avoiding infection and maintaining circulation, but is quite specific to the arteries in question. Endovascular treatment involves putting a covered stent into an open artery to support it, and is important for preventing the need of cardiac bypass in the case of an aorta repair. It is less invasive, faster, involves less bleeding and the procedure requires less anesthesia, however, the drawbacks of this method include the risk of infection, malpositioning, embolization, endoleak, proper staffing for 24 hours, and it is mentioned that there is a lack of trial data on the procedure. Damage Control Surgery is performed by use of shunting, ligation and packing, and is utilized to allow more time for investigation before surgery on patients with multiple injuries. Shunting both venous and arterial injuries will allow blood to flow to the limbs in the event of a vascular injury, and it can be done with various tubes found throughout a hospital temporarily if a commercial shunt is not available. Ligation (or closing) of specific arteries will be beneficial in some emergencies, causing limb ischemia and requiring fasciotomies, but saving the patient's life. Packing can be used to control venous bleeds, and is particularly useful for pelvic and retro-hepatic inferior vena cava injuries (Davenport, Tai, & Walsh, 2009).

The article concludes with demonstrations of vascular injury complications, and it reports some statistical data. Most of the following complications described are caused by delay of surgery and general repair. A False aneurysm is a hole that allows blood to exit an artery, but also allows blood to be contained within the artery by surrounding tissue. It is a complication that will follow penetrating and iatrogenic injuries. This complication can be repaired by injecting thrombin into the lumen, or ultrasound-guided pressure, and such an event will require surgery if repair is unsuccessful. Arteriovenous fistulas, described as abnormal connections of arteries and veins, are found in penetrating injuries and are fixed with simple surgical disconnection. Compartment syndrome, or pressure in a muscle compartment rising above 30mm Hg (30 millimeters of mercury in a manometer) due to reperfusion (reintroduction of blood to an ischemic area), commonly occurs in patients who have had prolonged periods of hypotension, arterial occlusion, combined arterial and venous injuries, a ligated vein, or a severe crush injury. This is counter-acted by performing a fasciotomy, where the fascial envelope of a particular muscle is opened, along with the skin, in order to allow pressure dissipation. The last complication is Amputation, during which an entire ischemic limb is severed, and such a procedure is necessary when the existence of irreversible ischemia damage occurs as a result of the delay of resuscitation and injury recognition. The three most commonly injured veins are mentioned, those being the superficial femoral at 42%, the popliteal at 23% and the common femoral at 14% (Davenport, Tai, & Walsh, 2009).

2.3.5 Hepatic Trauma

The article *Hepatic Trauma* explores the general case of trauma to the liver. Since the liver comprises of 5% of all trauma cases, it is of particular interest to the RECAS project. The liver is often involved in penetrating trauma due to its size. In the early 1900's, mortality rates for liver injuries were around 40%. Early laparotomy became utilized as a result of World War II, and hepatic resection during the Vietnam War. Not until the early 90's was a new technique developed for managing liver injuries. Surgeons found that there was a need for a technique that did not involve a laparotomy, especially when the patient is hemodynamically stable or DPL (Diagnostic Peritoneal Lavage) was negative, since laparotomy is very invasive and older patients have an increased risk of mortality. Surgeons also found that non-bleeding venous injuries, when operated on, would begin hemorrhaging rapidly, and they sought for an answer to whether or not the vein would heal without operation (Clay C. Cothren, 2008).

Clinics will suspect a hepatic injury following blunt or penetrating trauma depending on the patient's vital signs. Hepatic veins and the pernchyma are the most commonly injured structures around the liver following blunt trauma. Stab wounds and gunshot wounds often penetrate the liver due to its size and location in the abdomen. Immediately after entering the hospital, the patient will undergo a FAST (Focused Abdominal Sonography for Trauma) exam, and, if the patient is haemodynamically instable or if intraabdominal bleeding is shown in the exam, the patient will immediately undergo a laparotomy. If the weapon is still in place, in the case of a stab wound, it should be left in and removed slowly to fix lacerated blood vessels along the way out during the laparotomy. If the patient is haemodynamically stable, further imaging and investigation is recommended (Clay C. Cothren, 2008).

FAST has replaced DPL due to portability, speed, repeatability in the same patient and noninvasiveness. FAST can take three views of the body and show any intraabdominal fluid, which is assumed to be internal bleeding unless the patient has liver disease with ascites. FAST will reliably display intraperitoneal fluid when at least 400 ml is present, although it is not reliable at imaging the source of the bleeding. Anytime FAST reveals intraabdominal fluid, the patient should then have CT scanning. Multiple CT scans over time are important to see if the injury is worsening and, since FAST is not 100% sensitive, sometimes DPA (Diagnostic Peritoneal Aspiration) is allowed to eliminate abdominal hemorrhage as the cause. In low blood-pressure patients, the trip from ED to Radiology for CT scans is risky because the patient may suddenly become critical with nothing to measure vitals: the surgeon must accompany the patient to Radiology and be prepared to abort to the OR if the patient goes critical. Recently CT scans have become available within the ED, and this problem is fading. CT Scanning is ideal in haemodynamically stable patients because nonoperative management may be possible and laparotomy can cause hemorrhage (Clay C. Cothren, 2008).

Other indications for delaying laparotomy for CT scanning include persistent abdominal tenderness, significant abdominal wall trauma, distracting injuries, and altered mental status. Imaging may also allow nonoperative observation in patients with a penetrating injury to the right upper quadrant. If the CT scan reveals the penetrating trauma is confined to the liver, nonoperative observation is considered. The AAST (American Association for Surgery Trauma) has defined a grading scale for liver injuries, in terms of the surface area of the CT scan, which is swollen and filled with blood, and also in terms of the laceration length. It will allow treating physicians to easily transfer information on the injury, and help define failure and complication rates. Other important findindgs to note on CT scan are contrast extravasation, the amount of intraabdominal hemorrhage, and the presence of pseudoaneurysms; associated enteric injuries that would imply laparotomy should be excluded (Clay C. Cothren, 2008).

Unless a patient has overt peritonitis or other indicators for laparotomy, nonoperative management should be used. The author feels that nonoperative management should not be disregarded if the patient has a high-grade injury, large amounts of haemoperitoneum, contrast extravasation, or pseudoaneurysms, although they are at high risk for failure and will likely need angioembolization, or minimally-invasive occlusion of hemorrhaging blood vessels. There is no age cut-off for nonoperative management, and is suggested for older patients. By including angiography and angioembolization, nonoperative failure rates have decreased and survival has improved. Any patient with a grade III+ injury should stay in the SICU (Surgical Intensive Care Unit) with monitoring of haemodynamics, abdominal examination, and hemoglobin. For angioembolization, to address ongoing hepatic bleeding, transfuse 4 units of RBC (red blood cells) in 6 hours or 6 units in 24 hours. If haemodynamic instability is recurring, laparotomy is often required, along with perihepatic packing for hemostasis, or the stopping of blood flow. Patients will fail nonoperative management within 24 to 48 hours if laparotomy is required (Clay C. Cothren, 2008).

The author mentions that select patients with penetrating injuries to the right upper quadrant may be candidates for nonoperative management, although it is not universally embraced. As long as CT scans show the injury is confined to the liver, the patient is haemodynamically stable, has a reliable physical examination without evidence of peritonitis or mentally diagnosed depression, and will not require blood products, that patient will qualify. They should be admitted for serial examination and hemoglobin monitoring, any alteration of which shall prompt a laparotomy. Otherwise, laparascopy can confirm trajectory to the wound is only in the liver, or a procedure allowing a fiber-optic instrument through the abdominal wall to view the organ in question. Nonoperative management can be utilized in over 80% of cases. Angiography along with ERCP (or Endoscopic retrograde cholangiopancreatography) has created a nonoperative procedure with further decreased failure rates and improved survival. An earlier study from 1995 showed an overall success of 85% despite heavy hemoperitoneum on CT scans. Other studies have shown grade IV injuries having a 14% failure rate and grade V injuries having a 23% failure rate, while finding a correlation between the amount of hemoperitoneum and risk of failure, failure being defined as requiring operation. Some centers on nonoperative management have reported success in penetrating hepatic trauma, including victims of both stab wounds and gunshot wounds. While avoiding the demanding recovery from laparotomy, it has lowered hospital stays, transfusion requrements, and abdominal infection rates. Patients who require Follow-up Imaging do not show many symptoms, and patients with a grade IV+ injury are at high risk of complication (Clay C. Cothren, 2008).

One operative technique for hepatic trauma is Exposure, by way of laparotomy. A decent sized midline incision is created, and abdominal wall bleeding should be ignored until the sources of hemorrhage are controlled. Liquid and clotted blood is evacuated with laparotomy pads, and suction is used to identify the source of the bleeding. Mobilizing the right lobe of the liver is then accomplished by dividing the right triangular and coronary ligaments, and mobilizing the left lobe is done in a similar fashion. Occasionally it is necessary to extend the incision further up into the chest by way of medium sternotomy. Great care must be taken to avoid injuring the phrenic nerves, hepatic veins, and retrohepatic vena cava. The other major operative technique involved in hepatic trauma is Control of Hemorrhage. Right away manual compression and perihepatic packing will constrict bleeding, the drawback being that the liver cannot be operated on while being compressed in this way. This is more effective for the right lobe, as opposed to the left lobe, of which there is insufficient abdominal and thoracic wall anterior to provide adequate compression with the abdomen open. Fortunately, the author says, the left lobe may be mobilized and compressed within the surgeon's hands. If hemorrhaging continues persistently despite packing, injuries to the hepatic artery, portal vein, and retrohepatic vena cava should be considered (Clay C. Cothren, 2008).

The Pringle maneuver is used to try to slow hemorrhaging and provide temporary control by occluding the portal triad using a vascular clamp. Although some cases have been fine after sixty minutes, ideally this will be applied for less than a half an hour. An injury to the portal triad vasculature will cause massive hemorrhage, and it must be addressed immediately to minimize hepatic reperfusion injury. If hemorrhaging occurs behind the liver while the Pringle Maneuver is in place, it is likely an injury to the major hepatic vein or retrohepatic vena cava. If bleeding is controlled, the packing should be left undisturbed, and the patient observed in the SICU. Otherwise, attempt a direct repair with or without hepatic vascular isolation. This can be done by: isolating via clamping the diaphragmatic aorta, suprarenal vena cava and suprahepatic vena cava; the atriocaval shunt; the Moore-Pilcher balloon shunt: All of these are performed in addition to the Pringle Maneuver. Unfortunately, mortality is above 80% even in well-prepared centers. In general, these procedures are avoided due to that mortality rate. If reasonable hemostasis can be achieved despite the venous hemorrhage behind the liver with perihepatic packing, the patient can be transferred to an interventional radiology suite (Clay C. Cothren, 2008).

For penetrating injuries, typically a major blood vessel is lacerated ,and the injury is hard to visualize. Most variations of the procedure include inflating a balloon within the bleeding tract and filling it until the bleeding stops. Typically the balloon is left inflated for 24-48 hours and slowly deflated in the SICU. Angioembolization will supplement the procedure in this scenario, and it should be considered early in treatment. For injuries to the gallbladder or extrahepatic duct, operative ligation to the right hepatic artery is followed by a cholecystectomy, or removal of the gallbladder. Injuries to the extrahepatic bile ducts are typically complicated due to their proximity to other portal structures and the vena cava. Small lacerations with little tissue damage may be treated by inserting a T-tube into the wound, or by lateral suture using an absorbable 6-0 monofilament. The author continues that virtually all transections, and any injury associated with significant tissue loss, will require a Roux-en-Y choledochojejunostomy. Injuries to these hepatic ducts may not be possible to repair under emergent circumstances. One approach is to intubate the duct for external drainage and attempt a repair when the patient recovers. Another technique is to litigate the lobar duct if the opposite lobe is normal and uninjured. The author continues with postoperative techniques for care and complications. (Clay C. Cothren, 2008).

Chapter 3: Procedures, Technology, and Design

3.1 What types of procedures are going to be done?

The procedures we plan to include are emergency surgeries and procedures that can mean life or death for a patient. Typically, we hope to limit this to Level 1 and Level 2 surgeries, shown in Table 3 below. However, some more advanced procedures, such as a thoracotomy, will also be included.

Table 3: Procedures performed at various levels of Emergency Surgeries

Level 1 Procedures	Level 2 Procedures	Level 3 Procedures
Normal Delivery	C-section	Facial and intracranial surgery
Uterine evacuation	Laparotomy (excluding bowel obstruction)	Bowel surgery
Circumcision	Amputation	Pediatric and neonatal surgery
Hydrocele reduction, incision and drainage	Hernia repair	Thoracic surgery
Wound suturing	Tubal ligation	Major eye surgery
Control of hemorrhage with pressure dressings	Closed fracture treatment and application of plaster of Paris	Major gynaecological surgery, e/g/ vesico-vaginal repair
Debridement and dressing of	Eye operations, including	

wounds	cataract extraction	-
Temporary reduction of fractures	Removal of foreign bodies e.g. in the airway	-
Cleaning or stabilization of open and closed fractures	Emergency ventilation and airway management for referred patients such as those with chest and head injuries	-
Chest drainage	-	-

As can be seen based on the list of procedures in the table above, Level 3 surgies should not be performed in areas other than a fully equipped hospital. These procedures include long monitoring time, as well as prolonged intubation. The RECAS unit will focus mainly on Level 1 and 2 surgeries. These procedures provide emergency measure sin treatment of 90-95% of trauma and obstetrics cases. They also provide short-term treatment of 95-99% of the major life threatening conditions. The RECAS unit has been designed with these procedures in mind.

3.1.1 An Overview of the Emergency Surgery Process

Emergency surgeries refer to surgeries that must be performed immediately, or else a patient could suffer irreversible damage or die. They can range from major surgeries such as hemorrhaging from a gunshot wound and repairing a brain aneurysm to those less serious such as fixing a broken bone or removing an inflamed appendix.

Patients can either go to an emergency room complaining of pain or an ambulance is called for those suffering from obvious injury. Ambulance personnel and paramedics assess the patient who suffered a severe injury upon arriving on the scene. This project will focus on the latter.

Upon arrival to the hospital, the patient's status is assessed and immediate treatment such as intravenous fluids, transfusions, or medications are administered. Once the patient is stabilized, tests such as x-rays, CT and MRI scans, and EKGs are done to better diagnose a patient's condition. A surgeon steps in if these tests show a need for surgery. In some cases, hospitals cannot perform the required surgery; therefore, patients are transported by ambulance or helicopter another facility with a professional healthcare staff monitoring them throughout. Organizing and preparing the transfer of the patient usually takes an hour or less – not counting time of transport (Heisler).

Simply put, in cases of trauma, particularly gun shot wounds or car accidents, patients cannot afford to wait for surgery. Treatment closer to the time of the injury cannot only save lives, but prevent permanent damage in others. With little control over the time it takes to transport these patients to the appropriate facilities, the nest logical step is to bring the necessary supplies and personnel for treatment to them. This project will design an ambulance whose purpose is just that.

3.1.2 Cranial Gunshot Wounds

Ventricular Injury following Cranial Gunshot Wounds : Clinical Study, by Erdogen et al., discusses a study done over 9 year period which "67 consecutive patients admitted to the Department of Neurosurgery with the diagnosis of ventricular injury resulting from penetrating craniocerebral gunshot wounds or missile injuries" (Erdogen et al., 2004). The patients were admitted to Gulhane Military Medical Academy in Turkey and were followed for a period of 6 months to 9 years (Erdogen et al., 2004).

Of the 67 patients, 66 were male and 1 was female (98.51% vs. 1.49%). Ages ranged from 19 to 45, though the mean age was 23.1 (Erdogen et al., 2004). Patients were admitted under a variety of neurological conditions. Thirteen patients had a GCS score less than 5, twenty-three patients had a GCS score between 5 and 7, twenty-five had a score in the 8 to 10 range, and only six patients had a score greater than 11 (Erdogen et al., 2004). No patient was admitted with a GCS score greater than 13 (on a scale of 3 to 15).

The brain contains four ventricles, two lateral ventricles, the third ventricle and the fourth ventricle, all of which are lined with ependymal and filled with cerebrospinal fluid (Erdogen et al., 2004). According to Erdogen et al., "gunshot wounds to the head are usually fatal injuries" despite treatment; ventricular injuries are considered a "rare and usually life threatening condition," caused by bullets, fragments, and/or shrapnel that "penetrate the walls of the ventricles after damaging the skull and adjacent cerebral tissues" (Erdogen et al., 2004).

Of the 67 patients admitted, thirty-three patients (roughly have of the total admits) were found to have intraventricular foreign bodies (IFB), meaning they had bullets or shrapnel that had penetrated the ventricles of the brain. Three patients were recorded to have intraventricular air (air pockets within the ventricles as a result of the penetrating trauma). The most common entrance site of foreign bodies was through the frontal lobe, occurring in 26.4% of the patients. The lateral and third ventricles were the most common sites of hemorrhaging, accounting for hemorrhaging in 59 admitted patients (95.16%) while only 3 patients of those admitted experienced hemorrhaging in the fourth ventricle (Erdogen et al., 2004).

Complication	# of Patients	
Intraventricular Foreign Bodies (IFB)		33
	Frontal lobe as entrance site	26.4%
Intraventricular Air		3
Hemorrhaging in lateral and 3^{rd} ventricles		59 (95.2%)
Hemorrhaging in fourth ventricle		3
Suspected aneurism		17 (25.4%)
Death		22 (38.3%)

Table 4: Patients with Intraventricular Cranial Injuries

Ventricular injuries, in this study, were not always fatal -- 22 of the 67 admitted patients (32.8%) died despite treatment. Each patient, however, did require extensive assessment and care.

Upon arrival at the Department of Neurosurgery, each patient underwent radiological assessment to determine points of entrance/penetration of debris (shrapnel, bullets, etc.) and site of injuries. Seventeen patients with suspected aneurisms underwent digital subtraction angiography; no aneurisms were detected, however – only hemorrhaging at site of injury. Patients were also evaluated by the Glasgow Coma Scale throughout treatment and post-op to measure neurological progress. Seventeen patients (25.37%), of the 67 admitted, were intubated and hooked up to mechanical ventilators, and fifteen patients with GCS scores between 4 and 8 were closely monitored for intracranial pressure (Erdogen et al., 2004).

Patients underwent a variety of treatments. Primary Suturing was performed on 13 of the 67 patients (19.40%). Thirteen patients were treated by primary suturing (19.40%), while craniectomies, durai repairs, removal of foreign bodies, and debridement (or removal) of necrotic (dead) tissue were performed on the remaining 54 patients (80.60%) (Erdogen et al., 2004).

During a two week post-operative period, all 67 patients received third generation cephalosporins (3g/day) and metronidazole (7.5mg/kg) (Erdogen et al., 2004). All patients were monitored for at least 6 months, up to 9 years, via clinical and radiological protocol, as well as by the Glasgow Coma Scale. Complications of treatments included cerebrospinal leakage, infection, hydrocephalus, and convulsions. Nine patients developed intracranial infections and eight developed CSF fistulas (Erdogen et al., 2004). Two were found to have hydrocephalus, which were treated with shunts. One patient developed epilepsy post-op. All complications were detected and treated.

Staphylococcus was the most common infectious agent (Erdogen et al., 2004). This data raises one of our own primary concerns with creating a surgically operable mobile unit. In a more permanent Operating Room, sterility is of utmost concern, with a number of protocol measures to ensure cleanliness and prevent infection. As space and running water is more of a luxury on the road, measuring up to this same level of hygiene and sterility becomes a major concern.

How do we ensure the same quality of treatment in our small ambulance as would be provided in a state of the art hospital? How do we ensure that our patients do not die from surgery-related infection and complications (which critics will claim could have been avoided by waiting until arrival at a health care institution)? If military medics can perform procedures in the field in the middle of battle with their primary concern being survival, there must be a way we can ensure some level of sterility on the road. The circumstances we would largely be operating in would be in response to crisis, though hopefully not under threats to local or national security. Nevertheless this will be something we must closely address.

There are other issues that come to mind when exploring the possibility of performing cranial surgery on site in response to a large accident or shooting. The biggest issue that presents itself is the limitations on space and equipment. In the study discussed above, as well as in general treatment of penetrating cranial wounds, imaging is key in the identification of both entrance sites and of injury sites. A foreign body, such as a bullet or shrapnel, may be well within the operative field but is not necessarily visible to the human eye.

So, how do we compensate for the lack of an imaging department on the road?? In the case of a shooting or large accident, do we send a mobile MRI van with the ambulance? This raises the issue of costs, however. Why send a MRI van to a site if it's not needed? Would that same van be more efficiently dispatched to a low-income neighborhood to provide preventative screening?

Exploring when to dispatch imaging equipment with our mobile unit also raises the questions of screening and personnel. Currently, incoming 9-1-1 calls are not necessarily screened for medical purposes. How do we know when to send a cardiac surgeon versus a neurosurgeon to an accident site? Do we send both? Or do we send only one medical officer with a general knowledge of a broad range of surgical procedures? Furthermore, do hospitals and EMS companies HAVE the personnel numbers to send the extra members required to perform surgery on site? If EMS companies are already stretched thin enough to send only 2 paramedics per incident and still have employees on the clock 60+ hours per week with no downtime between transports, how can we expect EMS companies and hospitals to spare the extra surgeons or paramedics to complete surgery?

Despite these concerns, we felt it necessary to include this case study in our research. From our trip to the UMASS Memorial ambulance hanger, we learned that gunshot wounds are treated to a very minimal degree during transport. The current approach is to stabilize the patient's vital signs and minimize bleeding; they do not remove bullet fragments. By expanding the number of procedures performed on site and on the road, we hope to save lives that would otherwise be lost due to transport time, and prevent complications that could be caused by fragments that become further embedded between the time of injury incidence and time of treatment intervention. In the study detailed above, the mean amount of time between incidence of injury and surgical intervention was 2 hours (Erdogen et al., 2004). The study asserted that this time did not exceed mean civilian time (Erdogen et al., 2004). Our aim of this project is not to critique the trauma teams that responded in any of these studies; however, whether civilian or military, two hours seems too long.

3.1.3 Hemorrhaging

Hemorrhage is the medical term for bleeding. Following a traumatic injury, hemorrhage causes of over 35% of pre-hospital deaths 40% of deaths with the first day of the injury – second only to severe central nervous system injury. Severe hemorrhaging can lead to several other life-threatening injuries, and many of they occur simultaneously with hemorrhaging. These include: impaired resuscitation, shock, inflammation, and coagulopathy. The amount of blood loss determines the severity of each of the aforementioned medical problems; the greater the amount of blood lost, the worse the life-threatening condition (National).

3.1.4 Emergency Department Thoracotomy

According to Mejia et al. in "Emergency Department Thoracotomy," cardiac resuscitation has progressed through history, specifically with the "concept of resuscitative thoracotomy [dating] back more than 130 years to Moritz Schiff' (Mejia et al., 2008). Open heart resuscitation remained a popular option for the first half of the twentieth century, and in 1952, the Southern Surgical Association was presented with 1200 cases of arrest treated with open cardiac massage, yielding a 28% survival rate. The procedure was gradually substituted with closed chest massage and emergency department thoracotomy (EDT) (Mejia et al., 2008).

The study found one of the largest issues with analyzing and assessing EDT as procedural response to cardiac arrest was the large range of reported survival rates. Overall, however, they consistently found a low rate of survival for patients who lost vitals before arrival at a hospital. The best outcomes from EDT, according to the study, were in patients with "isolated penetrating cardiac wounds," while there were few neurological survivors as a result of blunt trauma and multiple traumas. Lower neurological survival was also associated with prolonged transport time and the lack of signs of life on site (Mejia et al., 2008).

The study describes EDT as a procedure for "patients in extremis" and specifies that the procedure should be differentiated from Operating Room Thoracotomy and ICU Thoracotomy (Mejia et al., 2008). The procedural technique is generally consistent between scenarios, but it is important to differentiate the thoracotomies as the specific terminologies designate location and timing of procedure.

As per the American College of Surgeons Committee on Trauma (ACS COT), thoracotomies in blunt trauma patients should be performed very rarely and should be "limited to patients that arrive with vital signs or [with] witnessed cardiopulmonary arrest" (Mejia et al., 2008)

Indications for EDT in the case of penetrating injuries include short scene time, short transport time, and witnessed or objective signs of life, which include pupil response, spontaneous breathing, carotid pulse, measurable or palpable blood pressure, extremity movement, and cardiac electrical activity (the patient is not asystole) (Mejia et al., 2008, Derryberry). EDT is also designated for penetrating non-cardiac thoracic injuries (injuries to the upper body and cavity surrounding the heart and lungs) and for exsanguinating vascular injuries, though both have a low associated survival rate (Mejia et al., 2008)

Other indications and contraindications for performing EDT (as per the ACS COT)			
Indications			
	Shock SBP < 60*		
	Hemorrhage	Contraindications	
	Air Embolism		Associated Head Injury
			Absence of signs of life after CPR
Trauma Specific Indications			
Penetrating	Pre-hospital CPR < 15 min		
Blunt	Pre-hospital CPR < 5 min		

*Shock SBP due to a known cardiac tamponade

Table 5: Indications and Contraindications for EDT

As our understanding from this article, thoracotomies serve essentially five purposes, or objectives. The basic objectives of an EDT include the release of pericardial tamponade, the control of vascular or cardiac bleeding within the thoracic cavity, the evacuation or elimination of bronchovenous air embolisms and bronchopleural fistulas (later defined in more detail), open cardiac massage, and the temporary occlusion of the descending thoracic aorta.

One of the major purposes of EDT is to “address the issue of cardiovascular collapse” (Mejia et al., 2008). In a case of trauma to the thoracic region, there is obviously concern of collapse around the heart and lungs. Cardiovascular collapse can be caused by either mechanical origins or by sever shock due to hemorrhage. EDT and open cardiac massage becomes crucial in these situations as “closed chest CPR is generally ineffective in patients whose arrest is due to hemorrhage, tamponade, or tension pneumothorax” (Mejia et al., 2008). In these cases, the main means of resuscitation is by performing a thoracotomy.

3.1.4.1 Cardiac Tamponade

Cardiac tamponade, as best described, is an increase in pressure within the pericardial cavity (the cavity surrounding the heart) and increased compression of the heart, caused by the build-up of fluid, often blood. In the case of direct trauma to the upper torso, this cavity is most likely compromised. In injury caused by penetrating trauma, such as GSW or knife wound, damage to the pericardium (the wall of the pericardial cavity) or nearby artery can lead to hemorrhaging, causing the cavity to fill with blood which in turn restricts the heart. In cases of blunt trauma, the pericardial membranes are not directly punctured by a foreign object. If ribs are broken in the incident, however, this can also puncture the cavity walls and lead to cardiac tamponade as well.

According to Mejia et al.,"the classic Beck's triad (elevated venous pressure, muffled heart tones, and hemodynamic compromise) is rarely observed in the emergency setting following trauma, therefore, a high index of suspicion for cardiac tamponade is necessary" (Mejia et al., 2008). In fewer words, the traditional triadic indications of cardiac tamponade are not always observed in cases following severe trauma.

Cardiac arrest and myocardial ischemia occur as the final stage of tamponade, resulting from the failure of the previously mentioned compensatory measures; "these patients should undergo immediate pericardial decompression and evacuation of blood by EDT" (Mejia et al., 2008).

According to Mejia et al., urgency of a thoracotomy is dependent on the stage of cardiac tamponade the patient is in; those in "the initial phases of cardiac tamponade may be temporarily managed with fluid resuscitation to preserve diastolic filling before being transferred to the operating room,… [while] EDT is reserved for patients in the final stages of tamponade" (Mejia et al., 2008).

Likewise, we would most likely reserve on-scene thoracotomy (or thoracotomy performed within the mobile ambulatory unit) for patients with blunt or penetrating trauma who are in the final stages of tamponade (experiencing cardiac arrest and myocardial ischemia). However, the procedure, like the rest of the surgeries we will have the team surgeon perform, will be decided on a case by case basis, as other events (other than cardiac tamponade) also require treatment via thoracotomy.

3.1.4.2 Intrathoracic Vascular or Cardiac Bleeding

According to Mejia et al., “life-threatening intrathoracic hemorrhage occurs in less than 5% of patients following penetrating wounds, and in even fewer victims of blunt trauma” (Mejia et al., 2008). The article goes on to clarify, however, that the lethality of punctures or tears to the pulmonary and thoracic vessels “is exacerbated by the lack of containment by adjacent structures or vessel spasm (Mejia et al., 2008).

The article describes the objective of EDT in terms of hemorrhage control as reaching homeostasis for bleeding, “with the plan of definitive control in the operating room” (Mejia et al., 2008). Ideally, we would want to reach ‘definitive’ control in our unit, if at all possible. If not, our unit will at least stabilize patients for a better chance of surviving transport.

The article goes on to list multiple options for the control of hemorrhaging, which include “direct digital pressure, stapling a myocardial laceration with a skin stapler, rapid suture repair, application of a side-biting vascular clamp to control an atrial laceration, packing to control chest wall bleeding, or clamping pulmonary parenchymal bleeding” (Mejia et al., 2008). The authors recommend skin staplers as their use “minimizes the risk of surgeon injury, before definitive operating room repair;” however they are for “employing the simplest technique that achieves acceptable hemorrhage control” (Mejia et al., 2008).

3.1.4.3 Evacuate Bronchovenous Air Embolism or Eliminate a Bronchopleural Fistula

Yet another objective of emergency thoracotomy is the evacuation of bronchovenous air embolism (the obstruction on the bronchial veins by air) and the elimination of a bronchopleural fistula (an abnormal passage from the bronchi to the pleural cavity) (Meddit, 2007).

Air embolisms can present when air passages or lung parenchyma and blood vessels are ruptured as a result of lung trauma (which is possible in any upper torso trauma) (Mejia et al., 2008). The typical scenario of air embolism occurs from a penetrating chest wound, which eventually results in hypoperfusion (decreased blood flow through the heart and lungs) as a result of a myocardial ischemia caused by the embolism (Mejia et al., 2008). This development is exacerbated by low venous pressure (or hypervolemia, low blood supply) and increased airway pressure, which seems a likely result of the blood loss and tamponade caused by any thoracic trauma (Mejia et al., 2008).

During thoracotomy, the surgeon should look for air bubbles in the coronary arteries. The article suggests that "pulmary hilar cross clamping is crucial to prevent further pulmonary vein embolism," but cardiac massage is also recommended to move the air bubbles out of the veins and resuscitate the heart (Mejia et al., 2008).

3.1.4.4 Cardiac Massage

Open chest cardiac massage is not a sole indicator for thoracotomy but can be performed once the chest is open as a means of resuscitation. This means of resuscitation is described as a "hinged clapping motion of two cupped hands with the wrists opposed, compressing the heart from the apex to the base of the heart, avoiding point pressure with the thumbs," or like a mini shark with rounded jaws (Mejia et al., 2008). Based on the author's findings, "open-chest cardiopulmonary resuscitation produces better blood flow than closed-chest massage and has been associated with survival without neurological deficits in normo volemic animal models of cardiac arrest after open cardiopulmonary resuscitation for 30 minutes," meaning it provides possibly the best chance of resuscitation and survival for patients with thoracic trauma (Mejia et al., 2008).

3.1.4.5 Temporary Occlusion of the Descending Thoracic Aorta

The final objective of a thoracotomy is the "temporary occlusion [or temporary blockage] of the thoracic aorta… to reduce subdiaphragmatic blood loss [bloos loss occurring below the diaphragm], shunt a limited blood volume and to prevent sudden cardiac arrest in patients with abdominal injuries (EDART). The occlusion of this part of the aorta, extending from the diaphragm, is a measure to control hemorrhaging, and demonstrates that thoracotomy may be necessary for abdominal trauma patients as well as thoracic trauma patients, depending on the extent of the trauma.

3.1.4.6 How to you perform an EDT?

A surgeon or other medical personnel performing an EDT needs the skills to perform periocardiotomy, cardiorrhaphy, and thoracic aortic cross-clamping, in addition to a basic rapid thoracotomy. He or she also needs to have some knowledge of vascular repair techniques (Mejia et al., 2008). Clearly, these are not skills a basic EMT or even a paramedic would have the training for, as this is not an easily completed procedure. Therefore, it would be necessary to have a qualified surgeon and/or medical officer dispatched with our ambulatory operative and surgical unit.

Thoracotomy, as classified by WHO, is generally considered a Level 3 surgery, requiring extensive follow-up (WHOSOURCE). Overall, we decided to exclude Level 3 surgeries from the list of procedures that would be performed in our unit. Considering the extensive nature of this procedure and the need for follow up, the more ideal operative location would be a hospital. However, as previously noted, cardiac arrest is a severely time sensitive condition, and in the cases where EDT was performed, short scene and transport time yielded better patient outcomes.

Due to EDT's low survival rate and necessity in cases of embolism, fistula, and hemorrhaging, I would argue there is no reason why we shouldn't include this in procedures our unit would perform. With an already low survival rate, there would be little to lose by performing a thoracotomy on scene; if anything, we would have the potential to save more patients.

Also as previously noted, closed chest CPR should be avoided for resuscitating cardiac arrest patients who are also victims of blunt or penetrating trauma. In the case where a patient is in cardiac arrest after trauma and closed chest CPR cannot be performed, would it not be better to perform a thoracotomy and open cardiac massage in hopes of resuscitating the patient instead of letting them remain essentially dead until reaching the hospital, where they may resuscitated (if lucky enough) or simply be declared DOA? After all, the name of our unit's focus is Ambulatory RESUSCITATIVE Care and Surgery.

In the event of a single or multiple gunshot wounds, knife wounds, or blunt blows to the chest, many of the events associated with the necessity of EDT are likely to present themselves. The events to which we refer to are intra-thoracic hemorrhaging (excessive bleeding), air embolism, and/or bronchopleural fistula. In the case of a GSW, it seems foolish to address bleeding without directly controlling the site of the hemorrhage. Also, the sooner air emboli in the vessels can be removed, the sooner, logically, the patient may be resuscitated.

When receiving an EDT, the patient should remain in the supine position on the backboard. There are two reasons for this positioning, one logically being access to the thoracic cavity, the other being concern about the condition of the spine. Upon admit, when an EDT is performed, the patient does not yet have spine clearance; therefore the procedure must be performed while the patient is in the supine position.

The patient's operative side should be slightly elevated, with the arms at right angles. Keeping the arms at right angles allows for peripheral access to the vascular region (Mejia et al., 2008).

The first incision should be made, beginning at the sternum, and continue "transversely across the chest and the level of the fourth of fifth intercostal space avoiding the bulk of the pectoralis major" (Mejia et al., 2008). What this means is the incision should carry through the chest at a 90 degree angle to the board and should be in line with the space between the 4^{th} and 5^{th} costals (rib bones) or between the 5^{th} and 6^{th} costals. The incision should continue in a curved fashion towards the axilla, or armpit, following the "natural curvature of the rib cage;" when performing an EDT on a woman, "the breast should be retracted superiorly to gain access to this interspace and the infra-mammary fold may be used as a guideline" (Mejia et al., 2008). Basically, when performing an EDT, the incision through the soft tissues should be swift and aggressive, but precise care should be taken when entering the pleural cavity.

The intercostal muscles should then be divided (as one layer) from the parietal pleura, using heavy scissors or a knife; this cut should be made "along the superior margin of the rib to avoid the intercostal neurovascular bundle" (Mejia et al., 2008). In cases of thoracic hemorrhage, the space within the ribs may be opened bluntly with the thumbs, while carefully avoiding rib shards in the case of blunt injury.

Next, a standard rib retractor is to be inserted with the handle directed inferiorly (in a lower position) toward the axilla, so that it is "not in the way in the case the incision needs to be extended across the sternum" (Mejia et al., 2008). After the pleural space is fully opened, the surgeon should shift the rib retractor "to a more midline [or more central] position to enhance maximal exposure" (Mejia et al., 2008).

1. Pericardiotomy & Cardiorrhaphy

After the chest is fully opened, the lung should be pulled back and a pericadiotomy (a surgical incision into the pericardium) should be performed, because a "normal appearing pericardial sac could potentially hide a tamponade" (Mejia et al., 2008).

The lung should be pulled back posteriorly to give access to the lateral aspect of the pericardium. If allowed, the surgeon may clamp the pericardium at the apex and make the cut between; if the pericardium is too full of blood, however, the pericardium cannot be clamped and "should be initially opened using a knife blade" (Mejia et al., 2008). The surgeon can perform the remainder of this procedure with surgical scissors, with the incision "parallel to, and at least 1 cm [in front of], the phrenic nerve" (Mejia et al., 2008). At this point, clots within the pericardium can be removed and cardiac bleeding may be controlled "immediately with digital pressure on the surface of the ventricle and partially occluding vascular clamps on the atrium or great vessels" (Mejia et al., 2008).

At this point, cardiorrhaphy, or the surgical suturing of the heart, can be performed. In a patient that presents with a non-beating heart, this should be done before defibrillation, while "efforts at cardiorrhaphy should be delayed until initial resuscitative measures have been completed" in the patient with a beating heart (Mejia et al., 2008).

The article recommends a skin-stapler to control bleeding of the myocardium (the middle muscle layer of the heart wall) and simple running or purse string sutures for atrial and venous lacerations. In all cases, Mejia et al. warn against the use of a Foley catheter to control bleeding due to risk of increasing the size of the initial wound (Mejia et al., 2008).

2. Open Cardiac Massage

As previously detailed, the surgeon's hands should be cupped, avoiding the use of thumbs, in performing open chest cardiac massage, but it may also be performed "using one cupped hand compressing the heart against the sternum" (Mejia et al., 2008).

If this is not enough for resuscitation, internal defibrillation of energy levels between 15 and 30 joules may be used to restore cardiac rhythm (Mejia et al., 2008).

3. Incising the Inferior Pulmonary Ligament to Mobilize the Lung

To complete this, the lower lobe should be pulled towards the head gently with the non-dominant hand. Doing so will place the ligament under tension which can then be cut with surgical scissors. This step is performed so that the lung may be retracted. The authors warn that "the proximal end of the… ligament ends at the inferior pulmonary vein… [so this step] should be carried out with extreme caution" (Mejia et al., 2008).

4. Thoracic Aortic Cross-Clamping

To perform this step, the surgeon should retract the left lung anteriorly while sliding a hand into the chest wall closest to the back, "from lateral to medial, following the concavity of the ribs as they arch toward the thoracic spine," or working from the part of the chest wall furthest from the midline of the body towards the center (Mejia et al., 2008). The aorta will be the first tube-like structure the surgeon encounters while doing so. After locating the aorta, the surgeon should compress the aorta manually to temporarily prevent bleed out. The surgeon should then cut into the pleural on both sides of the aorta, through which the thoracic clamp can be guided. Mejia et al. suggests this is best done under direct vision of the aorta, but likely hemorrhaging in actual trauma makes this improbable. Therefore, the incisions can be made with the thumb and fingertips, though very carefully, as too large a dissection risks damage to the aorta and neighboring vessels (Mejia et al., 2008).

The authors of this article strongly advocate for manual compression, as it eliminates the risk of misplacing the clamp and damaging the aorta. Performing this step manually, however, may require the help of another member of the trauma team to perform cardiac massage. This step is traditionally performed after pericardiotomy but may be performed first (after the chest wall is opened), in cases of extreme blood loss (Mejia et al., 2008).

5. Clamping the Pulmonary Hilum

According to Mejia et al., hemorrhaging "from a central lung injury requires rapid control of the hilum," the depression of the lung where the bronchi, blood vessels, and nerves pass (Mejia et al., 2008). To perform this step, ventilation should be momentarily stopped, and the surgeon should place a Satinsky clamp around the hilum while holding the partially inflated lung with the non-dominant hand. Umbilical tape or a Penrose drain can also be used to control lung bleeding (Mejia et al., 2008).

6. Planning for Definitive Repair in the Operating Room

The steps performed in a thoracotomy are obviously not a permanent solution to the physiological issues initiated by thoracic trauma. Therefore, it is important to have a definitive operative plan in place once cardiac rhythm is reestablished. According to Mejia et al., this preparation entails "notification of the operating room,… consideration for cardiopulmonary support or bypass, initiation of the massive transfusion protocol, and measures to avoid hypothermia" (Mejia et al., 2008).

After our unit has performed thoracotomy and has stabilized the patient for transport, the operating room can be notified en route with the extent of the injury and details of the thoracotomy that the responding surgeon has performed. This should give the hospital operating team ample time to prep for definitive surgery. Some at this point may question the use of any procedure without the intention of definitive repair. We would argue that a stable patient has a better chance at survival of transport than the unstable patient, while giving the base team time to prep and respond appropriately. Our hope is that performing emergency surgery on site not only increases chances of survival but also lessens the burden placed on hospital staff and space constraints.

Thoracotomy is not considered an easy procedure and the surgical decisions must be made swiftly. By including it in our procedures, we hope to increase the survival rates of a procedure that is traditionally considered a death sentence.

3.1.5 Blunt and penetrating abdominal surgery

In their article, "Blunt and penetrating abdominal trauma," Adam Brooks and JAD Simpson discuss the effects and complications involved with penetrating and blunt abdominal trauma. Brooks and Simpson stress that management of abdominal injury after trauma is extremely important, because if severe abdominal injury remains undetected or is evaluated, and therefore treated, inappropriately, there is a greater chance of mortality. According to the article, abdominal injuries were most frequently the result of "blunt multisystem injury following motor vehicle crashes or pedestrian trauma and, much less frequently in the UK, penetrating injury"

(Brooks and Simpson, 2009). As with any addressing any trauma, the accurate assessment, timely resuscitation, and appropriate investigations are crucial for survival of abdominal trauma.

According to Simpson and Brooks, "the priority of the trauma team is to get the patient to the operating room for definitive surgical treatment as soon as possible" if the abdomen is considered or suspected to be the major source of hemorrhage (Brooks and Simpson, 2009). Considering the time sensitivity and multisystem complications related to abdominal injuries and trauma, coupled with the sensitivity to transport in such patients, abdominal assessment surgery and laparotomy should be seriously considered for inclusion in the procedures performed by our emergency ambulatory surgical unit.

Abdominal trauma, similar to other traumas, can be divided into two major classes, blunt and penetrating. According to Brooks and Simpson, penetrating injuries, such as gunshot and stab wounds, predominate in the United States, South Africa, and parts of South America, while abdominal injuries in the United Kingdom, New Zealand, Australia, and parts of Europe tend to be mainly blunt trauma injuries (with penetrating trauma on the rise) (Brooks and Simpson, 2009).

The article references a study following patients at San Francisco Hospital over a two year period and goes on to describe periods of susceptibility, or, as Brooks and Simpson refer to them, 'major mortality peaks' for patients with abdominal trauma "who survive major [or initial] trauma [event] and are transported to hospital" (Brooks and Simpson, 2009). The first peak occurs early in the Emergency Department or the Operating Room and results from damage to abdominal vascular structures or injury to vital organ systems. All abdominal trauma cases with abdominal haemorrhage require emergency abdominal surgery in all cases to control bleeding. Brooks and Simpson also assert that Damage Control Surgery (DCS) may be necessarily considered in hopes of preventing mortality during this first peak (Brooks and Simpson, 2009). They describe the second mortality peak as related to the potential "development of a spectrum of critical illness" with specific concern surrounding the risk of Systematic Inflammatory Response Syndrome (SIRS) (Brooks and Simpson, 2009). SIRS is a major concern, because, when coupled with injection, it may lead to sepsis which "can progress to Multi-organ Dysfunction Syndrome (MODS)" or multi-system failure (Brooks and Simpson, 2009). Though MODS implies the failure of multiple symptoms and is "by definition multifactorial, abdominal complications… are significant contributing factors," making abdominal surgery and treatment a priority in trauma response (Brooks and Simpson, 2009).

According to Brooks and Simpson, trauma patients with possible abdominal injury as indicated "from either the mechanisms of injury, physical signs or associated injuries should be triaged with a high priority and be assessed and treated in the resuscitation room" (Brooks and Simpson, 2009). After activation of the trauma team, an initial assessment should be conducted "to confirm or exclude the abdomen as source of concealed bleeding that requires immediate surgery" (Brooks and Simpson, 2009).

Given the space constraints in our unit, Focused Assessment with Sonography from Trauma (FAST) provides perhaps the most reliable means of identifying abdominal hemorrhage. History and clinical examinations are important, as to determine mechanism (or vehicle) of injury (i.e. car accident, bullet, knife, or other penetrating object). Establishing mechanism is considered "very important as it provides information on the likely forces and potential injuries" (Brooks and Simpson, 2009). As with any incoming trauma, patient signs and symptoms should be collected if possible, while examining the patient for bruising and lacerations. Even if the patient is conscious, however, patient complaints are not always considered a reliable means of accurately identifying abdominal hemorrhage and need for surgery. Brooks and Simpson state the following in regards to patient complaint and overlooked bleeding:

> *"Complaint of abdominal pain from an alert patient is indicative of abdominal injury, although many patients have an altered level of consciousness, spinal or distracting injury and are unable to provide reliable information. [Therefore,] the initial clinical examination of the abdomen can often be misleading… Initially blood may cause little peritoneal irritation, and drugs, alcohol, head injury and other distracting injuries may act to mask abdominal signs."* (Brooks and Simpson, 2009)

In other words, there are many factors may cause abdominal bleeding and severe injury to be overlooked, if a high level of suspicion is not maintained. The traditional protocol maintains that "unconscious patients, or those with obvious injuries above and below the abdomen, are assumed to have abdominal injury until proven otherwise" (Brooks and Simpson, 2009). Abdominal injury is a possibly byproduct of blunt and penetrating lower chest trauma, and "should be suspected even when there are no external abdominal signs" (Brooks and Simpson, 2009). Brooks and Simpson articulate that lower rib fractures can be indicative of spleen or liver injuries, while seatbelt bruising can indicate thoracic and lumbar spine fractures and has a high coincidence with bowel perforation.

Seatbelt signs are not always present directly after trauma, however. Bruising may present by arrival at the hospital but typically take a few hours to present. As a result, this would not be a reliable indicator for our unit's team, as the arrival of the surgical team would be shortly after trauma.

As the article explains, there are other indications of abdominal trauma, including distension and tenderness, but many of these are not always reliable for indicating definite abdominal trauma. Tenderness is probably the most frequent and reliable of the clinically observable signs indicating abdominal injury (Brooks and Simpson, 2009). Clinically observable signs, including tenderness, may not be obvious enough, however, or may be affected, again, by altered consciousness, drugs, or distracting injury. Three factors, however, significantly increase the likelihood of abdominal injury and should be noted: accidents with velocities exceeding 20 km/hour, age greater than 75 years, and the presence of head, leg, and/or chest injuries in low velocity accidents (Brooks and Simpson, 2009).

As abdominal injury is often masked and often missed in clinical examination, imaging, testing, and surgery remain the main means of identifying abdominal injury and bleeding. In the setting of our mobile unit, FAST would probably be the preferred means of imaging. Although it has limitations, especially in identifying organ-specific injuries, it is considered a reliable means of identifying free fluid, or excess bleeding, and is incredibly portable. FAST is considered beside investigation, which can be used simultaneously during resuscitation. This investigative imaging is not considered absolute in ruling out abdominal injury (especially organ specific injuries), FAST is considered reliable and would be used in our unit as a rule-in investigation, as a positive FAST in an unstable patient indicates the need for a laparotomy (Brooks and Simpson, 2009).

One of the biggest advantages of FAST is its characterization as non-invasive. FAST is, therefore, an imaging investigation that would definitely be included in our unit. Its use would assist in determining the severity of the patient's trauma and determining if a laparotomy and damage control surgery is immediately necessary, eliminating any doubt that the patient would die before reaching the hospital or trauma center.

Throughout the treatment of abdominal injury, serial evaluation of patient's symptoms and progression is crucial. Our unit is mostly concerned with initial identification, laparotomy, and damage control surgery. It is not intended to replace definitive follow-up surgery in the traditional operative setting. Definitive surgery and lab follow-up, to keep an eye on WBC count and other indications of sepsis are incredibly important to ensure patient survival.

The first priority in an abdominal trauma patient is the restoration (or basic resuscitation) of airway and breathing. After this stabilization, a laparotomy may be performed if indicated by FAST. To do so, the patient should be supine with arms extended at right angles; Brooks and Simpson refer to this as the 'crucifix position,' similar to that of a patient undergoing a thoracotomy (Brooks and Simpson, 2009).

Preparation for a laparotomy should account for the possibility of a worst case scenario, meaning "preparation should be from neck to knees… [while] ensuring access to both sides of the diaphragm and the groins, with two large suckers and open large packs set up" (Brooks and Simpson, 2009). According to Brooks and Simpson, the patient should be prepped and draped before receiving anesthesia; at this point it is important to clarify that the RECAS unit team must not only consist of a surgeon and paramedics, but must also include anesthetists. The final response team will more likely resemble that of a fledged trauma team than of a typical EMS ambulatory response team.

A trauma laparotomy should commence "with a midline laparotomy from below the xiphisternum to the pubis around the umbilicus" (Brooks and Simpson, 2009). The abdomen is then split into four quadrants and packed off to reach and maintain temporary homeostasis. From there, the surgical team removes the packs, "starting with the quadrant with the least amount of bleeding" (Brooks and Simpson, 2009). Following the removal of the packs, "exploration of each quadrant includes achieving definitive [homeostasis], identifying bowel injury and minimizing peritoneal contamination" (Brooks and Simpson, 2009). Ultimate repair is considered once and only if the patient is stable.

Abdominal closure of the four quadrants may be permanent (if homeostasis is fully achieved and wounds are addressed) or temporary (if definitive or ultimate repair is required). Closure is also considered temporary if the abdominal packs are to remain in situ, if abdominal compartmental syndrome (ACS) is suspected, or if, as mentioned, a second laparotomy or definitive care is later required (Brooks and Simpson, 2009).

Our unit would also be responsible for performing Damage Control Surgery (DCS) or surgery designed to manage and "minimize the time a patient is exposed to the [lethal] triad" before expediting the patient "to a higher care setting where further organ support can be instituted" (Brooks and Simpson, 2009). The lethal triad is defined as the combination of hypothermia (low body temperature), coagulopathy (condition affecting the blood's ability to clot), and metabolic acidosis (excessive acid or pH level).

During traditional Damage Control Surgery, the operating surgeon is mainly responsible for addressing hemorrhage and contamination before transfer to the ICU for management of the lethal triad (Brooks and Simpson, 2009). In our unit, the operating surgeon's responsibilities would remain the same as in the traditional trauma setting, while management of hypothermia etc. would be conducted by the trauma team en route to the hospital. As Brooks and Simpson articulate, "the aim is for the patient to return to the operating theatre [(operating room)] for definitive surgery within 24-48 hours," giving ample time for our unit to transfer the patient to a trauma center for follow up (Brooks and Simpson, 2009). This greatly lessens concerns about the elapsed time between initial surgical response and follow-up. Of course, the time table is adjusted in the presence of concerns over the development of any complications such as ACS or sepsis, or in the presence of "the progression of previously unrecognized injuries" (Brooks and Simpson, 2009).

Abdominal trauma can be deadly if misdiagnosed and untreated. Intra-abdominal bleeding can be easily missed, as hemorrhaging may be present even in the absence of external abdominal injury. Mechanism and means of injury, when combined with clinical examination and imaging interventions, however, can help identify abdominal injury and the need for surgery.

Our unit would be responsible for the application of FAST in the identifications of such injuries, followed by initial surgical laparotomy and Damage Control Surgery (DCS). After stabilizing the patients surgically, the patient could then be transported to a trauma center for follow-up surgery and close monitoring for ACS, sepsis, and other complications.

3.1.6 Laparotomy

Laparotomy is a term for a surgery that entails a large, invasive abdomen incision. This surgery allows the surgeon to view the contents of the abdomen, including the organs, blood vessels, and tissues. A laparoscopy is the equivalent surgery of the laparotomy, except that it is minimally invasive. Small incisions are instead made, and a camera is inserted to view the abdomen's contents. Laparotomies are more likely to be performed in emergency situations than laparoscopies because they are both quicker and provide a larger view of the abdomen area.

This surgery is mainly performed on a person suffering from abdominal pain into order to diagnose them when testing results prove inconclusive, and the term exploratory is added to the surgery's name in these cases. A visual examination of the abdomen may help find the cause of the patient's suffering (Heisler). Nowadays, laparoscopies are performed a lot more often than laparotomies; however, laparotomies are conducted in time sensitive situations, a conditional basis of this project.

When a patient's condition is life threatening, surgeons perform laparotomies in order to treat the problem, diagnose it, or a combination of both. The problem could be organ damage, bleeding from an unknown source, or uncontrollable bleeding although the source is known.

Abdominal injuries that require a laparotomy are frequently caused by trauma, such as from a car accident, gunshot wound, or stabbing. In these cases, a major abdominal is obvious, however the exact organs, blood vessels, or tissues remain unclear. Laparotomies allow the surgeon to see, diagnose, and, in most cases, treat the injury.

After a trauma injury that causes pain in the abdomen area, a procedure called deep peritoneal lavage (DPL) is done prior to performing a laparotomy. In a DPL procedure, a small incision is made into the abdomen, and the surgeon flushes the abdomen cavity with fluid. While a DPL does not diagnose nor treatment the problem, it indicates bleeding – evidence indicating the need for a laparotomy. If a DPL shows bleeding, the laparotomy can diagnose its cause, and with the problematic area accessible, the surgeon might be able to fix the problem at the same time.

The surgery begins with administering the patient anesthesia and cleaning the skin of the abdomen with a disinfectant to prevent infection. Next, the surgeon will make the incision with a surgical knife into the abdomen. If the patient is experiencing pain in a particular area of the abdomen, the incision will be made near that area. Laparotomy incisions are shown in Figure 5 below. The abdomen contents are then inspected for signs of inflammation and infection. In some cases, biopsies are performed, meaning that samples of tissue are taken for testing. This ends the laparotomy procedure, but if a problem is found, the surgeon might at that moment be able to fix it while it is accessible. The incisions, if large, are closed with staples or sutures – the term for surgical stitches. Small incisions are closed with surgical glue of steri-strips – surgical adhesive strips.

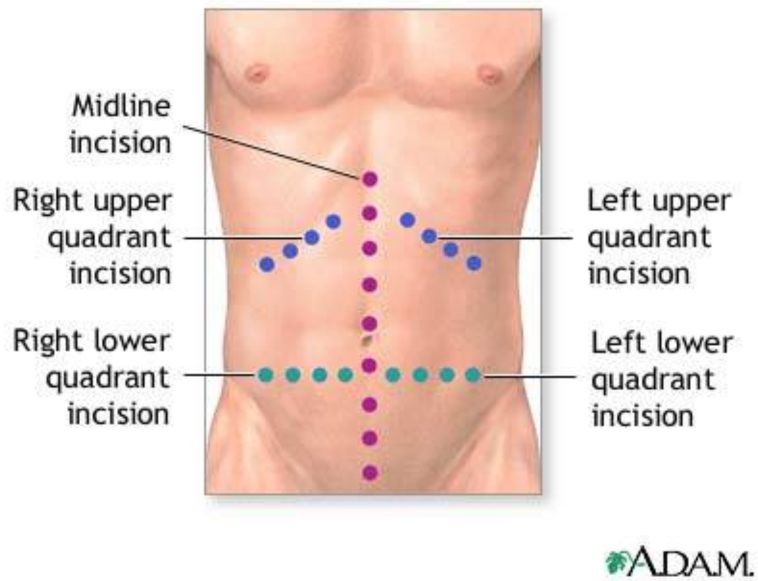

Figure 5. Incisions used in laparotomy surgery.

Specific risks for this surgery, besides the risks present in any surgery, are infection, bleeding from the surgery site, and incisional hernia – when abdomen tissue moves through and pulls out of the abdomen muscle (Heisler). In emergency situations, whether or not to perform the surgery is arguably unquestionable since no surgery results in death. Although minimizing risks is an important aspect of quality patient care, emergency situations don't lend vast amounts of time for cost benefit analysis.

3.1.8 C-section

In their article, "Caesarean section: Techniques and complications," Andrew Simm of Nottingham City Hospital and Pradeep Ramoutar of Derby City Hospital in the UK detail the history, techniques, and complications of the procedure.

The history of Caesarian section dates back centuries to ancient times, with written record. Early record of the procedure has led to some debate; contrary to popularly held belief, Julius Caesar was probably not birthed by C-section, even though one may first be inclined to think the procedure was named after him. Only recently has it been considered a safe enough procedure to be requested by mothers in the absence of medical indications (Simms and Ramoutar, 2004). (Simms and Ramoutar; 2004).

Survival was unlikely in early history of the procedure, with death nearly inevitable for the mother and the fetus. The original purpose of the caesarean section was mainly religious, rather than medical, performed to give the mother and fetus separate burials in cases of mortality, and the mother's organs were rarely, if ever, closed before burial (Simms and Ramoutar, 2004).

It wasn't until the 20th century that the fetus became the primary patient during labor and c-section; since then an increasing number of c-sections have been conducted with fetal health as the primary concern. Now the procedure accounts for about a fifth of deliveries in England. A caesarean section can be elective or emergency, and in April 2004, the UK's National Institute for Clinical Excellence (NICE) developed guidelines for the procedure. The following four categories of urgency (from highest to lowest urgency) have since been advised by the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) and backed by both the UK Royal College of Obstetricians and Gynaecologists (RCOG) and the UK Royal College of Anaesthetists (RCA):

1. Immediate threat to the life of the woman or fetus
2. Maternal or fetal compromise that is not immediately life threatening
3. No maternal or fetal compromise but early delivery required
4. Delivery timed to suit woman and staff (Simms and Ramoutar, 2004)

Simms and Ramoutar stress the importance of patient education in this procedure, though there are obvious limitations. For example, in case of emergency c-section, informed consent is limited to the basics of the procedure when the mother is conscious. In cases of trauma or other incident rendering the mother unconscious, when a c-section is required, the mother's and fetus' life take precedence over education. In all cases where the mother survives, however, the mother should be "visited on the ward postpartum, ideally by the operating surgeon" (Simms and Ramoutar, 2004).

In a traditional UK maternity operating theatre, a variety of staff, as well as students, can be found migrating between areas of the theatre. Simms and Ramoutar's main concerns surrounding the dynamic environment of the maternity ward surround the hygiene and sanitation of the procedure, with a reminder that surgical staff should change into fresh scrubs before entering the theatre (or operating room) (Simms and Ramoutar, 2004).

In our unit, this discussion reminds us of this concern as well, as well as the concern (once again) of staffing and space. Granted, our ambulatory unit will need some device to ensure hygiene (such as a hand sanitizer), but the inclusion of a full shower, changing room and scrub-in area seem improbable. Therefore, it will be important for staff and vehicles to be rotated between responses --- in an ideal scenario, each major city would have multiple mobile units --- to ensure health safety and sanitation. A unit should not be expected to respond to a second call while fresh blood is still on the floor of ambulance. Our unit is essentially useless if the trauma patients that we save subsequently die from infection or develop other complications due to unit contamination.

Simms and Ramoutar's discussion also raises the issue of staffing and space. Our unit will inevitably constitute a high-stress environment with limited space and supplies. Our unit is not for the weak of stomach or the weak at heart, but the rewards of accomplishment have the potential to be incomparable, as this unit has the potential to save numerous lives that may otherwise have been lost.

Again, however, our unit is not to be staffed by inexperienced surgeons and trauma team members, given the nature of the procedures to be performed. Training should likely be limited to a surgeon, or general trauma team, trainee in back and a ride-along, to assist with paramedic duties and to act as an extra body to help with transport up front. This unit is not the environment for multiple students to ride along, though procedures (as in a traditional operating room) may be taped for later review and for teaching purposes.

Before the procedure, the patient should be positioned at a lateral tilt of about 15 degrees and prepped with an indwelling catheter. The patient should also be draped, and the anesthetist should have access to intravenous lines. The intention of the particular positioning is to "avoid supine hypotension and reduced placental perfusion" (Simms and Ramoutar, 2004).

As with any surgery, the authors advocate that "god practice includes asepsis, minimal and gentle tissue handling, good homeostasis, eradication of dead space, avoiding excess suture material and reapproximation of layers with strangulation of tissue," meaning great care should be taken in restoring homeostasis and delivering the fetus, while minimizing distortion and disruption to the tissues (Simms and Ramoutar, 2004).

The surgeon should clean the skin, from the incision outwards, with either povidone-iodine of chlorhexidine gluconate to eliminate foreign bodies on the skin and minimize the chances of sepsis. From here a number of techniques can be utilized depending on the preferred method by the individual surgeon and methods allowed by presenting trauma or condition, in cases of emergency surgery. The basic course of action, however, is to open the abdominal wall and enter the abdominal cavity, to open the peritoneum and slice into the uterus, and to deliver the baby and the placenta (Simms and Ramoutar, 2004).

Vertical (midline and paramedian, or next to the midline) incisions and transverse incisions (across the body) have both been used for delivery by caesarean section. Classically, vertical incisions have been preferred, allowing speedy abdominal entry and minimal bleeding. This specific type of incision may also be extended upwards in the event of possible and actual complications and is advocated for use with local anesthesia (as is the likely scenario in lesser developed rural countries). Unfortunately, the vertical midline incision presents a cosmetically significant scar and is associated with the risk of post-op wound splitting and the development of a hernia. According to Simms and Ramoutar, the paramedian incision is no longer used as it presents no great advantage cosmetically or in terms of speed (Simms and Ramoutar, 2004).

Low incidence of post-op wound splitting or disruption and minimal scarring, in comparison to other incisions, make low transverse incisions the method of choice. This incision, however, is not recommended in the event of local anesthesia and may be accompanied by the loss of more blood (as more dissection is required for adequate space). According to Simms and Ramoutar, this incision is traditionally initiated about two fingers (just over an inch) above the pubic symphysis, or the conjoining of the pubic bones, and should gently curve upwards. The incision is typically about 15 cm in length, which the authors suggest be placed in a natural fold of skin (Simms & Ramoutar; 2004).

The incision should be swiftly continued through the subcutaneous tissue (the layer of tissue below the skin) to the rectus sheath, which should be cut transversely using heavy curved Mayo scissors. A heavy toothed clamp, such as a Kocher should be used to grasp the edges of the fascia (connective tissue), and the sheath should be dissected from the remainder of the abdominal muscles. Any nicked or perforated vessels, at this point should be sutured or electrocoagulated – cauterized, essentially. (Simms and Ramoutar, 2004).

The rectus abdominis (a vertical abdominal muscle along the midline) should then be separated at the midline by manual dissection. This will reveal the peritoneum, which should be opened sharply and widened by fine scissors. There are various modifications to these steps, such as the Maylard and Cherney procedures. Surgeon discretion applies, however, and NICE actually prefers a different method altogether (Simms and Ramoutar, 2004).

NICE's preference is a modified incision (not curved) conducted about 3 cm above the pubis symphysis (instead of the traditional 2.5 cm). In this methodology, sharp dissection is minimized (with a preference towards manual dissection with the fingers) and dissection of the subcutaneous layer and rectus sheath is minimized to a few centimeters in the midline. NICE prefers this methodology as these techniques have "the advantage of shorter operating time, less use of suture material, less intra-operative blood loss, less post-operative pain, and less wound infection" (Simms and Ramoutar, 2004).

The article goes on to detail uterine incision, delivery (removal of the fetus and placenta), as well as closure, but those details will be spared for our reader. Caesarean section, though a procedure that should be undergone with great care, is definitely a feasible procedure to include in our unit, especially in life or death situations. It may someday also be feasible (with the allowable resources) as a response for complications of at-home deliveries, especially in low income area (both urban and rural). To place the patient at a 15 degree angle, however, the right surgical table would need to be employed.

3.2 Implementing Technology: Imaging Equipment

3.2.1 Optical Atomic Magnetometers vs. Traditional MRI

While traditional Magnetic Resonance Imaging devices, or MRIs, have been made portable, researchers from University of California, Berkeley have been working on a new device. This new device uses inexpensive and low power magnets along with lasers to create images. This type of device would be ideal for a surgery vehicle because it is low in cost, low in power, and much small and lighter than traditional MRI machines (Humphries, 2006).

Traditional MRI scanners are used to create relatively high quality images of the inner structures of inner tissues, for biomedical, biotechnical, and many other applications. These machines, however, have many drawbacks. First of all, the machines themselves can range from $1 to $3 million in costs, never mind the cost of running the machine. The main drawback of traditional MRI machines is that they require powerful magnetic fields, which are generated by superconductive magnets, which produce detectable signals (Humphries, 2006).

A new device being developed in the labs of Alexander Pines and Dmitry Budker and the University of California, Berkeley, solves this problem of cost and high energy consumption. This new device is called an optical atomic magnetometer, and it relies on low-power magnets and would only cost a few thousand dollars. Eventually, the team would like to create a handheld, battery powered device that can be used anywhere – this type of device would be ideal for our purposes (Humphries, 2006).

In traditional MRI machines, a strong magnetic field forces some of the hydrogen atoms within a sample to "spin" in the same direction. Then, a radio-frequency pulse causes the hydrogen atoms that are aligned shift direction, causing them to enter a high-energy state. Once the atoms are in a high-energy state, the magnetic pulse stops, causing the atoms to realign and give off the energy they had in their previous state. A large magnetic coil in the MRI machine can detect this energy, and use it to create an image (Humphries, 2006).

In an optical atomic magnetometer, the sample is polarized with a magnet, then exposed to a varying magnetic field. In this field, each atom in the sample receives different levels of magnetism, giving it a different "spin." Once exposed to magnetism, the sample is moved to a detection chamber. The energy is detected with light instead of coil, unlike in a tradition MRI machine (Humphries, 2006).

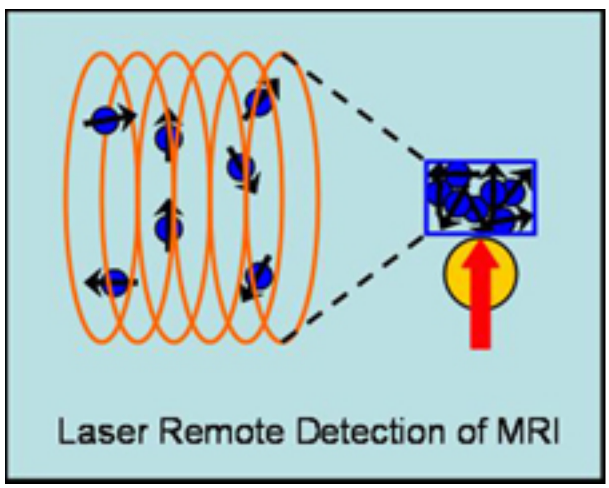

Figure 6: A drawing of the function of an Optical Atomic Magnetometer. (Shoujun XU, UC Berkeley)

A glass cell near the detection chamber is filled with rubidium atoms. These atoms are highly sensitive to changes in magnetic fiends, and can detect magnetic signals from the sample. Figure 6 shows a drawing of the laser remote detection through rubidium atoms that have been influenced by magnetism. When a laser light probes the rubidium atoms, the polarization of the laser light changes according to the strength of the magnetic fields they sense. These signals are used to reconstruct an image (Humphries, 2006).

At the moment, this technology is used for smaller, more clear-cut biological samples, such as the lungs, that have few overlap with other samples. Researchers propose that within the next 10 years, however, this technology will be suitable for more widespread medical use (Humphries, 2006).

3.3.2 Portable Imaging Devices: X-ray units

Portable X-Ray technology is a must-have to properly assess a patient's condition before surgery. Medical radiology will be used in terms of a mobile surgical vehicle to exam samples of hard tissues - such as bone and foreign bodies, in order to assess the need for emergency amputation or foreign body extraction – or soft tissues – such as the lungs, heart, and abdomen. However, in a surgery vehicle, with limited space and power, tradition X-Ray devices aren't exactly space and cost effective. Many companies today offer smaller, X-Ray units that produce high quality images with a lower cost of running that weigh and cost much less. MinXRay Inc. is one of those companies (MinXray Inc. 2011).

MinXRay Inc. offers a variety of models, for digital, medical, military, and veterinary use. For the medical models, they design exclusively for onsite diagnosing – which would be ideal of a surgical vehicle of this type. They x-ray imaging devices' use range from mobile imagine, military, forensics, disaster response, sports medicine, podiatry, and dental. Almost all of these applications overlap with those of our mobile surgery vehicle (MinXray Inc. 2011).

MinXray offers high frequency portable medical x-ray units that have the highest power-to-weight ratios available from any manufacturer. Their models are designed in any case where an x-ray unit would have to be brought to the patient. They are capable of all routine radiographic views that a tradition x-ray unit is; they are able to take detailed images of the chest, abdomen, skull, spine, and extremities with a short exposure time (MinXray Inc. 2011).

Figure 7: The HF120/60HPPWV PowerPlus model from MinXray, shown with the XGS MKIV stand.

Figure 7 shows the HF120/60HPPWV PowerPlus model from MinXray. It offers the largest amount of power of the portable x-ray models they manufacture. The total weight of this system, including the stand, is 96.5 pounds, or 43.8 kilograms. It is capable of producing up to 120kVDC and over 200 mAs. The HF120/60HPPWV PowerPlus contains 5 memory stations to store and recall frequenty used exposure techniques. This feature would be especially useful in an ambulatory setting, where time is a factor (MinXray Inc. 2011).

Figure 8: the MF100H+ Model from MinXray, shown being transported on the XGS MKIV Stand.

Figure 8 shows another model of portable x-ray units that MinXray manufactures. This model is called the HF100H+ portable x-ray unit. This model also has the "5 memory station" feature and is CPU controlled. Table 6 offers comparative specifications between the two units (MinXray Inc. 2011).

Table 6: Comparitive specifications between the x-ray units "HF120/60HPPWV Powerplus" and "HF100H+"

Unit	Output – kVDC	Output – mA	Weight
HF120/60HPPWV Powerplus	40-120	60-20	38.6 lb (17.5 kg)
HF100H+	40-100	30-20	45.5 lb (20.7 kg)

3.2.3 Portable Imaging Devices: Direct Radiography and Computed Radiology

MinXray also offers a line of digital products for direct radiography and computed radiology digital imaging technology. All their portable x-ray and digital imaging systems can be used fixed and transported, while producing digital images that are capable of being enhances, enlarged, duplicated, and sent to any location as DICOM 3.0 file, with no loss of resolution. Images can also be printed or archived locally on the scene on CDs of DVDs (MinXray Inc. 2011).

MinXray offers 4 different models of direction radiography and computed radiology devices: CMDR-2S, CMDR-1S, KODAK Point of Care CR Imaging systems, and the iCR3600.

Figure 9: The CMDR-2S Portable X-ray DR System, manufactured by MinXray

Figure 9 shows the CMDR-2S, which is a portable x-ray direct radiography system. It is essentially a portable x-ray device paired with a Varian imaging panel. This provides the user with a physically integrated and portable DR system. It offers many features such as an image acquisition time of 6-8 seconds, digital applications software, and imaging panel, included laptop computer, wireless capability, and stainless steel housing for easy sterility. Its total weight is 179 pounds, or 81.4 kilograms (MinXray Inc. 2011).

Figure 10: The CMDR-1S system, manufactured by MinXray

Figure 10 shows the CMDR-1S system, which is a portable digitial radiography system that features a Canon imaging panel coupled with MinXray's portable x-ray unit. It can be transported easily and ready in image in less than a minute. Some features include and image acquisition time of 3-5 seconds, wireless capability, and stainless steel housing and portable stand for durability and easy sterility. The overall system weighs 179 pounds, or 81.4 kilograms (MinXray Inc. 2011).

Figure 11: The Kodak Point of Care CR system, manufactured by MinXray

Figure 11 shows the Kodak Point of Care CR system. It offers a single place computed radiography line designed for the full spectrum of clinical applications. They are extremely compact, and an image can be made in under a minute (MinXray Inc. 2011).

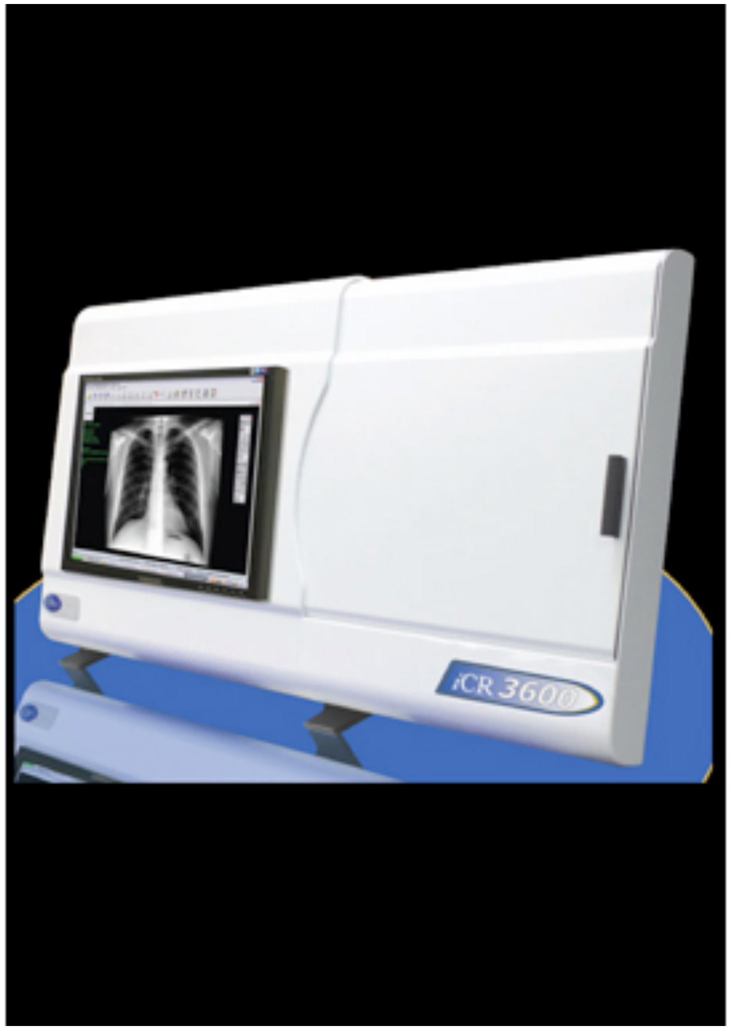

Figure 12: The iCR3600 model of CR Imaging systems manufactured by MinXray

This design of CR imaging technology, shown in Figure 12, incorporates the patented design of True Flat Scan Path. In this design, the phosphor plates used to image never leave the cassette, avoiding plate handling, damage, or wear during the scan process. This would be ideal for our vehicle, since paramedics are not trained to handle such devices. They would only require brief training on how to operate the equipment and understand it's image, but not how to function the machine. It is capable of making 300,000+ images per plate, so it is incredible cost effective. It can be wall mounted, or used on a tabletop (MinXray Inc. 2011).

3.3 Design Parameters

3.3.1 Operating Room Layout

The term operating room does not mean one single room where surgeries are performed. It refers to an entire layout made up of several rooms surrounding a centralized surgical suite. This layout varies from plan to plan, but the operating rooms are designed around both patient safety and work efficiency. A constant danger to patient safety is contamination, therefore the basis of designs serve to separate area considered sterile from those termed hazardous. Each separate room or area of an operating room is considered clean or hazardous based on its function. A space is termed hazardous if there is a "high potential for cross-contamination by disease-carrying organisms." In these areas, personnel must wear proper attire consisting of a mask and full body clothing. The following are the different room of an operating room:

The sterile supply room contains all the sterilized supplies and packaged instruments needed to perform surgeries. These are arranged on shelves and frequently checked for unusable items such as those whose packages are ripped or past their expiration dates for sterility. Surgery personnel take supplies and instruments from this room and assembled them before day's planned surgeries unless a crash cart system is in use.

The scrub sink area houses antiseptic soap, caps, eyeglass defogging agents, masks, protective eyewear, and scrub brushes. There many be multiple of these areas, and they are all located near the operating suite. The scrub sink areas are located far away from the sterile supply room or the supplies themselves in order to prevent water from the sink contaminating supplies. These areas are not used for cleaning or washing any surgical equipment.

The equipment room stores large instruments such as the image intensifier, laser machine, and operating microscope. The housekeeping supply room is used for the storage of general cleaning supplies as well as those used to sterilize surgical suites. To prevent cross-contamination across the hospital, these supplies must be solely used in the operating room. Anesthesiologists store all of their supplies in what is called an anesthesia supply room. This includes supplies such as: airway devices, anesthesia machines, catheters, and hoses.

Substerile rooms have blanket warmers, utility sinks, a washer-sterilizer, a refrigerator, and an autoclave. The refrigerator is for medications, small tissue grafts, and solutions. The autoclave sterilizes equipment to be reused – those not in packaging.

The area where the surgery is performed is known as the operating suite. The space is large enough for clean personnel to maneuver without touching non-sterile areas. It is also free of equipment and other clutter to allow ease of cleaning. This as well as the lack of small spaces and crevices prevents the trapping biological materials. If left there, they could cause cross contamination. The surfaces of the rooms including the ceiling and floors are nonporous, smooth, and constructed of fire proof materials and materials that can stand up to frequently washing with strong disinfectants.

Operating suites must also take air quality into consideration. Air must be frequently exchanged to prevent contamination by air-borne bacteria. Air for this exchange is taken from outside to, again, avoid cross-contamination across the hospital. However, this must to occur to often because of possible turbulence that would blow contaminants throughout the room. The humidity of the air also comes into play in order to minimize static electricity as well as prevent the ignition of flammable objects. A humidity level of about 50% is maintained to achieve this.

Both an overhead lighting system and surgical spotlights light the operating suite. The surgical spotlight uses halogen bulbs because they emit a pale blue light; it fatigues the surgery personnel's eyes less. Also, this type of lighting gives off energy in the form of brightness rather than heat, making it safe to use around delicate tissue. A post suspended from the ceiling holds these lamps up over the patient. A post typically contains two lamps, possibly three for increased visibility. Track lighting should not be used because its tracks could trap contaminants.

The National Fire Protection Association sets the standards for the electrical system in the operating room. Firstly, all electrical outlets must be grounded and explosion proof. Outlet column extend from the ceiling, eliminating the danger of accident or injury from electrical cords lying on the ground. The outlets receive also compressed air and suction. Operating rooms have a system called an equal-potential grounding system, which functions to make sure that the shortest distance for electricity to the ground is not through the patient. Figure 13 below shows a layout of an operating suite.

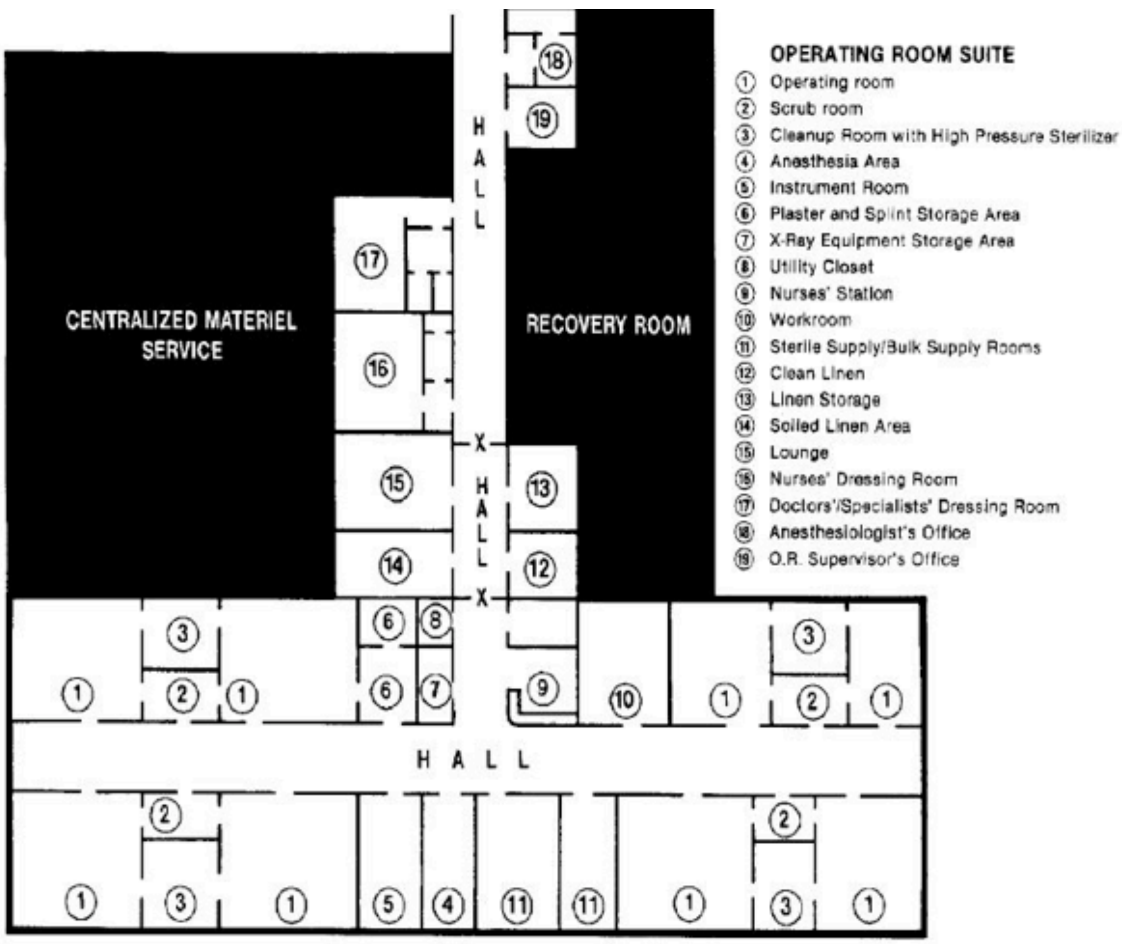

Figure 13. Layout of an Operating Suite

This project will take the general concepts from an operating room layout and implement them into an ambulance setting. Although the difference in space between the two is a significant obstacle, paring down the surgeries performed and surgical personnel without sacrificing patient quality care will be a necessity. The ambulance will be more like the operating suite, which much less storage space than an operating room. However, ambulances have the ability to stop at hospital facilities between trips for supplies. This project will take into consideration the general design principles and regulations of an operating suite for its ambulance deign.

3.3.2 Operating Room Equipment

The operating table is designed for movement in the vertical direction and for tilting in all directions. A firm pad separates the patient from the table, and it is made for easy removal for cleaning. Removable arm boards can also be added to the table for an extended arm of intravenous lines to rest. Leg holders are another removable option that to position legs upright for optimal surgical positioning.

The back table is a table located away from the patients where surgical tools and supplies not in immediate use are placed. The Mayo stand is a tray with an adjustable height located adjacent to the patient. Two legs hold it up. Tools used frequency are placed in the tray so surgeons have immediate access to them when needed.

A kick bucket is a bucket on wheels where members of the surgical team can throw away used sponges during surgery. The wheels allow for ease of movement and staff access around the entire suite (McGill).

3.3.3 Sterilization of Surgical Supplies

Surgical tools or instruments that come into contact with patient's bodily fluids and tissues need to be sterilized. Sterilization is a process that consists of several steps; therefore, the process will fail with the exclusion of any step. Sterilization can be achieved by a high-pressure steam method using an autoclave, chemical solutions, physical agents such as radiation, and by a dry heat method with the use of an oven.

Any effective sterilization technique requires time, contact, and temperature. Effective sterilization is dependent upon four main factors: the type of microorganism, number of microorganisms, number of small spaces and cracks on the surgical tool, and amount and type of organic material on the surgical tool. It's more difficult to kill certain types of microorganisms than other and many microorganisms compared to a few. Organic material left on surgical tools can protect microorganisms from death by acting as a shield. Therefore, all tools must be cleaned as well as sterilized in order to remove this organic material, or else sterilization fails. Crevices on surgical tools can easily house microorganism, and hard to reach areas like these make killing microorganisms harder (RepoLine).

Rinsing and cleaning must be done in addition to the sterilization process. The methods to prepare surgical tools require significant amount of time, space, supplies, and electricity. These factors need to be taken into account when developing a system for surgical tools use in the ambulance design of this project.

Surgical tools used in this project's ambulance must go through the same sterilization processes of that in a hospital. However, an ambulance lacks the storage capacity and power to achieve this. Therefore, the ambulance must work cohesively with a medical facility such as a hospital to overcome this problem.

3.3.4 Air Ventilation in the Operating Suite

Complications for surgery are commonplace and unavoidable. The leading cause of surgical complications is surgical-site infections. Air quality in operating rooms is a major factor contributing to surgical infections, and studies have proven that surgical infections are significantly reduced in operating rooms with cleaner air. Therefore, this project's ambulance design must include a ventilation system to control air quality.

Air distribution in hospital operating suites varies from a typical air-conditioned room like an office building in that it is much more critical, and therefore highly specialized. The purpose of an air distribution system in an office building is to supply a stream of air that rapidly mixes with the current air to provide a uniform temperature with minimal draft. If this system were implemented in a hospital room, it would spread airborne contaminants throughout the room. The air distribution system in an operating room must achieve favorable room conditions while considering airborne contaminants.

Airborne contaminants are generated from the microorganisms present in the room from the surgery as well as infiltration and ventilation from outside of the operating room. Ventilation can be controlled by a HEPA – high efficiency particulate air – filter, while maintaining a higher pressure inside of the operating suite than its surroundings prevents airborne contaminants from infiltration. The major source of airborne contaminants in an operating room is from the patient and the surgical team. Therefore, an air ventilation system must be designed in a way to move these airborne contaminants from the air surrounding the surgical area to outside of the room without mixing with the clean air.

The most straightforward was to reduce airborne contaminants is to increase the air ventilation rate, thereby diluting the air so to speak. This rate would far exceed that of the air conditioner in the office building, and causes uncomfortable drafts in the operating room.

Consequently, the air filter system must supply large volumes of air into the room, but control its flow in order to achieve comfortable room conditions in addition to the appropriate temperature and humidity. A way to control airflow is to supply air a low and uniform velocity; doing so helps in accomplishing a stable, downward flow of air. Figure 14 shows this concept.

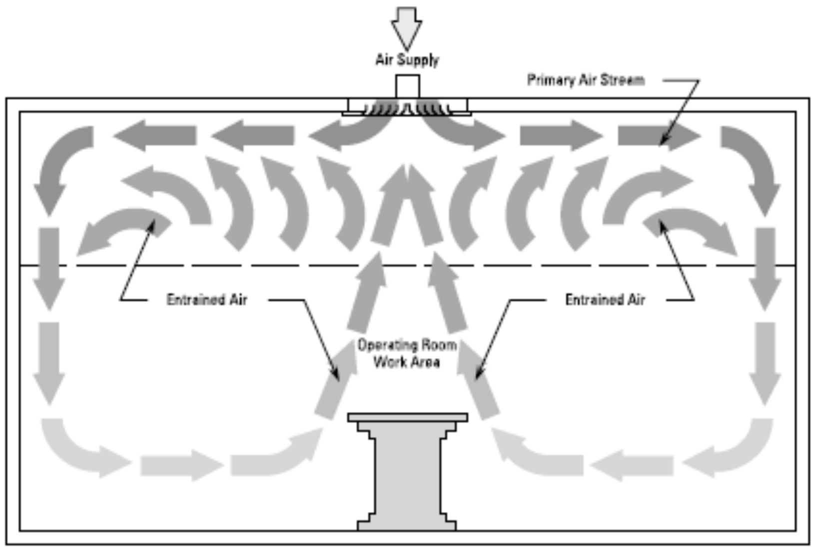

Figure 14. Ideal airflow for an operating suite

A laminar flow system uses the aforementioned concept in its design. The most effective implementation of this system would be to put laminar flow diffusers along the entire ceiling, which prevents the entrainment shown in the above figure. However, this arrangement requires a significant amount of air to achieve the flow patterns need for meeting air change per hour regulations. More air means more energy and higher cost, which despite efficiency rules it out. Figure 15 shows a schematic of this system.

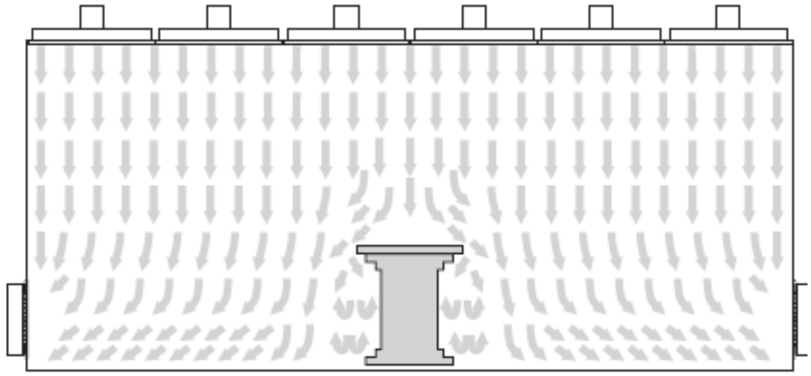

Figure 15. Laminar airflow system full ceiling design

In order to reduce required air amounts, laminar flow reducers can be placed above the operating table – the central are of the operating room. The low velocities of these diffusers still cause entrainment. This coupled with temperature differential of the new and old air results in an inward angle of air towards the center rather than straight down. Figure 16 illustrates this system.

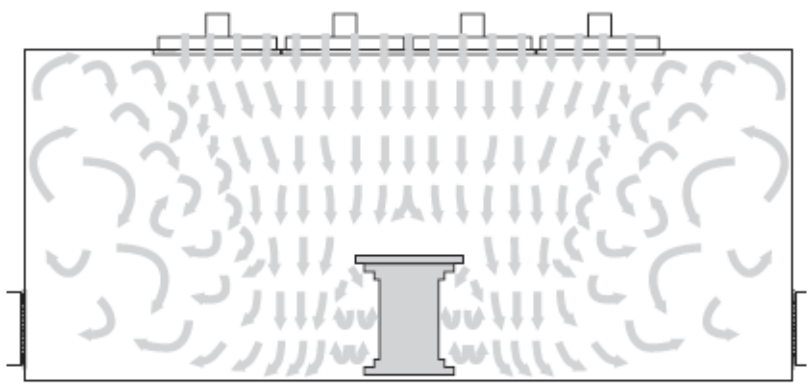

Figure 16. Laminar airflow system partial ceiling design

Creating an air curtain around the operating table can fix this drawback. Linear air diffusers on the ceiling, one above each of the four sides around the operating table, generates this air curtain. The linear diffusers should be placed far enough away from the edges of the operating table to incorporate surgical staff and equipment into the clean air area of the room, and they discharge at a small angle away from the operating table. Over fifty percent of the air supply from the HEPA filters is used to produce this air curtain, and the amount left over filters through the laminar flow diffusers.

This air curtain moves contaminated air to the outside areas of the operating suite, where they are directed outside of the room through a return grille. These are located about half a foot up from the floor, so they can collect not only contaminated air, but also gases heavier than air that sink to floor level. A room typically contains four of these return grilles, one on each wall. However, in cases where this is not possible, two can be placed – each on a wall opposite of the air curtain. Figure 17 below depicts this system.

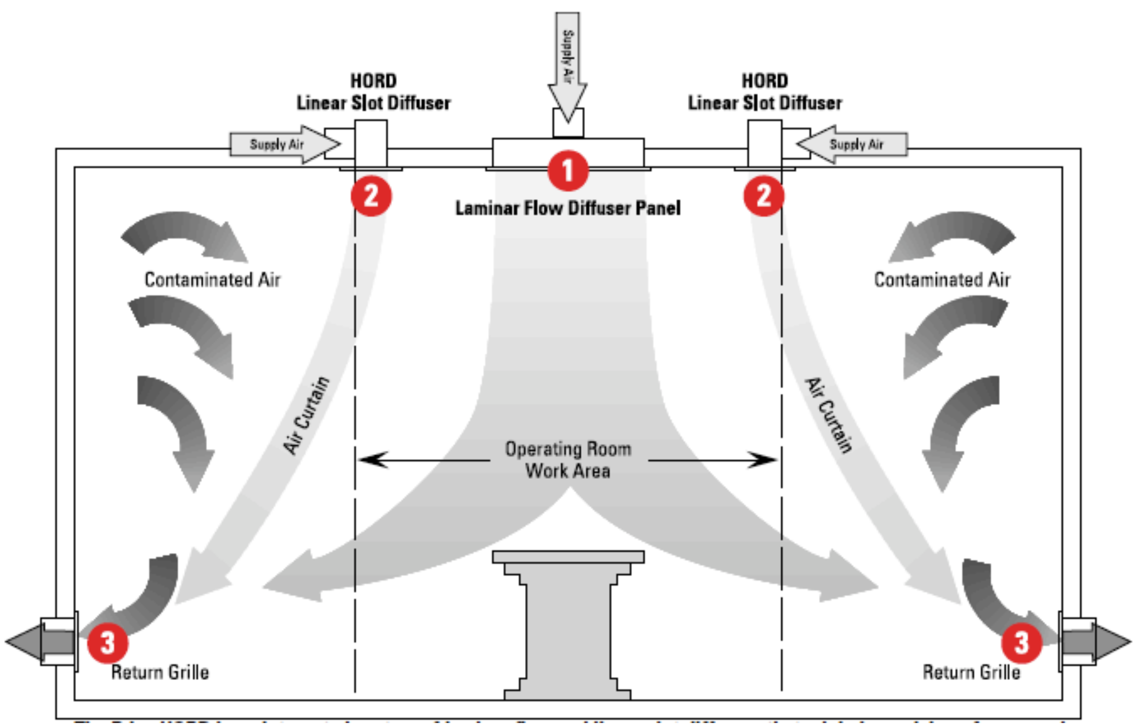

Figure 17. Laminar airflow system with air curtain

HEPA filters are used to supply the clean air distributed by these diffusers. Placing these filters outside of the operating room allows for repair in case of breakdown without breaching the sterile operating suite (Engineering Guide).

Modern operating systems use HEPA filters to improve air quality. A study published in 2004 details a computer system that can detect both the size and number of airborne particles in operating rooms. When these measurements exceed regulation values, the system warns authorized people visually and audibly (Engineering Guide).

Air quality in an operating suite is just as important as in that of an ambulance in order to prevent infections. Ambulances have doors directly leading to air in the outside environment. This comes into play when implementing an air ventilation system in this project's ambulance design.

3.3.5 Disposal of Medical Waste

Medical waste must be packaged specially, labeled, and decontaminated prior to disposal. There are six different categories of medical waste. Category I include human blood, its components, and items made from it with a volume of over twenty milliliters. Category II is comprised of bodily fluids in liquid form with a volume of over twenty milliliters of it. Objects that release bodily fluids from applied forces, such as a surgical sponge, are considered a category III medical waste. Category IV wastes are sharp objects, for example: needles, scalpel blades, and capillary tubes. Category V wastes are called pathological waste. This means diseased human tissues, organs, and body parts that pose threats to humans. Lastly, microbiological wastes are category VI medical waste; this refers to items such as cultures and infectious agents.

Category I and II wastes produced in operating rooms are placed in leak-proof bags. These bags are then put into biohazard containers, as well as Category III wastes. Category IV wastes are placed in puncture-resistant containers. These sharps must not be tampered with in any way; for example: recapping, snapped in half, or removed from syringes. Operating room solid waste, not classified as medical waste, is thrown away in leak-leak proof bags. These items do not need to be decontaminated prior to disposal, and they include: disposable gloves or gowns, masks, and gauze (Duke). Biohazard containers, like the ones used to dispose of sharps, are shown in Figure 18.

Figure 18. Different types of biohazard containers

Since surgeries will be performed in the ambulance design of this project, a medical waste disposal system must be incorporated into its design. Therefore, the types of wastes produced must be known as well as the proper procedures and regulations of how to dispose of them.

3.3.6 Case Cart System for Operating Room Supply Organization

While the ambulance design of this project must place patient quality care first and foremost, reality dictates that costs as well as efficiency are major contributing factors to its design.

The function of a case cart is to provide the necessary equipment to perform a certain surgery when needed. A case cart is considered a type of vehicle that houses the required instruments and supplies to perform one kind of surgery, once. Also, case carts can have several drawers with each pertaining to one surgery. Case carts are stocked either by the sterile processing department of a hospital or by the surgical services department itself. These carts are prepared beforehand for day's planned surgical procedures. There are also case carts located in the operating room supplied for the most common emergency surgery cases. At the conclusion of a surgery, supplies from the case cart are put back on the cart, where they are then sent back to the sterile processing department for disposal or reprocessing. The following paragraphs discuss the benefits of using a case cart system in an operating room.

Operating rooms stock a wide range of supplies as they perform a large number of different types of surgeries. This can lead to not only an overabundance of supplies, but also inconsistencies in sizes and packaging. An overstock of supplies can results in them becoming damaged and outdated. Operating rooms have several storage rooms throughout their layout. This dispersal of supplies means more time for assembling different items needed for each surgery. A case cart system would take the time away from OR staff managing inventory, which allows them to focus more on patient care. This also takes away prep time between surgeries, possibly allowing for more surgeries to be done. Movement of anything in an operating suite must take planning to avoid contamination. Also, the more movement, the greater the amount of particles scattered into the air. Case carts decrease traffic in an operating suite, and both contain infected supplies as well as preserve clean and sterile items in it (Miller). Figure 19 gives examples of these carts.

Figure 19. Example of a company's different case cart systems

Modern operating rooms have implemented case cart system, increasing their efficiency by saving time, space, and money. The basics of a case cart system can be implemented into this project's ambulance system to take advantage of its benefits.

3.4 Solidworks Design

For the basic design, we decided to model our unit roughly after the German Mobile Intensive Care Unit ambulatory vehicles (or M-ICUs) currently in circulation overseas. Some of the equipment varies, as our unit is intended for urgent surgical and trauma care, rather than for more sustained and terminal care.

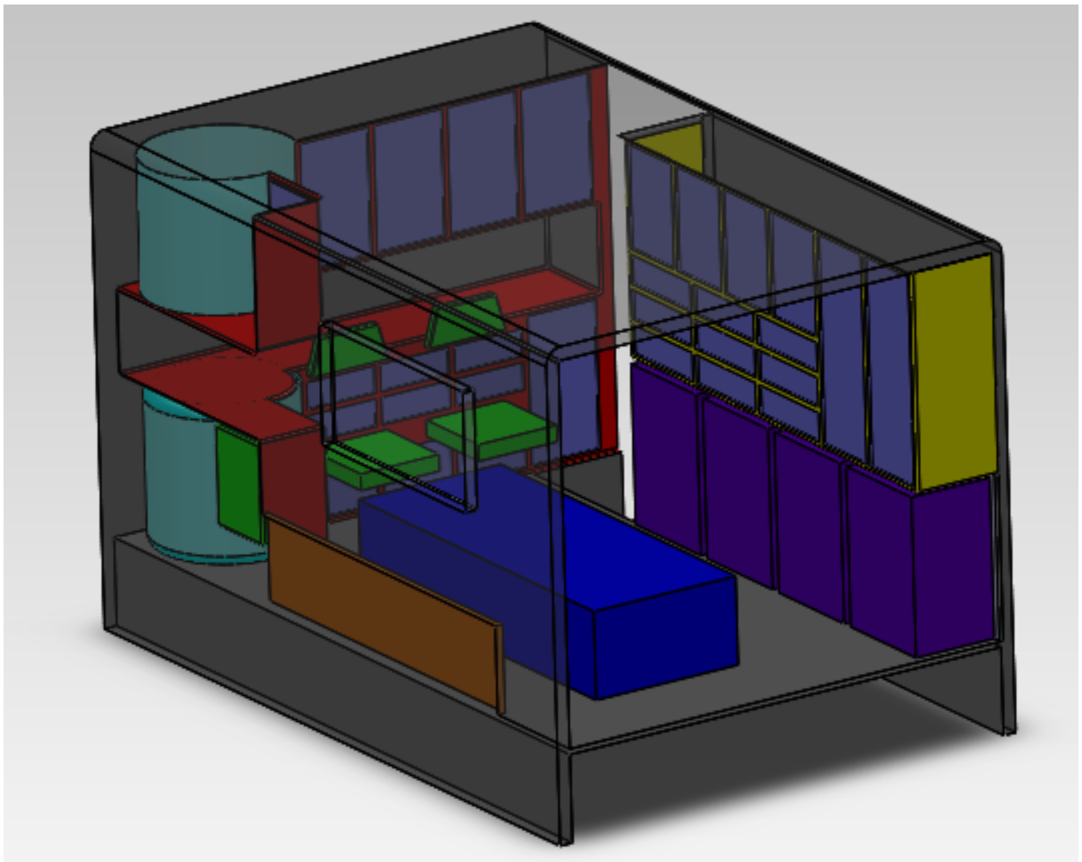

Figure 20: Solidwords design of the RECAS unit interior cabin

3.4.1 Cabinetry and overall design

The RECAS team decided that in order to be able to fit all of our equipment and supplies that are supplementary to an American ambulance, we would have to redesign the interior of the ambulance. First, we gutted the entire interior and redesigned the cabinetry types and locations. We decided to include a combination of sliding doors, full cabinet doors, and drawers for storing various supplies. The drawers and cabinets with full doors are to be used for supplies needed while the ambulance is stopped (namely surgical supplies, back boards, the stair chair, etc.), while the cabinets with sliding doors will be used to store supplies necessary during transport. In comparison to the existing layout, we added more cabinetry and utilized the space more efficiently. The spacing of the cabinetry also allowed for optimal usage of the exterior cabinets, not seen from the interior cabin.

As can be seen on the left side (facing into the ambulance from the rear doors), there are no cabinets. This space is reserved for imaging equipment implemented (listed in Section 3.2). We decided to mount the X-ray unit on the wall (as seen in Figure 21), with the imaging crane accessible from the ceiling. On this side, we have knocked out most of the current storage cabinets (with the exception of an externally accessible storage cabinet for a backboard and stair chair). Any electrical wiring for the x-ray and any other equipment will be stored behind the wall of the interior cabin; thus, the wiring is both out of the way during treatment and accessible from the outside of the ambulance for maintenance.

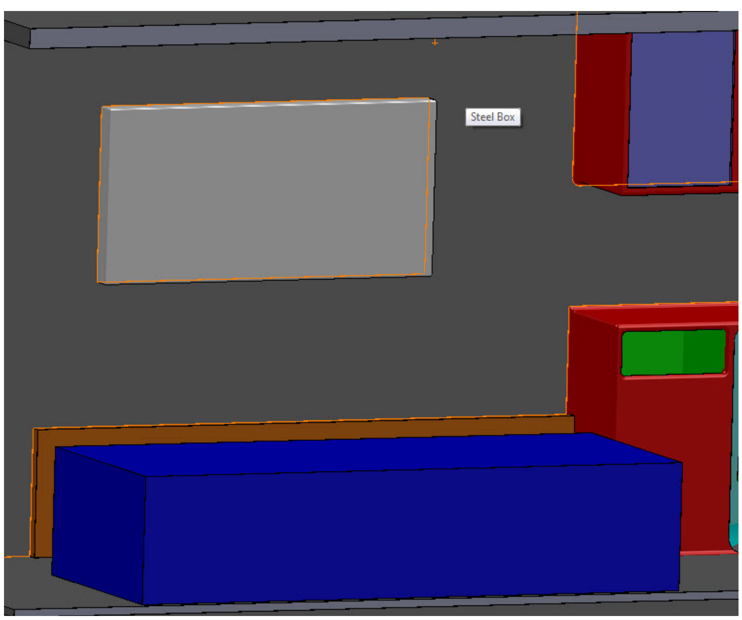

Figure 21: Solidwords design of the RECAS unit left side of cabin (X-Ray machine and stretcher)

On the opposing side, we have removed the bench currently implemented for the transport of a second patient. In the absence of a second patient in need of transport, the bench is used for patient accessibility by EMTs and the occasional transport of a ride-along, such as a family member. On this side, we placed some cabinetry for supplies needed for treatment during transport. These supplies need to be at a height that is reachable and easily accessible for paramedics. An important edition, which can be seen in purple in Figure 20, is the case carts – which will be discussed in further sections.

During examination of the current cabinetry design of American ambulances, two major concerns were presented. We found that a) it was difficult to clean biohazard waste from them, and b) it was difficult to restock supplies. This will be addressed by changing the materials used, as well as by the implementation of rounded corners. As few crevices as possible is also encouraged in order to ensure ease of cleaning, while the case cart system is intended to ease the burden of restocking between uses.

To the front of the ambulance, as our SolidWorks design demonstrates (in Figure 22), we plan to include cabinetry namely for equipment and supplies for stationary trauma care. There will also be a countertop along this wall between the upper and lower cabinets to allow for a working space for the paramedic and surgical staff to set up tools. This would be used instead of a surgical tray, as we want to minimize the number of free-moving components within the workspace.

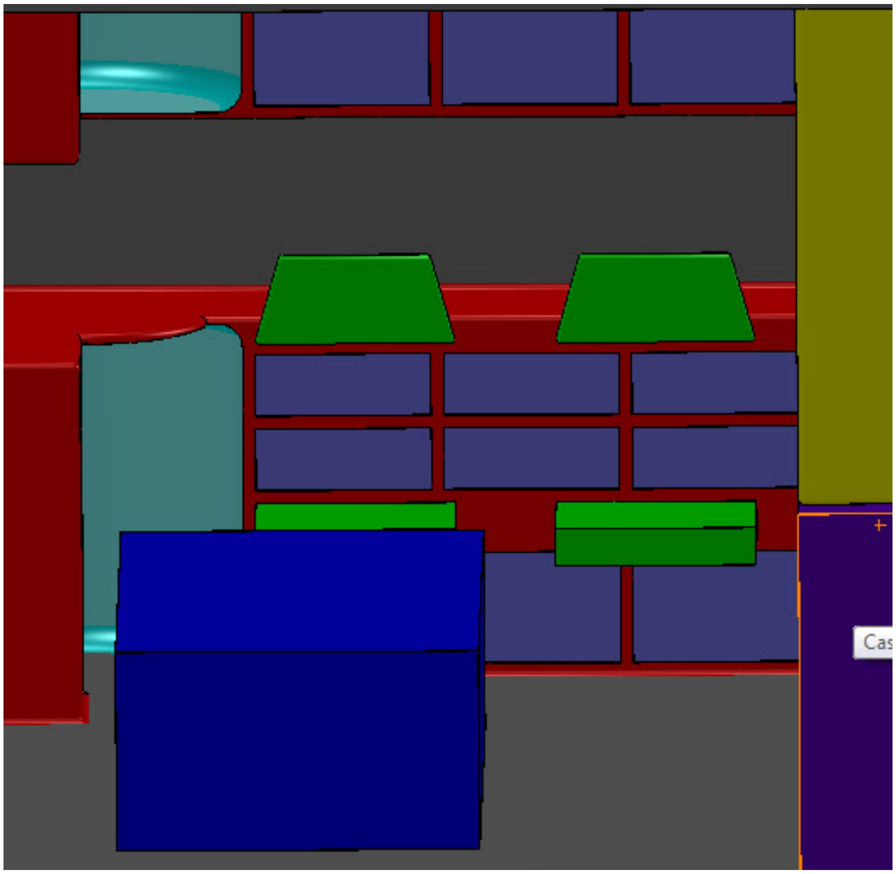

Figure 22: Solidwords design of the RECAS unit front of cabin

3.4.2 Cabinetry Doors

Cabinetry doors were also redesigned. In our new design, the doors will slide upwards, not unlike a garage door, into the interior of the cabinet, hidden when open. These rectangular metal pieces, once assembled, will be covered in a thin, malleable plastic, for cleaning purposed.

3.4.3 Seating and Stretcher

We thought about creating a track for which the surgical chair out after deliberation over space concerns as well as paramedic mobility, we decided that the track might pose more of an obstacle than a helpful accessory. Concern was expressed about tripping over the track, and we decided surgical procedures would be best performed while standing and that most procedures in transport could be performed while standing or from the CPR chair.

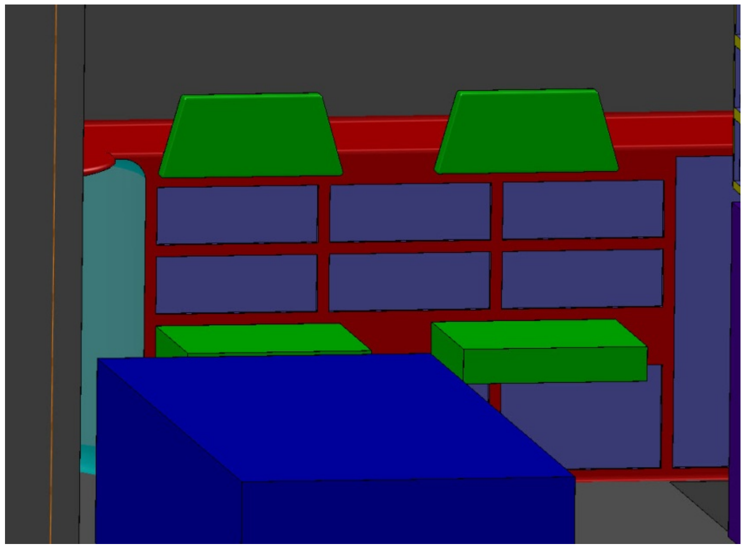

Figure 23: Solidwords design of the RECAS unit chairs and stretcher

For the CPR chair, we have the back mounted along the side of the counter while the seat itself pulls out from inside the counter (as seen in Figure 23). This retractable feature to the chair allows for more operative space while the unit is not in transport. We added a second chair next to the CPR chair for a second paramedic/surgeon to sit while the unit is in transport.

There is only one stretcher/bench in the ambulance, since our unit is not intended for quick transportation but rather stationary treatment and more intensive care. In cases of multiple trauma patients, a second ambulance would be dispatched, as later discussed.

3.4.4 Case Carts

Perhaps the most important aspect of our design is the implementation of the case cart system. These can be seen in the color purple in Figure 20 (and in Figure 24 below). One major benefit of including the case cart system is their organization of supplies by procedure and their mobility/accessibility to whoever is actively performing surgery. The cart may be wheeled over to the patient and the top may even be utilized as a surgical tray.

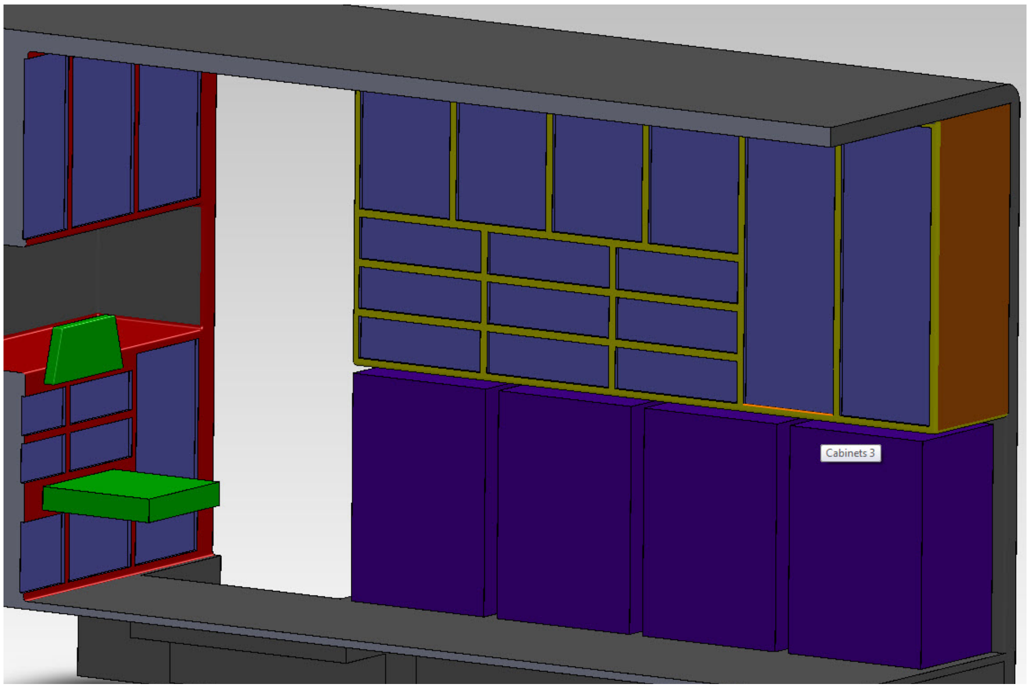

Figure 24: Solidwords design of the RECAS unit case cart wall

Another major advantage of the case carts is the ease in which they allow supplies to be replaced and restocked. Instead of being limited to the confines of the ambulance during restocking, these carts may be separately rolled out, sanitized, and restocked as deemed necessary.

When the ambulance is in motion, the carts lock in place safely below the yellow cabinets in Figure 20. To lock the cabinets, we did look into utilizing magnets, though concerns were expressed over resulting interference with the imaging equipment. Rather, we plan to have a door that slides down in front of the cabinets (much like a piano cover or a garage door) and locks to the floor. Contaminants may be of concern with a device such as this, but a way to remove the door could be developed (to better clean any crevices). Also, many of the other crevices and areas of concern (in regards to contaminants) have been removed, so from a sanitary perspective, our design is already much more suitable for a surgical environment.

3.4.5 Lighting

All lighting, not included in our initial design, will follow current regulation for medical treatment. Regulations can be seen below:

"Trans 309.16 Interior ambulance lighting. (1) *DRIVER COMPARTMENT. The driver compartment shall be equipped with a dome lamp, instrument panel lamps and indicators, master switch panel or console lamps and door−open indicator. The lighting shall be designed and located so that no glare is reflected from surrounding areas to the driver's eyes or line of vision from instrument and switch control panels or other areas that are illuminated while the vehicle is in motion.*

(2) *PATIENT COMPARTMENT. The patient compartment shall be equipped with overhead or dome lighting and switch panel lighting. Only white colored lamps or lenses may be used in the patient compartment. Patient compartment lights shall be automatically activated when the entrance doors are opened or when otherwise controlled by the driver's master switch. Interior light fixtures may not protrude more than 1.5 inches. Fluorescent lights that operate on 12 volts may be used, but they may not extend more than 4 inches from the mounting surface. Fluorescent fixtures may be mounted at the intersection of the ceiling and walls, and shall be equipped with removable covers that positively lock in place.*

(3) *ILLUMINATION LEVELS. Normal illumination in all patient areas shall be not less than 15 foot candle intensity measured along the entire center line of the clear floor without any outside ambient light. The primary cot and squad bench shall be provided with 35 to 55 foot candles of illumination measured on at least 90% of their surface. Lighting levels shall be controlled by the EMT with switches or with a fireproofed underwriter's laboratory approved rheostat."*

(Department of Transportation, 2009)

3.4.6 Materials

The materials used to build, as well as the design, were chosen in order to prevent contamination as much as possible. We tried to avoid making as many seams as possible, so there are few places for bio-hazardous waste to reside. Materials chosen are easily sterilized. Possible materials include: stainless steel, durable plastic, etc. In using plastics, however, we would have to make sure the plastic is not porous, as pores would allow for absorption of biological wastes and contaminants.

3.4.7 Waste

Waste disposal is now secured to completely avoid projectiles, as can be seen on the red cabinet in Figure 20. Waste enters the disposal system through an opening in the counter, and into a bin, which can be accessed once the vehicle is stationary. Separate containers for biological, paper, and miscellaneous wastes. A sharps disposal container would also be mounted on the counter for any needles and syringes.

3.4.8 Safety

All sharps were rounded in the interior – cabinetry corners are rounded as well as padded. Overhead storage was limited to light items that will be used in a limited manner. Both the case carts and various bins inside the cabinet are secured.

Some sort of harness would be implemented on both paramedic chairs. We would also have an insert to fill in the stairs next to the side door during surgery. While this drop can be dangerous during transport, the presence of stairs presents particular concern during surgery. The last thing we would want would be for a surgeon or paramedic to trip down the steps with a scalpel or needle in hand.

3.4.9 Sterility and Health Safety

Wall and counter corners were also filleted to avoid sharp corners that are difficult to clean. Surgical tools would be switched out and replaced with sterile, packaged tools after each use. Biological wastes would be disposed of promptly and properly after each transport. The unit would also be hosed down and properly sterilized between uses. As the highest rate of surgical complications is due to infection, sterility and infection prevention is a top priority in our unit. In trauma care, a sterile environment should be a top concern regardless, as open wounds leave patients particularly vulnerable.

One aspect that could be more fully developed would be an airflow system. As mentioned in our preliminary research, operating rooms rely on a laminar airflow system to remove airborne contaminants from the surgical environment and to maintain a comfortable temperature. We plan to adapt a similar airflow system in our unit. While the system in an ambulance is far more open than the system in an operating room environment, an airflow system may still be maintained to a degree to at least reduce air borne contaminants even if the unit's air flow cannot be fully controlled.

3.5 Equipment and Supplies needed

Equipment and supplies needed can be seen in Appendix A.

Chapter 4: Discussion, Considerations, and Conclusions

4.1 Discussion: Multiple Cases

While our ambulance is partially intended to respond to traumatic events with multiple wounded (such as a car accident), we have sufficiently discussed and decided against the inclusion of this additional bench. Depending on the situation, we would like to avoid ride-along kin or at least limit their accompaniment a ride-along in the passenger's seat only (next to the driving paramedic). In a case of multiple casualties, we would only transport one patient within the RECAS unit. Another ambulance would instead be dispatched. Depending on the severity of the incident, one of the following options may be selected to address injuries to multiple trauma patients.

4.1.1 Scenario One

Surgically treat Patient A in the RECAS-unit and transport to hospital in the supporting ambulance. After Patient A is surgically treated, Patient B would be surgically treated and transported within the RECAS-unit. This option seems optimal for casualties that require some immediate treatment (beyond basic fluids and care currently administered); Patient A, theoretically, would present more severe initial injuries or would require more immediate follow-up than Patient B.

4.1.2 Scenario Two

Surgically treat and transport Patient A in the RECAS-unit while Patient B is treated and transported in the supporting ambulance. This option would be implemented if Patient B's injuries/ailments are less severe and can survive transport OR if Patient B's trauma is deemed too severe and requiring treatment that is considered too extensive for what can be provided on scene.

4.1.3 Scenario Three

Surgically treat Patient A (with more severe injuries) in the RECAS-unit while using tools from our surgical ambulance to treat Patient B in the supporting unit. The patients would then be transported separately in the respective ambulances in which they were treated. Where Patient A's casualties are more severe, we would treat them in the fully supported surgical unit in case of need for follow-up treatment en-route. The one concern here would be the maintenance of sterility in treating Patient B. With the case cart system, however, tools would be contained in packaging designated by procedure, similarly to current case cart systems implemented in Emergency Rooms/Trauma Care Centers (i.e. a Thoracotomy kit).

4.1.4 Scenario Four

In cases of catastrophic events, such as 9/11, the unit would be dispatched to treat multiple patients. Patients would be consecutively treated on scene then transported for follow-up care. The hope is that more patients could be saved with the promptness of on-scene treatment though measures would have to be taken between patients to ensure the continuation of a sterile environment.

4.2 Considerations

4.2.1 How will the RECAS unit function at 90% success?

Considerations that have not been addressed by the RECAS team are those pertaining to what would require a 90% success rate of this vehicle. Something to consider is how many would be required in order to function in a high demand area (e.g. a highly populated city). In order to calculate the amount of RECAS units required, studies should be done both on the current ambulance dispatch system in America as well as the dispatch system, per unit of population, in Germany where the NEF, the German equivalent of the RECAS unit, is already implemented. An analysis of the types of calls made to dispatch call centers should also be done, in order to analyze the demand for a vehicle of this type. The location of acute trauma locations should be considered during dispatch studies.

4.2.2 Sterilization of Reusable Equipment

The RECAS team set a project objective to decrease waste wherever possible in the RECAS unit, which resulted in the team aiming for the implementation of sterilizable equipment in the unit, rather than disposables. However, this might pose a potential problem. First, the team would have to assure that the hospital, which the RECAS unit is in collaboration with, has an autoclave, or a similar sterilizing device, that could be of use to the RECAS unit. Another factor to consider is the cost of non-disposable equipment versus disposables. In general, disposable equipment is significantly less expensive than non-disposable. Take an incubation kit, for example. A metal, non-disposable incubation kit can cost upwards of $3000, depending on the manufacturer. A plastic, disposable incubation kit, however, only costs around $3 per unit, depending on the manufacturer. Simply, the non-disposal unit is 1000 times more expensive than the disposable – a large, one-time investment. However, the one-time expense may be beneficial, based upon how often a unit of this type is used. Further analysis should be done in order to determine the value of a system of this type. While this system may be more expensive, it greatly reduces the medical industry's impact on the environment.

4.2.3 How will this function within the framework of the United States insurance Agency?

The RECAS unit functions as a municipal ambulance, meaning that the town pays for and provides its citizens with the ambulatory service. The other type of ambulance is owned by a private company that would offer the service in instances such as transporting a patient from the hospital a nursing home. Towns used to supply not only the ambulances to its citizens, but also cover the cost of treating them. Over time, the equipment and the personnel that made up an ambulatory unit, make it a lot more expensive. Patients who use these ambulances are now charged for the service, which, if the patient has insurance, the insurance company will cover the bill. However, if the insurance company classifies the ambulance use as for a non-emergency situation, they will not cover the medical costs. Since the entire purpose of the RECAS unit is to only be used in emergent situations, insurance companies would cover the service according to their patient's medical plan. With more advanced equipment and personnel in the RECAS unit, it costs significantly more than a traditional ambulance. The town or city suffers this large cost to provide the service. Therefore, many towns might not be able to afford this service, or cutbacks might need to be made to other areas of the EMS systems.

4.3 Conclusion

In conclusion, the RECAS unit would be a mobile, pre-hospital environment that, through it's implementation of imaging technology, advanced equipment, and better-trained personnel, would allow for the performance of more in-depth procedures. With this unit, we hope to reduce hospital overcrowding, create national-emergency non-hospital care, as well as improve the care of patients overall by decreasing overall time of care. This unit should be implemented in areas where call screening is prevalent in the United States for daily use, as well as through military use in 2nd world countries where hospitals are few and far between. Because this is only an Interactive Qualifying Project, limited time and lack of budget led to further research needed. For example, in-depth examination of the United States insurance system should be done in order to conclude whether or not this unit is viable within this country's framework. Dispatch types and locations should also be analyzed in order to assess where a unit of this type should be put into use.

Appendix A

The following tables were obtained from Mass General Hospital of Boston, Massachusetts.

Table 7: Inventory list of an emergency Burn Case Cart

Shelf	Item	Quantity	Quantity Found	Location
1	Half Sheets	6		CSR
	Burn Vests	3		CSR
	Sterile Saline Bottles	4		CSR
2	Butt Pads	2		CSR
3	Small Burn Packs	4		CSR
	Large Burn Packs	2		CSR
4	Large Sterile Basins	2		CSR
	OR Towels	4		CSR

Table 8: Inventory list for emergency Chest Tube Case Cart

Drawer	Item	Quantity	Quantity Found	Location
1	Microfoam	1 box		CSR
	Petrolatum Gauze	1 box		CSR
	Chest Tube Connectors	20		UrgA CSR
	Y connectors	20		UrgA CSR
	0 Silk Suture	1 box		Acute CSR
	Skin Markers	5		CSR
2	Tube Thoracostomy Kits (27059)	6		CSR
3	Wayne Pnuemothorax Kit	4		SP1
	Rubber tubing	1 roll		CSR
4	Chest Drainage Units	3		UrgA/CSR
	Auto Transfusion Units	3		UrgA/CSR
Cart sides	Chest Tubes: 20, 24, 28, 36	10/ea		UrgA/CSR; 36 in SP

Table 9: Inventory list for emergency Difficult Airway Case Cart

Drawer	Item	Quantity	Quantity Found	Location
Left Side of Cart	**Boujies**	2		SP2
Right Side of Cart	NP (Nasopharangeal) Scope	1		Contact J. Texeira
	Adult Storz Bronchoscope	1		Contact J. Texeira, extra in SP2
	Pedi Scope	1		Contact J. Texeira
1	12 mL Monoject Syringe	6		Respiratory
2	Clickline Luer Plug w/ Strap	1 bag		Contact J. Texeira
3	Scope Eye Adapter	1		Contact J. Texeira
	Portable Light Source	1		Contact J. Texeira
4	Bronchoscope Adapter	5		Urg A CSR
5	**10 mL Syringes**	6		CSR
6	Atomizers	6		Contact J. Texeira
7	Storz Suction Valves	1 bag		SP2
Drawer 1	Camera w/ Cable	1		Contact J. Texeira
	Fiber Optic Light Cables (Male-male, male-female)	1/ea		Contact J. Texeira
	Video Macintosh Laryngoscope Blade	1		Contact J. Texeira
2	Oral Airway # 5	3		CSR
	Oral Airway # 2	2		CSR
	Oral Airway # 0	1		CSR
	Nasal Airway (#22, 24, 26, 28, 30)	1/ea		SP2
	Laryngoscope Blade (Miller, #0-3, Macintosh, #0-4)	1/ea		Acute CSR
	Laryngoscope Handles (Adult, Pedi)	1/ea		Acute CSR
	Stylette (Adult, Pedi)	2/ea		CSR
	CO2 Detector (Adult, Pedi)	1/ea		CSR
	Magill Forceps (Adult, Pedi)	1/ea		Urg A CSR

	Endotrachial Tubes (Uncuffed, 2.5)	1/ea		CSR
	Endotracheal Tubes (Cuffed, 3.0-9.0)	1/ea		CSR
3	**Laryngeal Mask Airways (LMA, #1, 1.5, 2, 2.5, 3, 4, 5)**	1/ea		SP
4	Intubating Laryngeal Mask Airway (ILMA, #3, 4, 5)	1/ea		SP2
	Retrograde Intubation Set	1		Contact J. Texeira
	Jet Ventilator	1		Contact J. Texeira
	Melker Cricotomy Catheter Set	1		SP
	Open Cric/Trach Kit w/ Scalpel (#10)	1		CSR

Table 10: Inventory list for emergency Ear, Nose and Throat Case Cart

Shelf	Item	Quantity	Quantity Found	Found in
Top (1)	30ml Syringes	10		CSR
	Primary IV/15	5		CSR
	Saline Bottles 500mL	5		CSR
	Saline 1000mL	4		CSR
	Splash Guards	20		SP
2	**Epistat Nasal Catheters**	4		SP
	Nasal Septal Splint	1		SP
	Vaseline Gauze 1x36	1		CSR
	Vaseline Gauze 3x36	8		CSR
	Vaseline Gauze 3x18	6		CSR
	Flexible Ear Curettes: infant & adult	1 box		SP
	Gauze Eye Patches	2		SP
	Merocel Pope epistaxis packing:10cm	1 box		SP
	Pope Ear Wicks: 24mm	1 box		SP
	Saline Fish	20		CSR
	pH paper (expires yearly)	1 roll		J. Texeira
	Rhino Rockets	1 box		J. Texeira
3	Tongue Depressors	1 box		CSR
	Bacitracin/Triple Antibiotic	1 box		CSR
	Silver Nitrate Sticks	2 tubes		CSR
	Cotton Tipped Applicators	1 box		CSR
	Head Lamp	1		J. Texeira
	Nail Clippers	1		J. Texeira

	Cotton Balls	1 bag		UrgA CSR
	Battery Powered Cautery	18		SP
Bottom	2”x2” gauze sponges	1 box		CSR
	4”x3” gauze sponges	1 box		CSR

Table 11: Inventory list of emergency Obstentrics and Gynocology Case Cart

Drawer	Item	Quantity	Quantity Found	Found in
1	**Word Catheters**	6		SP2
	PH Paper	1 Roll		SP2
	Light Source	1		SP2
	Light Bulbs	10		SP
	Flash Light	1		CSR
	Sponge Holding Forceps	2		Urg A CSR
	Rochester Pean Forceps	2		Urg A CSR
	Lab Forms (Notice to Parents)	Multiple		Screening
	Tenaculum	1		Urg A CSR
2	**Formalin Jars**	5		Urg A CSR
	Surgilube	Multiple		CSR
	Karman Cannula 4, 5, 6, & 7 mm	3/ea.		SP2
	Scopettes	7 packs		SP2
	iPas Syringe Kit	2		SP2
	Blood Tubes	10		Urg A CSR
	GenProbe Combo 2 Assay Swabs	5		SP2
3	Speculum Sm,, Med., & Lg.	5/ea.		SP
	Condoms	10		SP2
4	Maternity Pads	1 bag		CSR
	Mesh panty	1 bag		Urg A CSR
	Sanitary Belt	2		Urg A CSR

Table 12: Inventory list for emergency Innerspace IV Case Cart

Top of Cart:	Item	Quantity	Quantity Found
	Emesis Basins	10	
1	Surgilube	25	
	Med Label	1	
	Bandaids	1 box	
	2 x 2	½ box	

	Alcohol Wipes	1 box	
2	Surgical Clipper Heads	5	
	Red Dots	10 pkgs.	
	Specimen/Micro Bags	20	
	IV Start Paks	10	
	Emesis Bags	6	
Drawers			
# 1: IV's			
	10 mL Saline Flush	10	
	Autoguard Insights – 14 G and 16 G	4/ea	
	Autoguard Insights – 18G, 20G, 22G, 24G (.75 in)	10/ea	
	Microclave Connectors	10	
	Male/Female Sterile Caps	5	
	IV Extensions	5	
	Antibiotic Ointment	20	
# 2: Phlebotomy			
	Vacutainer Butterflies (21 and 23 G)	5/ea	
	Vacutainer Holder	20	
	Vacutainer Transfer Needles	25	
	Blood Tubes (Green , Purple, Blue, Yellow, L.Red, L.Purple, Grey)	10/ea – 20/ea Small Purple and Green Tops	
	Tape (Cloth)	1/ea	
	Tape (Plastic)	2	
#3:Suction/ Tegaderm/ Safety Needles			
	18, 20, 22 G Safety Needles	5/ea	
	5 and 10 mL Syringes	5/ea	
	3 mL Syringes	15	
	Filter Straws	5	
	Insulin Needles Tipped	5	
	Sputum Traps	2	
	Yankauer Suction Tubes	2	

	12 & 14 FR Suction Catheters	2/ea	
	Tegaderm	25	
# 4: Respiratory			
	Adult Nasal Cannula	5	
	Adult/Pedi Non-rebreathers	3/ea	
	Adult/Pedi Nebulizers	3/ea	
	Peak Flowmeters	2	
	Saline Fish	20	
# 5: Miscellaneous			
	Yellow Tops	10	
	ABG Kits	3	
	Blood Culture Bottles	3/ea	
	Chloraprep	5	
	Iodine Swab Sticks	5	
	Blood Culture Kits	5	
	Black Tops	10	
	Q-tips/Tongue Depressors	10/ea	
	Culture Swabs	5	
	UA Specimen Cups	4	
	Castille Soap Packets	20	
	4 x 4 Gauze Sponges	4	
	Tourniquet	1	
	CLEAN/NEW Hemoccult Developer/Slides	2	
# 6: IV Fluids			
	1000 mL Normal Saline Bags	8	
	Secondary IV Sets	4	
	Sigma Tubing	5	
	Primary IV Sets	6	

Table 13: Inventory list for Pacer Box Case Cart

	Item	Quantity	Quantity Found	Location
	Temporary Pacing Balloon-Tipped Electrodes (Temp. Wires) 5 FR	2		SP2

	Arrow PSI Kits ("Cordis Introducer Sheaths") 6 FR	2		SP2
	Pacer Magnet	1		Contact John Texeira
	Pacing Boxes (Pacing box must also include charged 9V battery)	2		Contact Biomed (X41333) or Resp. Supervisor on Weekends (Pgr.24225)
	9 volt battery	2		Urg. A Clean Supply Room – **PLEASE MAKE SURE THE BATTERIES ARE TAPED TO THE INSIDE OF THE TOP OF THE PACERBOX**
	Disposable Extension Cables	2		UrgA CSR

Table 14: Inventory list of emergency Procedures (conscious) Sedation Case Cart

Drawer	Item	Quantity	Quantity Found	Location
1	**IV Start Pack**	4		CSR
	Alcohol Wipes	10		CSR
	Microclave Connectors	10		CSR
	Autoguard Insyte: 18, 20, 22, 24 (.56 & .75)	5/ea		CSR
	10mL Syringes	10		CSR
	Vacutainer Holders	10		CSR
	Medication Labels	1 roll		CSR
	Tegaderm	30		CSR
	3mL Saline Flush Syringe	10		UrgA CSR
	Skin Markers	10		
	Vacutainer Butterflies 21&23g.	5/ea		CSR
2	Primary IV/15 drop	10		CSR
	Saline Bag/100ml (4pk)	3		UrgA CSR
	Saline Bag/250ml	4		UrgA CSR
	Saline Bag/1000ml	4		CSR
3	**Red Dot Electrodes**	15 packs		CSR
	Yankauer Suction Tubes	6		CSR
	Grey & Brown Leads	1/ea		Equip.Room.
	BP Cable	1		Equip.Room.
	Reusable O2 Sat Cable	1		Equip.Room.
	Oral Airway: 0, 2, 5	4/ea.		CSR

	Nasopharyngeal Airways: 22, 24, 26, 28, 30	4/ea		SP2
4	BP Cuff: Child & Infant (with and without bulb)	1/ea		CSR
	BP Cuff: Adult long & Adult large	1/ea		CSR
	BP Cuff: Adult Small & Adult Regular with and without bulb	1/ea		CSR
	Disposable O2 Saturation Probe: adult & pedi	2/ea		CSR
	Reusable O2 Saturation Probe	1		UrgA CSR
5	Ambu bag: Infant, Pedi, Adult	1/ea		CSR
	Ambu mask: neonatal, 1, 2, 3	2/ea		UrgA CSR
	Non-rebreather (adult)	2		CSR
	Non-rebreather (pedi)	2		UrgA CSR
	Nasal CO2 cannula (adult)	2		CSR
	Nasal CO2 cannula (pedi)	2		UrgA CSR
	Infant nasal cannula	2		UrgA CSR
	O2 Face Mask (infant, pedi)	2/ea		UrgA CSR
	O2 Face Mask Adult	2		CSR
Sides	Grey & Brown leads	1/ea.		Equip.Room.
	Reusable O2 Sat cable/probe	1		Equip.Room.
	Tape (all types)	2/ea.		Equip.Room.
	Procedure Sedation Policy	1		J. Texeira

Table 15: Inventory list for Procedure Case Cart

Drawer	**Item**	**Quantity**	**Quantity Found**	**Location**
1				
	Face Masks	5		CSR
	Sterile Gloves (6, 6.5, 7, 7.5, 8, 8.5)	2/ea		CSR
	Suture Removal Kits	4		CSR
	Stapler Remover	2		CSR
	Steri-Strips	2/ea		CSR
	Benzoin Tincture	2		CSR
2				
	Shurclens	5		SP1
	Chloraprep	5		CSR
	Betadine Solution	2		CSR
	Bacitracin	25		CSR
	10 mL Syringes	5		CSR

	Needles (18G, 20G, 27G Long)	5		CSR
	Xeroform Gauze	5/ea		CSR
	Scalpels (11 Blade and 15 Blade)	2/ea		CSR
	Wound Culture Swabs	5		CSR
<u>3</u>				
	500cc Sterile NS	4		CSR
	60 mL Syringes	5		CSR
	Zerowets	5		SP1
	Hydrogen Peroxide	5		CSR
	4x4	4		CSR
	2x2	10		CSR
	Kerlix	3		CSR
	Tube Gauze	1		CSR
	Tube Gauze Applicator	1		Contact J.Texeira
	Tape (paper/micropore 1 in)	3		CSR
<u>4</u>				
	Suture Materials • 4-0/5-0/6-0 Ethilon • 3-0/4-0/5-0 Vicryl • 3-0/4-0/6-0 Prolene • 4-0 Chromic Gut • 5-0/6-0 Fast Absorbing Plain Gut	1 bx/ea		Acute CSR
	Staple Gun	3		CSR
	Sterile Bowl	3		CSR
	Wound Packing Gauze (Plain and Iodoform, both sizes)	2/ea		CSR
<u>5</u>				
	Suture Kits	4		CSR
	Sterile Towels	2		CSR

Table 16: Inventory list for emergency Trauma Case Cart

Drawer	Item	Quantity	Quantity Found	Location

1	Cric Kits	3		UrgA CSR
	Thoracostomy kits	3		Acute CSR
	Kelly clamps	2		UrgA CSR
2	Adult, Infant, & Pedi Paddles	1/ea.		Central Reprocessing
	30 fr. 30cc balloon Foley cath	2		UrgA CSR
3	DPL kits	2		Central Reprocessing
	0 Silk	1 box		Acute CSR
	2-0 Prolene	1 box		Acute CSR
	3-0 Vicryl	1 box		Acute CSR
	Cardiac Pledgettes	10 pack		SP2
	Cardiac Pacing Suture	1 box		Acute CSR
4	Cut Down Tray	2		UrgA CSR
	T-POD	1		SP1
Side	Thoracotomy Trays	2		UrgA CSR
	36Fr. Chest Tubes	10		SP

Table 17: Inventory list for Broselow Case Cart

Drawer	**Item**	**Quantity**	**Quantity Found**	**Location**
1	**Autoguard Insyte 20, 22, 24 (.56 & .75 in 24g)**	5/ea		CSR
	Microclave Connector	3		CSR
	Blood Draw Tubes (PGrGoB)	3/ea		CSR
	Microtainer "bullets" (PGrR)	10/ea		SP
	3ml saline flush syringes	5		UrgA CSR
	Broselow tape	1		J. Texeira
	Arterial blood sample syr. 3ml	5		SP
	Jamshidi IO Needle	2		SP
	Pedi Blood Cult. Bottles	2		CSR
	IV Start Pack	5		CSR
	Pedi EKG electrodes	5		CSR
	Kitty Kat EKG electrodes	5		CSR
	Neonatal EKG cable	1		J. Texeira
	Arm boards (various sizes)	2/ea		CSR
	Masimo infant, neonate & pedi O2 Sat. probes	2/ea		Expensive Eq. Cart Acute
	Reusable Pediatric SP02 probe	1		J. Texeira
	Tape (cloth, plastic, no stick)	1/ea		CSR

	Porta-Warm Mattress	1		UrgA CSR
	Catheter Adapter	5		UrgA CSR
	Pedi Yankauer suct. Catheter	1		CSR
2	ET tubes uncuffed, 2.5; cuffed 3.0, 3.5	1/ea		CSR
Pink	Feeding (NG) tubes – (6, 8 fr.)	2/ea		SP2
2	Pedi Stylette	1		CSR
Cont'd	Suction Catheter (8 fr.)	5		CSR
	Bulb Syringe	1		UrgA CSR
	Laryngoscope Handle	1		Acute CSR
	Mil. Laryngoscope Blade 0, 1	1/ea		Acute CSR
	Oral Airway, Sz. 0	1		CSR
	Ambu masks, Sz. 1, 2	1/ea		UrgA CSR
	Infant nasal cannula	2		UrgA CSR
	Pedi non-rebreather	1		UrgA CSR
	ET CO2 detector, pedi	1		CSR
	LMA sz 1, 1.5	1/ea		SP
	Foley Catheter (5fr.)	2		SP
	BP cuff, infant: w/&w/o bulb	1/ea		CSR
3	ET tubes, cuffed 4.0	1		CSR
Purple	Feeding (NG) tubes (8, 10 fr.)	2/ea		SP2
	Pedi Stylette	1		CSR
	Suction Catheter (10 fr.)	5		CSR
	Bulb Syringe	1		UrgA CSR
	Laryngoscope Handle	1		Acute CSR
	Laryngoscope blade, Mill. 1	1		Acute CSR
	Oral Airway, 2	1		CSR
	Ambu Masks, 1, 2	1/ea		UrgA CSR
	Pedi nasal cannula	2		UrgA CSR
	Pedi O2 mask w/ tubing	1		UrgA CSR
	Pedi non-rebreather	1		UrgA CSR
	LMA 1.5 &2	1/ea		SP
	Pedi ET CO2 Detector	1		CSR
	Foley Catheter, 8 & 10 fr.	2/ea		SP
	BP cuff, infant: w/&w/o bulb	1/ea		CSR
4	ET tubes, cuffed 4.5	1		CSR
Yellow	Feeding tubes, 10 fr.	2		SP2
	Pedi Stylette	1		CSR
	Suction Catheter, 10 fr.	5		CSR
	Laryngoscope handle	1		Acute CSR
	Laryngoscope blade, Mil. 1, Mac 1	1/ea		Acute CSR
	Oral Airway, 2	1		CSR
	Ambu masks 2, 3, 4	1/ea		UrgA CSR
	Pedi nasal cannula	2		UrgA CSR
4	Pedi O2 mask w/ tubing	1		UrgA CSR
Cont'd	Pedi Non-rebreather	1		UrgA CSR
	LMA, 2	1		SP

	Pedi ET CO2 detector	1		CSR
	Foley Catheter, 10 fr.	2		UrgA CSR
	BP cuff, child: w/&w/o bulb	1/ea		CSR
5	ET tubes, cuffed 5.0	1		CSR
White	NG Feeding tubes, 10 fr.	2		SP2
	Pedi Stylette	1		CSR
	Suction catheter, 10, 12 fr.	5/ea		CSR
	Laryngoscope handle	1		Acute CSR
	Laryngoscope blade, Mill. 2, Mac 2	1		Acute CSR
	Oral Airway, 2	1		CSR
	Ambu masks, 3, 4	1/ea		UrgA CSR
	Pedi nasal cannula	2		UrgA CSR
	Pedi O2 mask w/ tubing	1		UrgA CSR
	Pedi non-rebreather	1		UrgA CSR
	LMA, 2	1		SP
	Pedi ET CO2 detector	1		CSR
	Foley catheter, 10, 12 fr.	2/ea		UrgA CSR
	BP cuff, child w/&w/o bulb	1		CSR
6	ET tubes cuffed 5.0, 5.5	1/ea		CSR
Blue	Salem Sump 12, 14 fr.	2/ea		CSR
	Adult Stylette	1		CSR
	Suction Catheter 10 fr.	5		UrgA CSR
	Laryngoscope handle	1		Acute CSR
	Laryngoscope blade Mac2,Mill2	1/ea		Acute CSR
	Oral airway 2	1		CSR
	Ambu Masks 3, 4	1/ea		UrgA CSR
	Pedi Nasal Cannula	2		UrgA CSR
	Pedi O2 mask w/ tubing	1		UrgA CSR
	Pedi non-rebreather	1		UrgA CSR
	LMA 2, 2.5	1/ea		SP
	Pedi ET CO2 Detector	1		CSR
	Foley Catheter 10-12fr.	2/ea		UrgA CSR
	BP cuff, child: w/&w/o bulb	1		CSR
7	ET tubes cuffed 5.5, 6.0	1/ea		CSR
Orange	Salem Sump 14-18 fr.	2/ea		CSR
	Adult Stylette	1		CSR
7	Suction Catheter 10 fr.	5		CSR
Cont'd	Laryngoscope Handle	1		Acute CSR
	Laryngoscope blade mac 2, mil 2	1/ea		Acute CSR
	Oral airway 2, 5	1/ea		CSR
	Ambu masks 3, 4	1/ea		UrgA CSR
	Pedi Nasal Cannula	2		UrgA CSR
	Pedi O2 mask w/ tubing	1		UrgA CSR
	Pedi non-rebreather	1		UrgA CSR
	LMA 2.5	1		SP
	ET CO2 Detector Adult	1		CSR

	Foley Catheter 10-12 fr.	2/ea		UrgA CSR
	BP Cuff Child, Small Adult: w/&w/o bulb	1/ea		CSR
8	ET tubes cuffed 6.5, 7.0	1/ea		CSR
Green	Salem Sump, 14-18 fr.	2/ea		CSR
	Adult Stylette	1		CSR
	Suction Catheter, 10-12 fr.	5		CSR
	Laryngoscope Handle	1		Acute CSR
	Laryngoscope blade mac 3, mil 3	1/ea		Acute CSR
	Oral airway, 5	1		CSR
	Ambu mask 3,4	1/ea		UrgA CSR
	Adult nasal cannula	2		CSR
	Adult O2 mask w/ tubing	1		CSR
	Adult non-rebreather	1		CSR
	LMA 2.5, 3	1/ea		SP
	ET CO2 Detector Adult	1		CSR
	Foley Catheter 12-14 fr.	2/ea		UrgA CSR
	BP Cuff, Small Adult: w/&w/o bulb	1		CSR
9	Mercury Med. Hyperinflation	1		UrgA CSR
Beige	Magnehelic pressure gauge	1		J. Texeira
	Chest tubes 12, 16 fr.	2		SP
	Nebulizer mask (pedi)	2		UrgA CSR
	Dbl lumen cent. Line 4, 5fr	1/ea		SP
	Pedi rib spreader	1		J. Texeira
	Pacifier	2		CSR
	Sweet ease	4		CSR
	Pnemopericardial drainage set, 8.5 fr.	2		J. Texeira
	O2 Tubing	1		CSR
	Pedi Magill forceps	2		UrgA CSR

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