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Reducing Noise, Contaminants and Unintended Stresses in Emergency Medical Triage Units

An Interactive Qualifying Project

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ABSTRACT

Current emergency medical departments and system triage units are confronted with frequent challenge to reduce sound levels of noise, contaminant and unintended stresses that impact the quality of patient care. These are known to be the major sources of medical vulnerability and uncertainty in pre-hospital care. The remodeling of emergency system triage units and continuous incorporation of modern technology into emergency medicine to improve patient experience and shorten hospital stays increase rewards and high quality of care. Recovery, efficiency, evaluation, diagnosis, intervention, treatment and services (REEDITS) are recognized in emergency medicine as valuable benchmarking measures of rewards and quality of care. REEDITS enables comparison to be made among standard of practices, processes and performances in the healthcare systems so as to locate the most imaginable rewards and risks. The level of noise, contaminant and unintended stresses in pre-hospital and emergency medicine must be monitored and controlled to improve the measures of the REEDITS.

The objectives of this project are to evaluate noise, contaminant, and unintended stresses in emergency system triage units and use the experience to establish ways to better improve the quality of patient care. The derived results yield an opportunity to understand the measures of acronym name REEDITS. Sound insulating machine boxes, smart materials for ambulance construction, and implementation of sound absorbing ceiling and floor tiles are identified as possible ways to improve quality of care. In order to achieve the results, the employed project methodology includes external research, internal data collection and data application. The External research methods use all non-human resources, whereas the internal data collection focus on conducting group interviews and surveys about the impact of contamination, noise and unintended stresses on the quality of care. Enhancing patient comfort, shortening hospital stay and reducing readmissions are important indicator scores for the quality of care in emergency system triage units.

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CHAPTER 1. EMS AND LIFE-SAVING PRACTICES

1. Introduction

Emergency Medical Services (EMS) plays an important role in healthcare systems in America and the world. The providers of EMS are oftentimes called Emergency Medical Technicians (EMTs) or first responders. Depending upon the level of training, education and responsibilities, EMTs in the United States and many parts of the world are classified into three main groups, namely: Basic Life Support (BLS), Intermediate Life Support (ILS) and Advanced Life Support (ALS) or paramedics. They render pre-hospital care from patient stabilization, intubation, and evaluation to transport to a hospital or clinic for extended evaluation by an emergency doctor or physician. Ambulance transport assists patients whose immediate medical needs transcend domestic resources and capabilities. Hospitals and doctors depend on EMTs to administer first response medical care and relay necessary preparatory information to best address the emergency medical situation of the sick and injured patients. Since the 1920's, there has been continued effort to improve emergency medical services or ambulance care and the professional development of EMTs. Emergency medical responders are frequently facing challenges in terms of the availability of resources and better improved workspace and environmental conditions in ambulance compartment. There are substantial data to support the need for continuous improvement of pre-hospital care and occupant safety in the ambulance compartment. The roles and responsibilities of the BLS, ILS and ALS or paramedics are interrelated activities and medical determinants aimed at providing optimal initial emergency care to the sick and injured. They provide pre-hospital evaluation and communication to a hospital or clinic how serious the medical emergency is.

This project focuses on reducing contamination, noise and unintended stresses in ambulance compartment. These EMS-related issues range from nosocomial infections to monitoring machine alert noises and vehicle vibration. They are known to have an adverse impact on the occupants in an ambulance compartment. This project has three distinct objectives aimed at understanding the specifics of proposing solutions to the everyday issues EMTs face. The project objectives are outlined as follows, (1) Examine and evaluate noise, contaminants, and unintended stress in ambulance compartment or triage units. (2) Develop methods for the control of noise, contaminants, and unintended stress in ambulance triage units. (3) Establish new ways to eradicate noise, contaminants, and unintended stress. Using these objectives as a guide, the team developed strategies which may be implemented in emergency medical care units to better improve the safety of the occupants in ambulance compartment. By applying a layer of titanium dioxide coating to ambulance interiors, cleaning the cramped space inside becomes instantly easier because the surfaces may then be sterilized with ultraviolet light exposure. Encasing ambulance supplies and consumables with plastic shields with the coatings reduces the risk of contaminants in the ambulance compartment. Reducing noise pollution in the ambulance compartment or a hospital emergency department requires installing a sound muffling casing around noisy electrical equipment, implementing sound insulating curtains between patients in heavily populated departments, and adding soundproof tiles for hospital floors and ceilings.

The project is divided into four chapters that fully account the developmental stages of the solutions. Chapter 1. EMS and Life-Saving Practices, describes the significance of EMS, the project objective and proposed solutions. In Chapter 2. EMS and Patient-Centric Quality Care advancements in pre-hospital care and the literature pertaining background are summarized. This section also compares the United States standards in emergency care practices and procedures to those utlilzed globally. Chapter 3. Methods, Procedures, and Outcomes for Contaminant, Noise Pollution, and Unintended Stress Testing, discusses possible solutions to the existing problems in each area of concern with ambulance care. A summary of the results is contained in Chapter 4. Conclusions. The analysis of the proposed methods, impact of the results and recommendations for future work are presented in this same chapter.

CHAPTER 2: EMS AND PATIENT-CENTRIC QUALITY CARE

2. Introduction

Among the entire EMSs currently serving Americans, public EMSs hold the greatest share of the market: around 60% of the emergency cases involve public EMSs. A public EMS is defined as an EMS with all employees being public workers and under public administration. The three most common structures found in the current public EMSs are: fire department based and public hospital based. In case of the fire department based structure, the EMS is a unit of the public fire department of a city or a town, and placed under the administration of the fire department. This is also known as the most common structure of the public EMS and account for about 60% of the existing public EMS. The employees of the EMS could be existing fire fighters, who get trained and certified as BLS, ILS or paramedics, or special operation paramedics with minimum or no involvement in fire fighter work[26]. The use of existing fire fighters has the benefit of eliminating the need of hiring extra workers for the fire departments, thus reducing cost; that is the reason why most fire department based EMS follow this tradition. In addition, there are many cases where an EMS- trained fire fighter, who could perform both fire fighter and EMS worker tasks, would be very helpful, most apparently in the case of fire. However, many studies indicate that special operation paramedics would provide better work in most situations[39]. No matter whether the EMS workers are existing fire fighters or special operation paramedics, they are both considered employees of the fire department, and thus they are paid and governed by the fire department. Similarly, equipment and operational cost of the fire department based EMS are funded by the fund of the fire department, like other units of the fire department.

2.1 Structure of EMS

2.1.1 EMS Services

Public EMS: Structure, operation and funding source

The EMS systems in the United States consist of a variety of components and activities which work together in providing pre-hospital care to all Americans. As seen in Figure 1, there are public EMS, private EMS, volunteering EMS and others. Their proportions are given respectively 60%, 30%, 8%, and 2%.

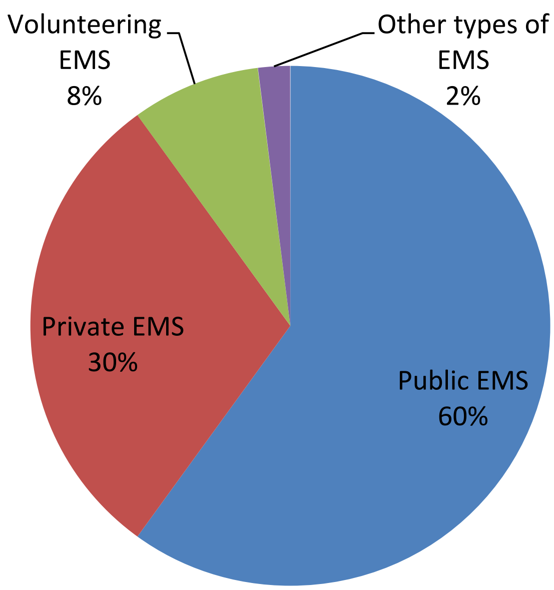


Figure 1: Proportion of EMS

According to Figure 1, public EMS is a major provider of EMS. All of the EMS workers, no matter whether they are existing fire fighters or special operation EMS paramedics, are considered employees of the fire department, and they are and governed by the fire department. A source of funding of the fire department based EMSs is the premium they charge on the service users; however the public fund is still the main funding source. As a result, the operation of the fire department based service is subject to public funding for the fire department, which is usually based on tax revenue[47]. Regarding operation activities, the fire department based EMS provides regular EMS activities such as first aid responding, transporting patients to hospitals, etc. The fire department based EMS structure is most commonly found in small cities and rural towns, where the fire department is the one responsible for all emergency situations. In those areas, the fire department based EMS is the only EMS provider and plays an important role in the community. In bigger cities, fire department based service could also be found, such as in New York City, but they work along with, and also compete against, other types of EMS like private EMSs[39].

A less common structure of public EMSs is public hospital based structure. This structure represents about 35% of the existing public EMSs (see Figure 2). In this case, the EMS is founded as a unit of a city or state hospital, and placed under the administration of that hospital. In this structure, the EMS workers are EMS paramedics hired by the public hospital, and they work fulltime as EMS paramedics, i.e. not performing other tasks in the regular hospital activities. Similar to the fire department based EMSs, the public hospital based EMSs are also mostly funded by public fund; in this case, they are funded by public hospital fund. They also rely on the fees they charge for the services provided; but similar to the case of the fire department based EMSs, public funding is still the main funding source for public hospital based EMSs[81].

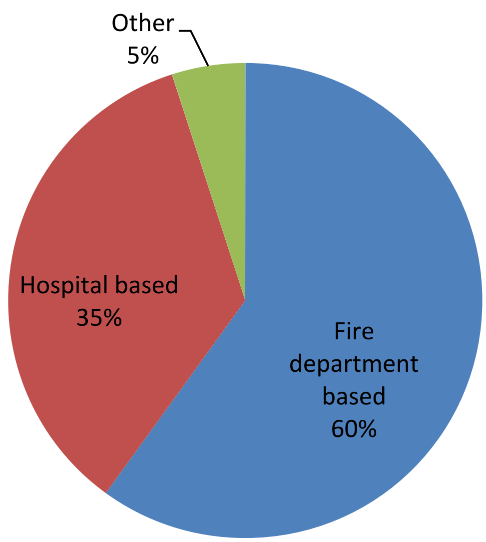


Figure 2: Proportion of Public EMS

Similar to the fire department based EMSs, the public hospital based EMSs also provide regular EMS activities, including first aid responding and patient transportation. The public hospital based EMS structure is mostly found in small to medium-sized cities with large public hospitals. In larger cities, public hospital based EMSs also exist, though not commonly, and they provide services in a much smaller scale, usually only to the affiliated hospitals[11].

a) Advantages of public EMS

Unlike private EMSs, for public EMSs, profit is not an important goal; instead public interest plays a much more important role. In addition, public administration system of the public EMSs also assures that public interest is the goal of the service. One example of this focus on public interest, as indicated by many studies, is that a public EMS tends to charge lower fees for the users comparing to the fee level of an equivalent private EMS. In addition, public EMSs have a lot of special programs focusing on public interest, such as no fee for poor users; service extended to remote area, etc. [11]

Due to public funding and public administration, an important advantage of a public EMS is its stable and guaranteed continuing service. It would be very rare for a public EMS to go bankrupt and stop providing service, as public funding would help it with operational cost. For a private EMS, bankruptcy would be a real threat. In addition, a public EMS is more unlikely to be affected by external conditions than a private EMS, due to public administration. For example, a private EMS may stop providing service due to an internal conflict within the company; but for a public fire department based EMS, it would have to continue providing service, as most state laws require the fire department to operate in those cases[39].

b) Disadvantages of public EMS

Many studies pointed out that having public EMSs would cost more to cities and states than hiring private EMSs to do the job. One of the reasons is the complexity of the organizational structures in most public agencies, including public hospital and fire department, which generate extra administrative cost. Another reason is that public EMSs focus on public interest and profit is not an important goal; thus many public EMSs are running with operational loss and require extra funding resource. Some researchers even pointed out that, since profit is not an important goal for public EMSs, the operation of public EMSs is usually not optimized, resulting in unnecessary costs[11].

Many studies also indicated that public EMSs are not as innovative as private EMSs. It is because public EMSs usually do not focus on profit so they do not pay too much attention on innovation and improving services. Furthermore, since public EMSs are under public administration, it would not be simple for public EMSs to pursue too much innovation, due to the complicated structure of public administration. Usually proposals for new technology from public EMSs would have to go through many steps for approval with sometimes burdening procedure. As a result, public EMSs tend to be obsolete in term of technology comparing to private EMSs[39].

Table 1: Advantages and disadvantages of public EMS

Advantages	Disadvantages
Lower fees for the users	More cost to cities and states
Stable and guaranteed continuing service	Not innovative
Service in remote areas	Unnecessary costs for operation

Table 1 reviews the advantages and disadvantages of public EMS, as reviewed in the above sections. Comparing the two opposing sides demonstrates that although public EMS is present across the United States as well as most parts of the world, there is a lack of innovation with this system. In order to overcome this and implement technology that would further increase patient care, further research must be performed as a way to decrease costs to cities and states.

Private EMS: Structure, operation and funding source

Although privatization of EMS only started less than 30 years ago, private EMSs have been expanding significantly and now capture close to 30% of the market for EMSs. In contrast with public EMSs, private EMSs are performed by private companies that are contracted or permitted to operate EMS in a region by the region government. In the private EMS structure, the EMS workers are EMS paramedics hired and paid by the private companies. The private companies are also in charge of all administrative and operational activities of the private EMSs; this is different from public EMSs, which are under administration of the affiliated public agencies. Based on the funding source, there are two most common types of private EMSs: private contractors and pure private EMS providers[39].

Private contractor is the private EMS that gets contracts from a city or town government to provide EMS in the region. This is the most common type of private EMS, accounting for more than 60% (Figure 3). Since they operate as private EMS contractors, their most important funding source is the public funding based on the contract. However, usually the public funding for those contractors is not as much as the one for public EMSs; in return usually these private EMSs are allowed to charge higher fees for service users. For example, according to a study by Michael Drumm[11], the switch from public EMSs to private EMS contractors by the city of Manhattan in 1997 would reduce public funding by 30% but would require service users to pay an extra fee of $345 on average. As a result, service fee collection is also a major funding source for these private EMS contractors. The study by Drumm also indicated that this funding source may account for 30% to 40% of operational fund for private EMS contractors[26].

Similar to public EMSs, private EMS contractors also provide all the regular services for the regions they serve, such as first aid responding or transporting patients to hospitals. Public EMS contractors are usually found in rural areas and small cities, where public agencies like fire department and public hospital are not capable of providing EMS. In those areas, it is usually the case that it would be more cost efficient for local governments to hire contractors doing EMS than to start up a whole completely new public EMS. Since they are contractors, these private EMS are usually placed under less public administration. Some studies found that most common controls local governments have on private EMS contractors are general standards set forth in the contract, requirement for annual reports and periodic review of contract terms. As a result, private EMS contractors can retain much more autonomy in operation comparing to public EMSs, which are placed under direct public administration[71].

Figure 3 describes the private EMS and the proportion that are pure private providers versus the private contractors. As shown, 60% of all private EMS are private contractors which receive contracts from a city or town government to provide EMS in the region. Although their funding is less than public funding, innovations to these ambulances are simpler to make due to the small size.

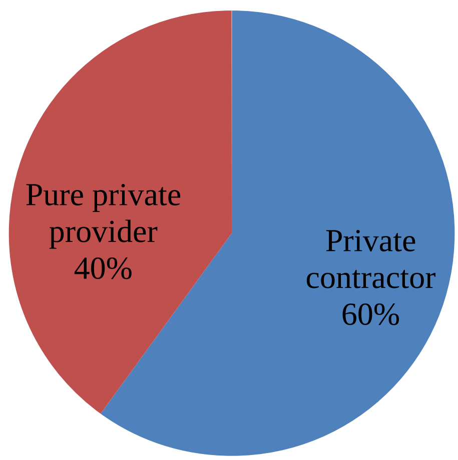


Figure 3: Proportion of Private EMS

Beside private EMS contractors, another type of private EMSs is pure private EMS providers (Figure 3). Unlike private EMS contractors which got contracted and funded by local governments, the pure private EMS providers only receive permits to operate EMS but do not receive or share any public funding. As a result, they usually have to compete against other local EMS providers for market and user fees. Since they are not under any contract with local governments, they are subject to very little government control, except for general regulations that apply to all EMSs. One clear example of the autonomy of private EMS providers is that they are free to create their own fee structures to charge on their service users, although cities like Chicago did attempt to place a ceiling on the fee these providers could charge. In addition, while public EMS providers and public EMS contractors are obligated to provide all regular EMS activities and are not allowed to deny service in most cases, pure private EMS providers have more freedom to select the services they are willing to provide, although they are obligated to respond to critical situations according to laws[81].

Since pure private EMS providers do not receive public funding, they rely entirely on user fee collection for funding. As a result, private EMS providers usually charge a higher fee for their activities than public EMS do. In return, private EMS providers offer many special services that are not available from public EMS providers, such as patient transportation using helicopter, special doctor arrangements, etc. and also charge special fees for those services. Pure private EMS providers are usually found in large metropolitan areas like Chicago, Baltimore, San Francisco, etc. where local public EMS and private EMS contractors could not provide enough service to the large population. In those areas, pure private EMS providers compete against other types of EMS providers using their special features such as quick response, special care, or special doctor arrangements, etc. [26].

a) Advantages of private EMS

Many studies have pointed out that private EMSs are more innovative in term of technology and services provided comparing to public EMSs. For example, many private EMSs offer transportation option with helicopters that is usually not available for public EMSs. The reason is that a private EMS usually has to compete for higher profit and market share; thus it places a strong focus on improving service and acquiring new technology, in order to attract more service users and collect more fees. For instance, a study by Poole shows that on average private EMSs spend 50% more on new technology and services comparing to public EMS providers[71].

Many studies also pointed out that the operational cost of private EMSs is much lower to that of public EMSs. For example, Sumner mentioned in his article that the decision to abandon public EMSs and contract private EMS providers of the Mitchell County in Georgia would help save the county and taxpayers $400,000 a year. In another example, the report from the Oceanside City Council in California showed that privatization of EMS would help the city save more than $1.5 million per year. The reason for this reduction in cost is due to the fact that the main goal of private EMS providers is profit so they have a strong incentive to optimize operation and reduce cost. As a result, private EMS providers usually require less cost for the same services provided by public EMS providers[71].

b) Disadvantages of private EMS

The disadvantage of private EMSs that most people are concerned about is that since profit is the most important goal of most private EMSs, the fees that these private EMS providers charge on their users may be too excessive and unaffordable for the poor people. Indeed in her research, Michelle Andrews mentioned that, "this . . . is really about whether individuals, families and employers should pay 80 to 100 million dollars a year because private out-of-network ambulance companies are allowed to charge rates that are three to five times above what Medicare pays them for the very same service."[6] Drumm in his research also mentioned that about 20% of the fees charged by private EMS might be excessive[26]. Balaker and Summers mentioned two ways to alleviate this issue: increase competition and increase Medicare coverage for the poor. Increasing competition for the EMS provider market would force the private EMS providers to lower the fees to a reasonable level in order to stay competitive and attract enough customers.

Increasing EMS coverage for poor people would make sure they receive adequate services without worrying about the high fees, especially in the regions where public EMSs are not available[8]. In addition, Johnson also stressed the importance of regulations to prevent excessive fees from private EMSs, such as established fee ceiling etc[47].

Another disadvantage of private EMSs that people usually concern is the risk that the services may be unstable and stop working unexpectedly. For example, in contrast to public EMSs whose funding source is assured by public funds, private EMSs have to rely solely on the revenues they collect based on their services. Thus, there might be a case that a private EMS could not generate enough revenue to sustain operation, and stops operating services unexpectedly. In the case of the private EMS working as a private contractor, this scenario would be a nightmare as there is no other existing EMS to back up when the private provider becomes defaulted, leaving the whole town to no EMS provider. Poole mentioned a possible solution for this problem is setting up an emergency fund and annual review of financial status of private EMS providers[71].

Table 2: Advantages and disadvantages of private EMS

Advantages	Disadvantages
More innovative in technology and services	Excessive and unaffordable fee for the poor people
Lower operational cost than public EMSs	Rely on the revenues collected based on services
Ability to make EMS improvements quickly	Lack of emergency funds

Volunteering EMS: Structure, operation and funding source

The third type of EMS providers, and also the less common type, is volunteering EMSs, which accounts for about 8% of the entire existing EMSs in the United States. Unlike workers of the public and private EMSs, workers in the volunteering EMSs are not fulltime employees; instead they are volunteers who are willing to provide EMS with no pay or with some monetary assistance. In most cases, these volunteering EMS workers hold other regular fulltime jobs and get trained to become part-time EMS workers. Volunteering EMSs are usually affiliated with public organizations, such as religious organizations (e.g. churches), educational organizations (e.g. universities), or local community organizations; and usually these volunteering EMSs are placed under the administration of the governing board of the affiliated organizations[81].

Regarding funding sources, there are three most common ways of funding for volunteering EMS: donations, service fee collection, and government support. The first source, donation, is the most common source of funding for these services. Often these donations come along with the donations given to the affiliated organizations. For example, the donation given to the volunteering EMS of Bates College in Maine is usually in a donation package given to Bates College. Volunteering EMSs also charge service fees on the users, although the fees they charge are much lower to those of private EMSs and usually also lower to those of similar public EMSs. In some areas, especially in rural areas where public and private EMSs are not available, local government could also provide assistance to these volunteering EMSs in order to provide EMS to residents in those areas. [39]

Similar to public EMSs and private EMS contractors, volunteering EMSs also provide all regular EMS in the regions they serve, including first aid responding and transporting patients to hospitals. However in reality, if there is a public or private EMS available in the area, the volunteering EMS will usually serve as a secondary EMS provider, i.e. they only respond to non-critical cases or when the main EMS provider is overloaded and requires assistance. In the rural areas where the volunteering EMSs are the only EMS providers, they will play the role of the main EMS providers, responding to both critical and non-critical conditions. However, in these cases, the volunteering EMSs would usually be placed under some degrees of administration of the local governments[81].

a) Advantages of volunteering EMS

Among the three types of EMS providers, volunteering EMS providers have the lowest operational cost, as most of the volunteering EMS workers work unpaid or with very little monetary assistance. Fitch and Criffiths, in their research, showed that on average the operational cost of a volunteering EMS provider is only about 60% the operational cost of an equivalent private EMS provider and 40% of an equivalent public EMS provider[39].

Similar to public EMS providers, another major advantage of volunteering EMS providers is that they do not operate for profit, i.e. public interest is the most important goal of volunteering EMS providers. It could be seen from the very low fees they charge on the service users, comparing to the fee levels of private and public EMS providers. Moreover, most volunteers working in the volunteering EMSs are local residents who want to help their community; thus they have a great incentive to serve and usually try to provide the best services they can give[39].

b) Advantages of volunteering EMS

Table 3 demonstrates the advantages and disadvantages of volunteering EMS, unlike the public EMS system as previously discussed. The advantages outweigh the disadvantages which include low operation cost and they do not operate for profit.

Table 3: Advantages and disadvantages of volunteering EMS

Advantages	Disadvantages
Lowest operational cost	Limitation of technology and services offered.
Public service most important goal	Not legally tied to services
Not operate for profit	Could run out of service and stop operating suddenly

Besides the advantages of volunteering EMS, the disadvantages are also included in Table 3. A major disadvantage of volunteering EMSs is the limitation in term of technology and services offered. This is due to the fact that the operation of volunteering EMSs relies on unstable funding sources such as donations or government supports; thus it would be very difficult to set aside fund to acquire new technology or to improve services[81].

Another major disadvantage of volunteering EMSs is the risk that they could run out of service and stop operating suddenly. For instance, since the most important funding source for most volunteering EMSs is donation, these volunteering EMS providers will stop operating once donation coming in is not enough. In addition, since EMS workers in volunteering EMS providers are volunteers who are not legally and monetarily tied to their services like public and private EMS workers to their services; thus the turnover rate for volunteering EMSs is high. Fitch and Criffiths showed that during the time when the economy was in a recession, many volunteering EMSs stopped working as their EMS volunteers stopped showing up for EMS work and instead looking for jobs[39].

Table 4: EMS advantages and disadvantages

Types	Features	Advantages	Disadvantages
Public EMS	**Fire department based or hospital based**	Focus on public interest	High funding cost
	Public employees	Stable operation	Limited technology
	Public funding		
Private EMS	**Private contractor or pure private provider**	Technologically innovative	Driven by profit
	Private employees	Lower operational cost	Risk of disoperation
	Funding source: public contract or service fee		
Volunteering EMS	**Volunteers**	Low funding cost	Limited technology
	Funding source: donations, public support, service fee	Focus on public interest	Unstable operation

2.1.2 General Structure

There is a general structure of EMS Levels based on titles, training and education. The four EMS levels include: First Responder, Basic Emergency Medical Technician, Advanced Emergency Medical Technician, and Paramedic. Appendix A graphically depicts the different

EMS levels and breaks each down into subcategories of training courses, required training hours, and skills developed at each level of training. Movement into higher levels of EMS training increases the overlap of previous training. For instance, First Responders only take a first responder course, but Basic Emergency Medical Technicians have the skill set of a First Responder, as well as the new skills learned in the Approved EMT Course. Advanced Emergency Medical Technician builds upon the training of a Basic EMT by taking the Advanced EMT course in addition to the Approved EMT course. Finally, the Paramedic takes all the previous courses as well as the Paramedic Course.

Despite the differences in education, there are skills common among all EMS levels. These include assessment and evaluation of general incident scene safety, effective charting and reporting skills, routine medical equipment maintenance, radio operations, triage of patients, and emergency vehicle operation. Differentiation of EMS levels is based on time, which directly correlates to the amount of training and expertise needed to advance to the next level of EMT proficiency. Figure 4 depicts the amount of time in hours needed to obtain each of the four EMS levels of certification.

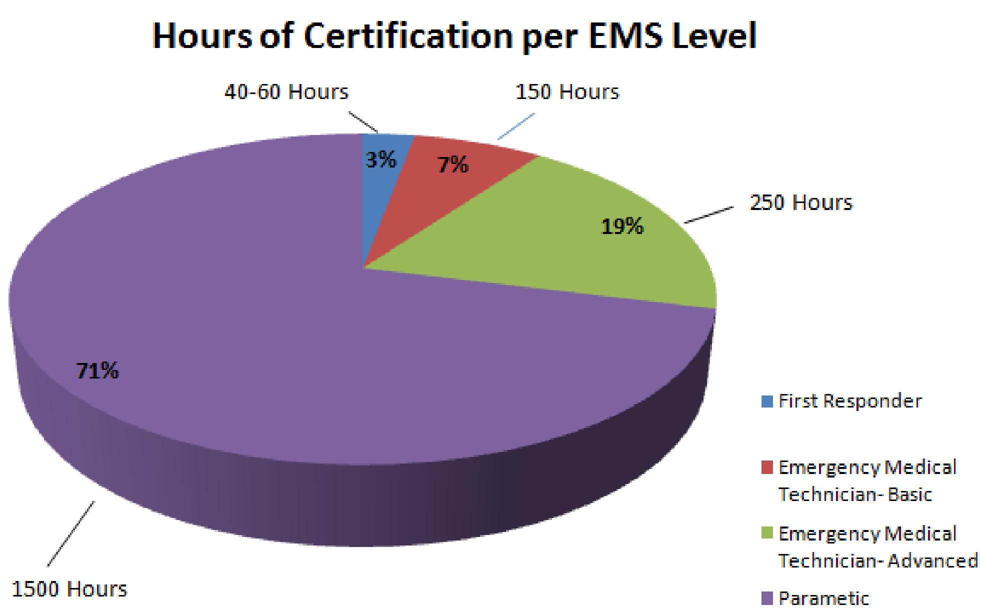


Figure 4: Time-Based EMS Certification Levels

From Figure 4, First Responders need the least amount of training hours, 40-60, and have the most basic expertise including oxygen administration, CPR, automatic external defibrillation, bandaging/splinting, and emergency childbirth. These skills encompass only 3% of the total training offered to EMT's. Basic Emergency Medical Technicians have 7% additional training after passing the First Responder level, which is about 150 hours. Skills at the second EMS level include all first responder training, no visualized airways, and administration of nitroglycerin, epinephrine with an Epi-Pen and aspirin. Advanced Emergency Medical Technicians have 19% or 250 hours of training after passing First responder and Basic EMT levels. Training includes all Basic EMT training, intravenous access, and cardiac monitoring. Paramedics have 71% or over 1500 hours of classes in addition to First Responder, Basic and Advanced EMT training. Paramedic skills include all Advanced EMT training, manual defibrillation, transcutaneous cardiac pacing, 12 ECG's, advanced airway management (surgical), intravenous and intravenous access, medication route and pharmacology, pleural decompression, and CPAP and Rapid Sequence Induction. Appendix A.1 is a flow chart representation of the above discussed EMS levels, aiding in further understanding of differentiation in abilities and training of EMT's.

There are highly structured education systems in place to facilitate training courses for each of the four EMS levels. The First Responder course takes the form of an EMT Diploma program where students partake in an information session followed by an internship for clinical expertise assisting an ambulance crew or working in a hospital. Approved and Advanced EMT courses are EMT Certification Programs. These programs offer students medical courses like human anatomy and physiology and mandatory EMT training. Paramedic courses are EMT Associate Degree Programs focusing more on the medical courses and extensive field internships. All EMS levels must complete additional licensing requirements, usually an exam, at a state or national level. The most common test is from the National Registry of Emergency Medical Technicians. A recertification test and re-fresher class are taken every two or three years to ensure maximum training and proper safety procedures are followed by EMT's.

2.1.3 External and Internal Structure

Contaminants are unavoidable in EMS activities and reducing contamination is always an important goal and a requirement for EMS providers. Reducing the risk of infection and spread of disease is directly correlated to enhancing patient safety. Current state and agency standards and regulations also have specific EMS requirements and recommended practices that aim to reduce contaminations. Below are summaries of the most important and common points:

Chemicals used for decontamination and disinfection purposes:

- The 2008 Guidelines for Disinfection and Sterilization in Healthcare Facilities of the Department of Health and Human Services recommend the following chemicals for sterilization and disinfection of medical devices used in EMS[83] (Tables 5,6):

Table 5: Sterilization methods recommended by the Department of Health and Human Services for medical devices

Methods Recommended	Percent Content
Heat sterilization (including steam or hot air)	100%
Ethylene oxide gas	100%
Hydrogen peroxide gas plasma	100%
Hydrogen peroxide	7.5%
Peracetic acid	0.2%
Hydrogen peroxide and peracetic acid	7.35%, 0.23%

Table 6: Disinfection methods for medical devices

Critical items (having contact with membrane or non-intact skin)	Semi-critical items	Noncritical items
Glutaraldehyde-based formulation (>2% glutaraldehyde); glutaraldehyde (1.12%) and 1.93% phenol/phenate	Ethyl or isopropyl alcohol (70-90%)	Ethyl or isopropyl alcohol (70-90%)
Ortho-phthalaldehyde (OPA) 0.55%	Sodium hypochlorite (5.25-6.15% household bleach diluted 1:500 provides > 100 ppm available chlorine	Sodium hypochlorite (5.25-6.15% household bleach diluted 1:500 provides > 100 ppm available chlorine
Hydrogen peroxide (7.35%)	Phenolic germicidal detergent solution	Phenolic germicidal detergent solution
Peracetic acid (concentration 0.2% or greater)	Iodophor germicidal detergent solution	Iodophor germicidal detergent solution
Hydrogen peroxide 7.35% and 0.23% peracetic acid (will corrode metal instruments)		Quaternary ammonium germicidal detergent solution
Wet pasteurization at 70 degrees Celsius for 30 minutes with detergent cleaning		
Hypochlorite, single use chlorine generated on-site by electrolyzing saline containing >650-675 active free chlorine		
Sodium hypochlorite (5.25-6.15% household bleach diluted 1:500 provides > 100 ppm available chlorine		

Recommended practices

The 2010 National Fire Protection Association (NFPA) Standard Infection Control Program requires the following preventive practices for fire department based EMS. These requirements are also observed by other public and private EMS[61]:

- 4.5.2.2: All EMS members shall be immunized against infectious diseases as required by the authority having jurisdiction. The fire department physician shall ensure that all members are offered currently recommended immunization at no cost to the members.
- 5.5.4.1: Potentially contaminated personal protective equipment shall be stored in a dedicated, well-ventilated area or room.
- 5.5.5.1: Area or containers for the temporary storage of contaminated medical supplies or equipment prior to disinfection or disposal shall be separated physically from EMS members and patients in facilities or on vehicles.
- 5.8.1: Medical waste or other regulated waste shall be disposed of in a designated disposal area.
- 7.1.1: Prior to any contacts with patients, members shall cover all areas of abraded, lacerated, chapped, irritated, or otherwise damaged skin with adhesive dressings.
- 7.1.2: Any EMS member who has skin or mucosal contact with body fluids shall thoroughly wash the exposed area immediately using water or saline on mucosal surfaces and soap and running water on skin surfaces.
- 7.1.3: If soap and running water are not available, waterless cleansers, antiseptic wipes, alcohol, or other skin cleaning agents that do not need running water shall be used until soap and running water are obtained.

- 7.1.4: After removal of any personal protective equipment, including gloves, all members shall wash their hands immediately or as soon as feasible.
- 7.2.1: EMS members shall wear medical gloves prior to initiating care to protect against variety of diseases, modes of transmission, and unpredictable nature of the work environment.
- 7.2.5.1: Masks, splash-resistant eyewear, and fluid-resistant clothing shall be used by members providing treatments during situations involving spurting blood, trauma, or childbirth, or other situations where gross contamination is anticipated or possible.
- 8.1.2: Hands and contaminated skin surfaces shall be washed with nonabrasive soap and water by lathering the skin and vigorously rubbing together all lathered surfaces for at least 10 seconds, followed by thorough rinsing under running water.
- 8.1.3: Where provision of hand-washing facilities is not feasible, appropriate antiseptic hand cleansers in conjunction with clean cloth, paper towels, or antiseptic towels shall be used.
- 8.2.1: All disinfectants shall be approved by and registered as tuberculocidal with the U.S Environmental Protection Agency (EPA).
- 8.2.2.2: Disinfectants shall be used only with ventilation and while wearing appropriate infection control garments and equipment.
- 8.3.6: Dirty or contaminated runoff from emergency medical equipment and cleaning and disinfecting solutions shall be drained into a sanitary sewer system or septic system.
- 8.3.8: Reusable emergency medical equipment that comes in contact with mucous membranes shall require cleaning and a high-level disinfection or sterilization after each use.

- 8.4.2: If a garment is penetrated by blood or other potentially infectious materials, the garment shall be removed immediately or as soon as feasible.
- 8.4.4: Clothing that is contaminated with body fluids shall be placed in leak-proof bags, sealed, and transported for cleaning or disposal.
- 8.5.4.1: When moving containers of contaminated sharps from the area of use, the containers shall be closed immediately prior to removal or replacement to prevent spillage or protrusion of contents during handling, storage, transport, or shipping.
- 8.7.2: After contact with blood or other potentially infectious materials, equipment and environmental and working surfaces shall be cleaned and decontaminated using any cleaner or disinfectant agent. Working surfaces shall include floors, woodwork, ambulance seats, and countertops.
- 8.7.4: All bins, pails, cans, and similar receptacles intended for reuse that have a reasonable likelihood of becoming contaminated with blood or other potentially infectious materials shall be inspected and decontaminated on a regularly scheduled basis and cleaned and decontaminated immediately or as soon as feasible upon visible contamination.

Additional common regulations for EMS regarding contamination:

- Contaminated needles and other contaminated sharps shall not be net, recapped, or removed unless the employer can demonstrate that no alternative is feasible[59].
- Sheets and pillow cases shall be changed after each use; all linens shall be properly laundered. All clean linen, equipment and supplies shall be properly stored in clean storage area in each ambulance[78].

- Any absorbent material such as carpeting, fabric, or inside/outside plastic type carpeting, etc. that resists cleaning and decontamination shall not be used[59].
- All exposed surfaces should be free of vent devices that would permit the entrapment of biological contaminate[59].

Noise Reduction Standards and Regulations

Although strict noise standards are in place for ambulances and emergency departments, enforcing these regulations are difficult. These vehicles and departments are made for emergency situations in which often times maintaining low noise levels can be a last priority, especially when human lives are on the line. The recognition of this problem is the first step to solving noise issues. The following of these regulations and the creation of innovative noise reduction techniques can decrease noise volume in emergency triage care.

Standards and Regulations for Ambulance Structure

The KKK has certain ambulance regulations that the United States must follow in order to have a certified EMS on the road. These standards pertain to every aspect of an ambulance including design, testing, and performance of the vehicle. Restrictions are made with personnel safety as a main priority. As previously stated, there are three types of ambulances used in the United States, each for specific purposes. Although each type is different externally, they all follow the same guidelines stated in the KKK-1822 Standards.

Another set of requirements is set by the National Fire Protection Association (NFPA), who creates codes and standards that are designed to minimize risks and effects of fire. The NFPA is made up of 6,000 volunteers who are committed to reducing the burden of fire and other hazards on the quality of life[76]. These volunteers are also responsible for voting on proposals to determine whether or not they should be implemented into the codes and standards.

Local governments adopt their regulations and use them as a criterion for building, processing, design, and service of EMSs.

Ambulance manufacturers in the United States are required to follow the KKK Standards, and additionally they obey the NFPA codes and standards. Below, Table 4 demonstrates the similarities and differences between the KKK and NFPA concerning the exterior structure of ambulances. In the table, the column denoted Subject includes the various exterior structure components and are compared to the NFPA and KKK. The NFPA and KKK Codes can be found in each of their respected standards, and are briefly summarized in their description column.

Table 7: NFPA versus KKK ambulance noise standards [76, 97]

Subject	NFPA Code	NFPA Description	KKK Code	KKK Description
Vehicle Overall Height		N/A	3.4.10.3	Purchaser shall specify.
Vehicle Ground Clearance		N/A		N/A
Exhaust Systems	5.6.3	The tailpipe outlet shall not terminate within 12” of fuel fill, O2 storage, and patient entry doors.	3.6.4.6	12” from fuel filler and a maximum 1” beyond the side of the body.
Suspension Clearance Angles	5.8.1	Angle of approach- 10” Breakover Angle- 10” Angle of Departure- 10” Traction control shall be provided.	3.4.10.4	Angle of approach- 20” Breakover Angle- 10” Angle of Departure- 10”
Suspension	5.8.2	Traction control shall be provided.	3.6.5.6	Traction control unless not furnished by OEM.
	5.8.4	Any air ride suspension shall have an air dryer and automatic moisture ejection device.	3.15.4.8	Optional equipment.
Tires	5.9.5	Each tire shall be equipped with a visual indicator or monitoring device.		N/A
Bumpers	5.11.1	A front bumper at least equal to the chassis	3.9.6	OEM chrome front bumper required.

		manufacturer's front bumper.		
Stepping Surfaces	5.11.2.8.2	NFPA step surface compliance and validation to testing.		N/A testing –commercial grip strut.
Mirrors	5.14.2	All primary side view mirrors used by the driver shall be adjustable from the driver's position.	3.9.5	Mirrors be independently adjustable.
Bulkhead Door	6.7.7	N/A – Sliding window, it shall be latchable from the cab, minimum 150 sq. inches	3.10.14.1	17" x 46" latchable door.
Reflective Stripping	6.25	Retro reflective stripe minimum 4" width 1) 25% of the width of the front of the ambulance visible. 2) 50% of the length visible from each side.	3.16.2	6" minimum, 14" maximum orange reflective stripe that encircles the entire body.
Warning Lights	7.9.14	Lighting requirements for small ambulance less than 25 feet.	3.8.2.1	KKK Emergency Lighting system configuration or approved alternate systems are NFPA 1901 or SAE J2498.
Siren/Horn Locations	7.10.3	Audible warning equipment shall not be mounted on the roof of the ambulance.	3.14.4	Addresses siren only. Air horn optional and location not addressed.

Table 7 illustrates that the NFPA and the KKK Standards have slight variations concerning ambulances exterior structure. Most of the variances are insignificant since both requirements can be met. For instance, the reflective stripping has two different standards. But both of these can be met, so although the wording is different, no issue is caused.

From state to state the regulations vary slightly depending on individual needs, while remaining in the constraints set by the KKK and NFPA. For instance, large cities like Los Angeles and New York have distinct paint schemes to distinguish themselves from others. Figure 5 shows the variations of ambulances across the United States. There are minute differences, but all are recognizable as ambulances for the safety of citizens. As seen below, each ambulance in the United States is equipped with warning lights, reflective stripping, and includes red paint to stand out and catch the attention of citizens. Although it cannot be seen in in Figure 5, each EMS vehicle includes large rear doors for the EMTs/paramedics to enter into the cabin space along with the patient.

Massachusetts	New York City	Los Angeles
		
Texas	**Wisconsin**	**Florida**
		

Figure 5: United States' Ambulances by State

Other countries around the world appear to have similar ambulances as the United States. Although they are still recognizable as EMS vehicles, each country has different standards and regulations which vary slightly. Figure 6 depicts the similarities between ambulances in Canada and the Unites States, where Canada has based their ambulances on the United States Federal KKK-1822 standards for type I, II, and III ambulances. With the exception of Canada, other countries have a different set of standards. For instance, England's ambulances are constructed using CEN 1789 which is the European Union Standard for ambulances and medical transportation vehicles. These are noticeably different from the ambulances in America with an entirely different paint scheme. Although the color is very different, they are still bright for safety purposes and include warning lights, a side storage door, and large rear doors just like the ones in the United States. The dimensions of the vehicle are within inches of what the KKK-1822 Standards have set. The main difference between England's ambulances with the United

States, beside the color, is that their three types of ambulances serve a different purpose. Their type A ambulances are used for patient transport, type B is the emergency ambulance, and type C is for mobile intensive care. Other countries shown include Japan, China, and Mali which also follow their own standards. Even though each country has certain external requirements, all of the ambulances serve the same purpose.

United States	**Canada**	**England**
		
Japan	**China**	**Mali**
		

Figure 6: Ambulances around the World [21]

Noise is a sound created from a source that is usually loud, unpleasant, or causes a disturbance. For man, noise has been an environmental issue beginning as far back as ancient Rome. Even back then, there were noise regulations such as ironed wheel wagons were not allowed during the night due to the sleep disturbance it caused with the wheels against the stone pavement[102]. For modern ambulances, the noise can originate from many sources such as cars, trains, machinery, people, aircrafts, alarm and medical devices. This noise pollution causes disturbance for people in everyday life and can even cause permanent hearing damage over extended periods of time. Controlling noise has and will continue to be a problem in society for years to come due to the amount a person is exposed to on a daily basis.

The World Health Organization (WHO) has been trying to decrease noise pollution around the world. They found that in Europe, about 40% of the population is exposed to road traffic noise (55 decibels) and 20% are exposed to noise levels beyond 65 decibels every day. On top of this, more than 30% of Europeans are exposed to noises above 55 decibels during the night, which disrupts sleep[102]. These statistics are prevalent in developed countries especially, and in cities where mass amount of people live densely and are constantly near transportation services. Due to the noise pollution constantly growing proportionally with the population, the WHO has set up guidelines in an effort to minimize noise.

In order to measure noise, it can be approximated by using simple methods. The frequency content of sound, overall sound pressure levels, and the variation of these levels with time are all taken into consideration when noise is being measured. Sound pressure is defined as a basic measure of vibrations of air that make up sound. Noise is calculated over a period of time and is in units of decibels (dB). For a human, there is a wide range of decibels that can be heard ranging from nearly 0 decibels up to around 150 decibels which is when the eardrum will rupture[102]. A table of various noise sources with their specific decibel level is shown in Table 5 as a reference guide. As seen in the chart under the column titled comments, it can be noted that there are references to how loud a noise is in relation to 70 decibels. For a human, the perception of noise doubles as the noise increases every 10 decibels[102]. As an example from the table, when a garbage disposal is running it produces nearly 80 decibels, which is twice as loud as a vacuum cleaner at 70 decibels. But a power mower at 96 decibels will sound 4 times as loud as a vacuum cleaner even though it is only 20 decibels louder.

Table 8: Decibel recognition by noise source [65]

Noise Source	Decibel Level	Comment
Breathing	10	Barely audible
Whisper, rustling leaves	20	
Quiet rural area	30	One- sixteenth as loud as 70 dB, very quiet
Library, bird calls (44 dB); lowest limit of urban ambient sound	40	One – eighth as loud as 70 dB
Quiet suburb, conversation at home. Large electrical transformers at 100 feet	50	One- fourth as loud as 70 dB
Conversation in restaurant, office, background music, air conditioning unit at 100 feet	60	Half as loud as 70 dB. Fairly quiet
Passenger car at 65 mph at 25 feet (77 dB); freeway at 50 feet from pavement edge 10 a.m. (76 dB). Living room music (76 dB); radio or TV-audio, vacuum cleaner (70 dB).	70	Arbitrary base of comparison. Upper 70s are annoyingly loud to some people.
Garbage disposall, dishwasher, average factory, freight train (at 15 meters). Car wash at 20 feet (89 dB); propeller plane flyover at 1,000 feet (88 dB); diesel truck 40 mph at 50 feet (84 dB); diesel train at 45 mph at 100 feet (83 dB). Food blender (88 dB); milling machine (85 dB); garbage disposal (80 dB).	80	2 times as loud as 70 dB. Possible damage in 8 hour exposure.
Boeing 737 or DC-9 aircraft at one nautical mile (6080 feet) before landing (97 dB); power mower (96 dB); motorcycle at 25 feet (90 dB). Newspaper press (97 dB)	90	4 times as loud as 70 dB. Likely damage 8 hour exposure.
Jet take-off (at 305 meters), use of outboard motor, power lawn mower, motorcycle, farm tractor, jackhammer, garbage truck.	100	8 times as loud as 70 dB. Serious

Boeing 707 or DC-8 aircraft at one nautical mile (6080 feet) before landing (106 dB); jet flyover at 1000 feet (103 dB); Bell J-2A helicopter at 100 feet (100 dB)		damage possible in 8 hour exposure.
Steel mill, auto horn at 1 meter. Turbo-fan aircraft at takeoff power at 200 feet (118 dB). Riveting machine (110 dB); live rock music (108-11 dB).	110	Average human pain threshold. 16 times as loud as 70 dB.
Thunderclap, chain saw. Oxygen torch (121 dB).	120	Painful. 32 times as loud as 70 dB.
Military jet aircraft take-off from aircraft carrier with afterburner at 50 feet (130 dB).	130	
Aircraft carrier deck.	140	
Jet take-off (at 25 meters)	150	Eardrum rupture.

Noise pollution interferes with daily life including disturbances in daily speech communication, sleep, and performance in various activities. Although noises up to 75 decibels can be bothersome, these will not cause hearing impairment over an extended period of time. In speech communication for example, it is necessary to have the voice at least 15 decibels louder than any background noise occurring[102]. With a person's average tone at 50 decibels, all other noises at that time need to be less than 35 decibels (equivalent to a library) for there to be no interference. On the other hand, noises that exceed 75 decibels over time will be detrimental to hearing. This is the case for about 120 million people worldwide. Their hearing loss could have occurred over time, or could have been hurt from a one-time exposure. In fact, at any moment hearing loss for a child occurs at 120 decibels, and for adults at 140 decibels[67]. People need to be aware of the noise level of different sources in order to protect themselves for the present and the future.

Emergency vehicles have their own standards for noise pollution which are set with peoples' health and safety in mind. In particular, ambulances have a difficult task when it comes to noise pollution. The purpose of an ambulance is to provide immediate service to a person or people in the state of an emergency and transport them to a hospital. With this, there is the need for a siren which needs to be loud in order to alert people that an ambulance is coming and has the right of way on a road. Besides the siren there are many other sources of noise pertaining to an ambulance internally and externally.

In the KKK-1822 Standards, it is specified what the maximum noise level can be, as seen in Table 6. These regulations need to be set for the safety of patients, EMTs/paramedics, and pedestrians. Every ambulance in the United States follows the same guidelines, but these standards are different in other countries. The table below compares the standards of the United States to England. Other countries obey similar criteria. It is important to remember that a child exposed to 120 decibels for example can result in hearing loss. In the case of a siren, it may produce up to 120 decibels 10 feet away from the source, but the noise level decreases with distance.

Table 9: United States versus England siren standard [36, 97]

Noise	United States	England
Patient Compartment	80 dB	78 dB
Siren	123 dB	123 dB

In an ambulance, an EMT/paramedic is constantly exposed to noise levels over the barrier of 75 decibels which is where the line is drawn for noise causing hearing impairment over time. These regulations are provided in the United States by the KKK for the EMTs/paramedics and patients health and safety. With a siren set at 120 decibels, this means that the walls of an ambulance must have great sound barriers to keep the interior at a safe level below 80 decibels. On the inside, noise is created from vibrations in the vehicle driving on the road, the siren, speech, and the use of various equipment. If the noise level increases too much it is not only unsafe for hearing reasons, but also for the safety of the patient. In an emergency the EMTs/paramedics need to be able to communicate effectively between each other and the patient.

As previously stated, noise pollution is an issue everywhere, especially where the population density increases. For other places besides an ambulance, noise regulations are also set. Table 7 shows a variety of public locations where noise regulations were made. These standards are implemented in the United States.

Table 10: United States noise level regulations [67]

Source	Maximum Noise Level Regulation
Ambulance	80 dB
Hospital Room (night)	40 dB
Airplane (interior)	85 dB
Classroom	35 dB
Festivals	100 dB

The Occupational Safety and Health Administration (OSHA) have performed extensive studies pertaining to noise. The table above shows that regulations exceed 75 decibels which may appear alarming since that is the limit at which long periods of exposure can cause partial hearing loss. OSHA has determined the length of a time a person can be exposed to a noise level until hearing damage occurs. This data can be seen below in Table 8. The table created by OSHA confirms that the regulations made at various public locations (Table 11) are safe since people generally do not spend extended periods of time there where hearing impairment could occur.

Table 11: OSHA sound regulations [67]

Hours per Day Until Hearing Loss	Sound Level
8	90 dB
6	92 dB
4	95 dB
3	97 dB
2	100 dB
1.5	102 dB
1	105 dB
0.5	110 dB
0.25 or less	115 dB

In order to establish standards for human tolerance of noise levels, there must be testing involved to ensure that the standards are feasible. The testing guidelines for each source of noise vary. For instance, testing noise in an ambulance must have a different set of standards than testing noise in a classroom. It is important that the standards set are followed precisely so that equal measurements are made for the same source at different locations.

Ambulances have strict guidelines pertaining to testing noise levels. Since these emergency vehicles are, at some point, used by the majority of the population, it is vital that the noise is kept to a minimum to ensure safety. In the United States, ambulances use AMD Standard 006 – Patient Compartment Sound Level Test[1]. This standard clearly specifies the scope, purpose, applicability, requirements, test procedure, and the test conditions. Using this set of guidelines, ambulance manufacturers design the vehicles so that when AMD Standard 006 is followed, the vehicle will pass the noise regulations stated in KKK-1822 Standard.

Standards and Regulations for Unintended Stresses

The patient cabin of an emergency medical triage unit is not the desired, roomy, comfortable location in which emergency medical technicians can calmly perform. Unintended stresses act upon the technicians, crew and patient from basic emergency triage unit operation. Once additional external stressors are factored in, the patient cabin can turn into an unpleasant environment for all parties. Established standards and regulations, both federal and state mandated, attempt to minimize patient and emergency medical technician discomfort, but certain negative effects are unavoidable with the current ambulance design.

Emergency medical technicians commonly experience pains associated with cabin size, namely compartment and patient cot height. As per the National Fire Protection Association Standard for Automotive Ambulances, ranges of acceptable height values have been mandated to ensure a baseline comfort for technicians. Standardizing these values also allows technicians to operate comfortably in different ambulance models without too much adjusting required. The total patient compartment size must be a minimum of 7.7 m^3 (275 ft^2), and the minimum aisle width on at least one side of patient cot must be at least 300 mm (12 in).[ii] A minimum distance of 1092 mm (43 in) is required of upper surface of the bottom seat cushion to the ceiling. Effectively, this is the minimum head clearance an emergency medical technician has to operate in without contacting an overhead compartment or ceiling of the patient compartment (Fig 7).

Figure 7: Emergency Medical Triage Unit Patient Compartment

Road limitations and driving aisle widths limit the amount of occupied space withing the patient compartment. This directly affects the emergency medical technicians who work in these cabins. The size constraints most often lead to back pain, particularly in the lower lumbar region of the technicians's torso. Major changes to cabin design would be diffcult to implement.[30] Minor modifications and spacial rearrangements can be made to lessen unintended stress on the emergency medical technicians.

Understanding EMS Organizational Structure aids in recognition of potential issues and improvement solutions, creating a safer system for the EMT and patient. The paper focuses on seven EMS internal organization structures: Boston, Worcester, New York City, Chicago, San Francisco, Philadelphia, and Los Angeles. All have three common structures ranging from breadth to depth: operations, divisions, and programs. Figure 8 describes the hierarchy of EMS structure and provides examples of each. Operations are all-encompassing functions that define the name of Emergency Medical System through actions. While operations serve an umbrella of purposes, divisions represent the backbone of EMS in terms of organization and skill level. Programs are the least spanning, but have the greatest depth of public education and preparedness, ensuring future safety of the people.

Figure 8: **EMS General Internal Structure**

There are three main types of operations that all city structures have, field, dispatch, and special operations. Field operations are the delivery mechanism of aid in response to 9-1-1 calls from citizens. EMTs, paramedics, ambulances and any special care vehicles are included in field operations; the police and fire vehicles and on-site personnel may also be involved depending on circumstances. Dispatch operations consist of the EMT telecommunications staff answering 9-1-1 calls and re-routing call to awaiting EMS units. Communications staff also provides instructions to the civilian caller, records all incoming call information, and coordinates between ambulances and receiving hospitals in the area. Special operations deal with planning and oversight of major events. Monitored planned events are sports competitions, VIP events, and banquets. Non-planned events covered by special operations are hazardous material spills, mass contamination, and mass casualty occurrences.

There are three main types of divisions, training, executive management, and fleet services. Training division maintains current employee training and standards and provides extensive education to new hires. The executive management division is in charge of the direction of medical leadership, research, education, and all operations and programs, forming the control center of the EMS system. Fleet services maintain the ambulances after and between emergency calls. Their main job is to fix mechanical problems with the ambulance and interior machines, but in some cases they may carry out ambulance cleaning duties.

There are two types of ambulances that the fleet maintains: Advanced Life Support (ALS) and Basic Life Support (BLS) vehicles. Figure 9 describes the main staffing differences between different levels of ambulance care.

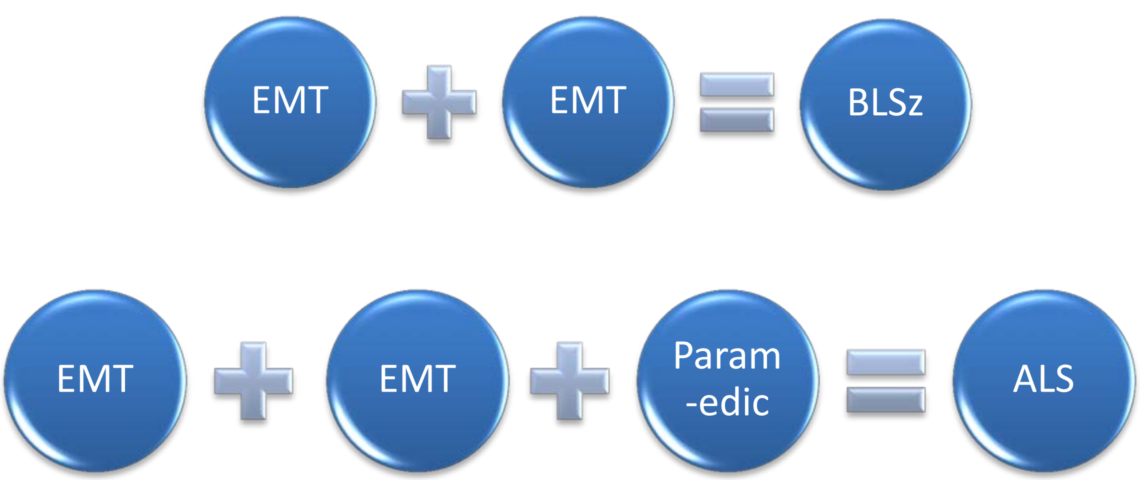


Figure 9: Structure of Personnel on BLS and ALS ambulances

Basic Life Support Units that are designed for inter-facility transportation and pre-hospital response to ill or injured patients. Each unit is staffed with 2 licensed emergency medical technicians. The Advanced Life Support units have a minimum of one paramedic and one EMT, can administer certain medications, and have advanced airway equipment, cardiac monitors, advanced cardiac life support equipment and blood glucose testing equipment.

Two common programs are community initiatives and emergency preparedness. Programs focus of future success through present planning. Community initiatives educate the public on health, safety, and appropriate ways to utilize emergency services. Emergency preparedness looks at long term public safety through education and training of public and health officials to work as a cohesive team in the event of a hazardous emergency.

Despite the structural similarities, there are statistical differences between each city EMS department as shown in Figure 10. New York City has the most staff, units, and calls, where Worcester has the least staff, units, and calls. The other city statistics directly correlate to the size of the city population, where an increase in population is an increase in staff, units, and calls.

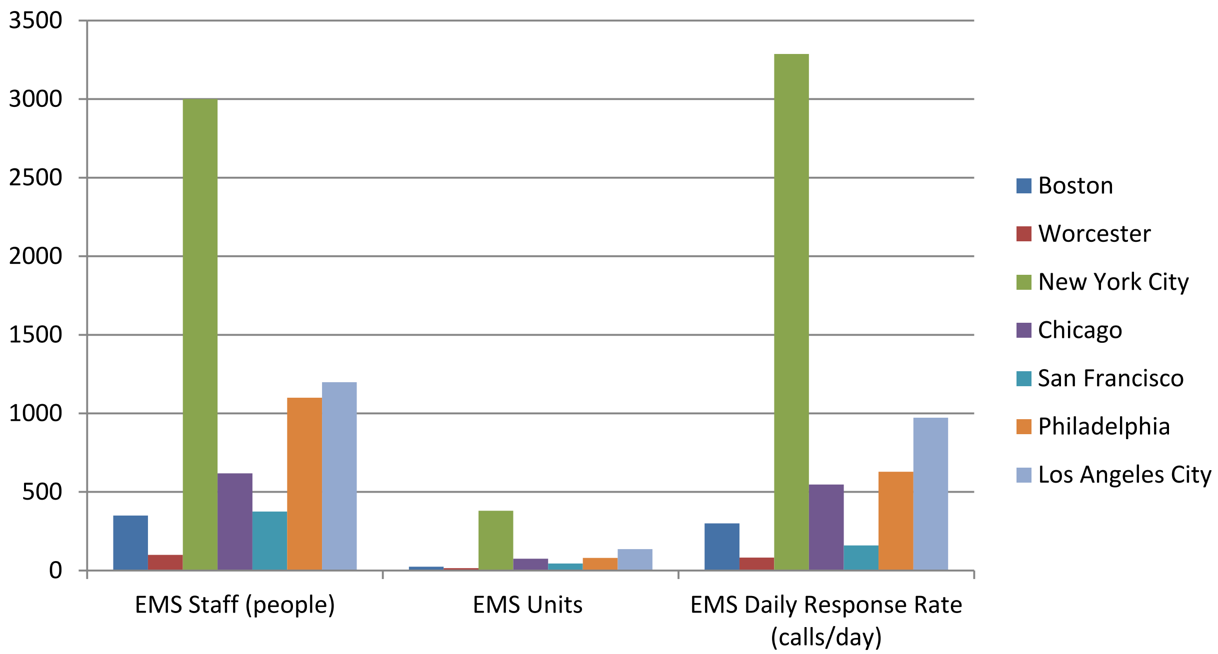


Figure 10: EMS Statistics

The main difference between city EMS departments is the number of people serviced by the ambulance and emergency triage units. This changes the amount of staff needed and size of departments. Organizational structure becomes more complex with an increase in population. This is reflective in most cities being harbored under the fire department as an adjoining division or branch. The only two separate EMS are found in Boston and Worcester, while the rest rely on cooperative support between Fire and EMS programs. In these cases, firefighters are given higher levels of EMS training to help EMTs and Paramedics in the transport, diagnosis and treatment of severely injured citizens.

Comparison of the numerical data in Figure 11 to the population of each city further supports the argument that population effects city EMS structure and processes.

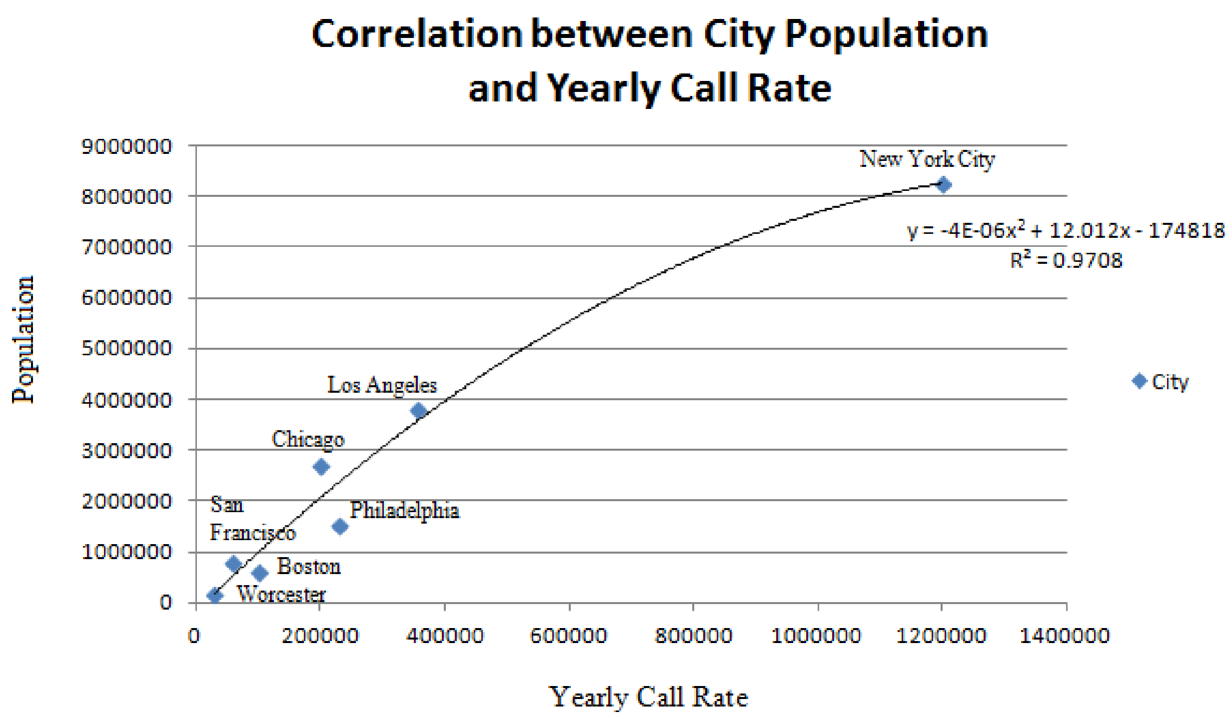


Figure 11: City Population vs. Yearly Call Rate- Seven city populations compared to EMS call rates in a scatter plot with a correlation line and R^2statistic.

There is a positive correlation curve between population and yearly call rates. New York City has a population of 8,244,910 and the subsequent highest call rate out of the 7 seven cities at, 1.2 million calls per year. Note that this supports the expansion of NYC EMS through an increased EMS staff of 3000 people, and 380 units. In comparison, Worcester is the smallest of the seven cities with a population of 181,631 people and only a 30,000 yearly call rate. The decrease in medical coverage needed and calls taken by the Worcester EMS also affects the number of staff members and amount of ambulance/emergency triage units utilized, with numbers at 100 and 15, respectively. Los Angeles and San Francisco are the third and fourth cities closest to the line of best fit, defined as $= -4 \times 10^{-6}x^2 + 12.012x - 174818$. Los Angeles has a population of 3819702 and yearly call rate of 355,460, while San Francisco has a population of 625087 and yearly call rate of 100,000.

The R^2statistic, or coefficient of determination, represents how accurate the line-of-best-fit is compared to the actual data points plotted. In figure 11, the coefficient of determination is 0.9708, which is close to 1.0, known as the value of highest accuracy. Therefore, despite the three outliers, the graph represents the positive correlation curve well. The three outliers include Boston, Philadelphia, and Chicago. Both Boston and Philadelphia have a lower yearly call rate than expected, at 58,400 and 229,709 and with populations of 812,826 and 1,536,471, respectively. Chicago is slightly above the yearly call rate, despite the population, with 2,707,120 people living in the city and a yearly call rate of 200,000. Problems that may occur for EMS structures in Chicago are not the same as in Boston or Philadelphia. Chicago is managing a higher influx of calls, without the staff and units to decrease response time. Therefore, unit placement, a strict shift schedule for EMS staff, and a proper dispatch system is important for maximum efficiency. Boston and Philadelphia have less calls and more supplies in the form of

EMS staff and units. There is more time to focus on awareness programs and prevention plans, which further aid in the long term success of the program. Potential problems may include, staff and unit decomposition of unused skills and parts. Annual recertification programs and routine equipment checks can prevent slightly less utilize equipment and man-power from becoming outdated and unpracticed.

EMT uniforms, roles, and responsibilities are similar in the seven researched cities. Figure 12 illustrates what a typical uniform looks like. Uniforms can be purchased online or at many regional stores. EMS clothing is functional with pockets on pants for storage, a chest pocket for a clip-on radio, and minimal hanging material to get caught on machines or soiled by patients. The purpose of uniforms is to establish a standardized appearance that all citizens in distress can recognize. In addition, most Emergency Medical Systems require a logo to be worn on the shirt for identification purposes. Certain EMS will also specify the type of pants and shirts. Long hair is to be pulled back and cannot cover the logo. No jewelry or perfume is allowed either. Uniforms must be clean, well-fitting, and wrinkle free at all times. Uniforms in an EMS system are a part of the structure and recognition process within the organization and in public.

Figure 12: EMT Uniforms- Examples of EMT uniforms [89]

According to the U.S. Labor Department, Ambulance Services are defined as EMS units whose function is to deliver aid and subsequent transportation to determined treatment centers. The patient is defined as an individual with immediate clinical needs who is directly or indirectly involved with a damaging incident(s). There are two main ambulance service roles as per the Occupational Outlook Handbook of the U.S. Labor Department. The first is that the role of an EMT unit is to alert, mobilize and coordinate at the scene of the incident all primary NHS resources necessary to deal with any incident. The second role is for EMS units to minimize the disruption of healthcare services and to bring about a speedy return to normal service provision through cooperation of multi-agency responses across organizational boundaries.

There are five main universal EMT responsibilities: assessing medical needs, taking vital signs, taking a SAMPLE history, properly transporting patients, and maintaining composure under stress. To access medical needs, the EMT draws upon past training exercises and education to determine quickly which level of injury the patient has sustained. The Abbreviated Injury Scale (AIS) is a current system used by hospitals and EMTs to determine the severity of the injury sustained by a patient. Figure 13 displays the organizational value of the AIS system, where injuries are rated on a scale of 1-6, with 1 as the least deterring ailment.

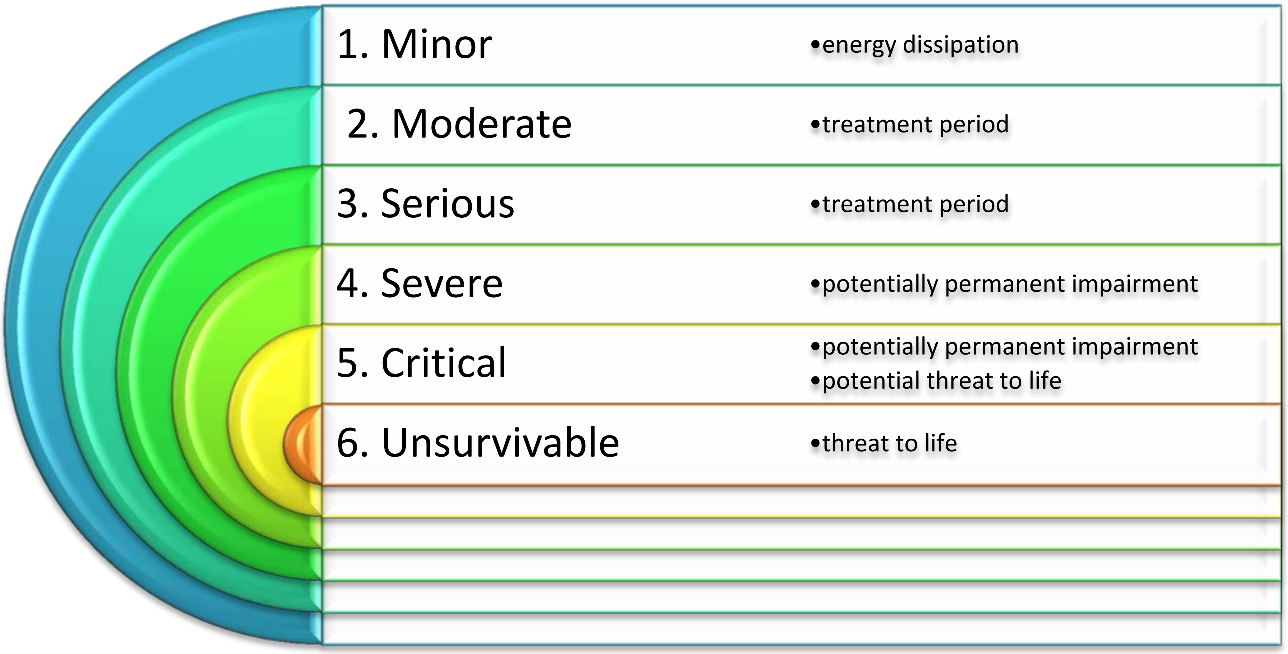


Figure 13: Abbreviated Injury Scale- 1 is the least injury and 6 is the worst injury.

EMTs are able to generally categorize injury into 6 grouping and then further breakdown analysis with four main typical outcomes: energy dissipation, treatment period, permanent impairment, and threat to life. Group 1 is considered energy dissipation. An example of this is dehydration and can easily be fixed with saline, water, food, and rest. Groups 2 and 3 are known as the treatment period and may involve broken bones that need to be set and monitored. Group 4 and 5 are potentially permanently damaging; heart attacks and seizures fall under these parameters. Group 6 is a threat to life and an example of this is a severe car crash or broken spinal cord. If handling multiple patients, the AIS system allows for the EMT to make an educated decision that favors the most critical injury and gives the bulk of initial patient care to that individual until back-up EMS units arrive.

The second EMT responsibility is to take initial vital signs and then continue to monitor these signs throughout patient transportation. Figure 14 describes the three main levels of vital sign monitoring. The three main vital sign levels are consciousness, respiration, and appearance.

The EMT is required to check consciousness by asking the patient a series of verbal questions, raising tone inclination and volume, light physical tapping of the patient, and noting any additional abnormalities. Upon checking for the first vital sign, respiration is checked through visual recognition, stethoscope usage, taking of the pulse, and potentially restarting of the heart.

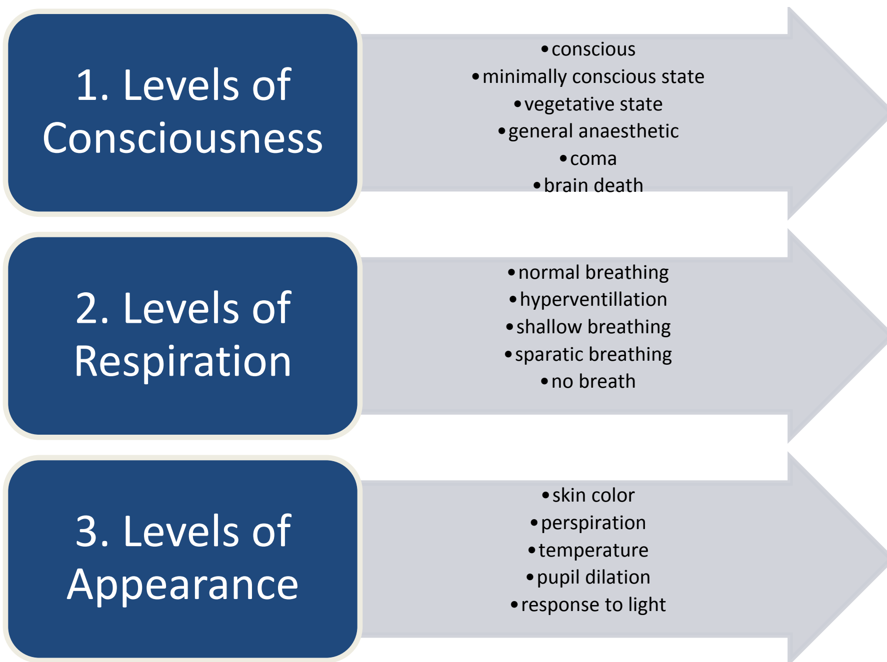


Figure 14: Levels of Vital Signs

The third vital sign is the observation of appearance and behavioral studies. The patients' reaction to light, appearance of being too warm or cold, favoring of a body part, or pupil dilation can all be used to pinpoint the specific injury and resulting treatment. The third EMS responsibility is the successful completion of a SAMPLE history report. Figure 15 visually describes the acronym SAMPLE: Signs and symptoms, Allergies, Medications, Pertinent past medical history, Last oral intake, and Events leading to injury/illness. It is important to ask the patient all the SAMPLE history questions before administering drugs or complex procedures because a patient may be allergic to a medication or the given drug may mix with previous drugs taken to cause harmful side effects. How an injury occurred can also lead to certain types of procedures or measures taken to ensure no additional injury. The hospital doctors also need a copy of the SAMPLE report in order to speed up processes and ensure no miscommunication.

Figure 15: SAMPLE Diagram

Proper movement of patients onto the triage unit, into the ambulance, out of the ambulance, and onto a hospital bed is also a responsibility of the EMT. Proper lifting and moving methods include using at least two people, making sure the patient is properly strapped into the stretcher, coordinating movements with the coworker and using the correct lifting techniques.

The last responsibility of the EMT is to maintain composure. EMTs cannot faint at the sight of blood or become excitable when dealing with high stress situations. EMTs provide structure and professionalism to a complex and sometimes scary situation. It is important that when filling out the SAMPLE history, checking vital signs, performing pre-operation preparations, and performing any other duties that the EMT regularly checks to make sure their mental state is satisfactory. EMTs are encouraged to seek guidance if experiencing insomnia, nightmares, anger, disorientation, panic attacks, depression, memory loss, or increased alcohol use. In these cases, a break or switching of roles in the EMS system may be required in order to ensure a smooth, minimal percent error, daily procedure.

2.2 Technology

2.2.1 Past Technology and Advancements

The history and development of EMS ambulance designs, materials and practices in relation to contaminants is eternally transforming to increase efficiency and accuracy of life-saving practices. Since 900 A.D. there has been record of human transport through aid. The issue of contamination becomes increasingly prevalent as societal thinking advances from transport to life saving measures of aid. Figure 16 shows the progression of technology from 900 A.D to the

21st century, focusing on the main turning points of ambulance design, materials, and practices to promote safer transport by decreasing contamination.

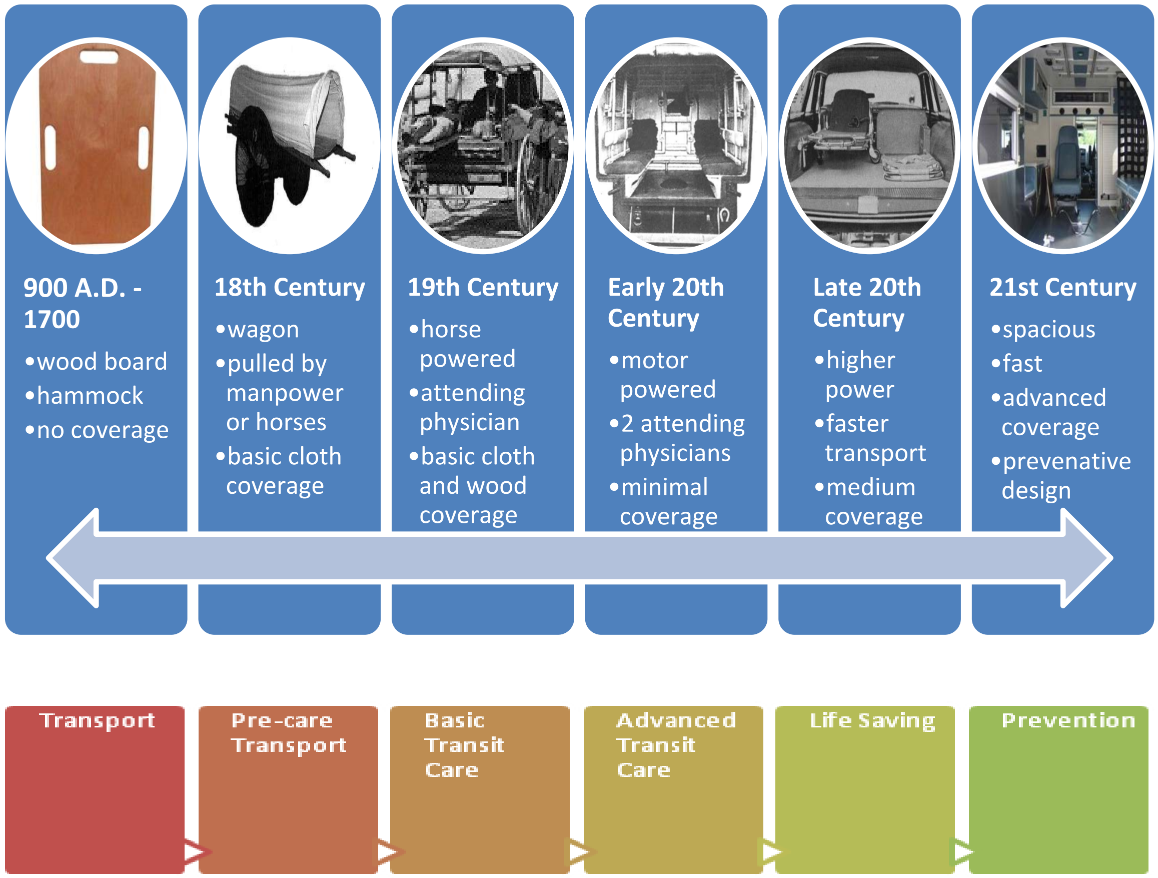


Figure 16: History of Ambulance Design

In ambulance design, several factors affect contamination including patient coverage, ventilation, and cleanliness. Patient coverage is important to preventing the influx of exterior microbes near the wound site. For example, the wooden carrier board of 900 A.D. provides no coverage from dust, pollution, and microbes encountered in transit. The first instance of patient coverage is in the 18th century where cloth is placed over the injured patient. However, in the early 20th century a more effective box design is enacted and continues to be perfected well into the 21st century. Also in the early 20th century, the issue of ventilation arises. As the ambulance design is an enclosed box, there is a need for filtered airflow to prevent the stagnation of microbial ingested air from infecting the physicians and further infecting the patient. The progression of an open cloth flap, to open ducts, to a true vent system with filters is seen in the early 20th, late 20th, and 21st centuries, respectively. Cleanliness is a factor that affects not only the current medical staff and patient, but also the future teams and patients working in ambulances. Even into the late 20th century, the main concern for ambulance designers is speed of transit between the site of injury and a hospital. In the 21st century the idea of cleanliness becomes more prevalent as parts that are easy to clean are consciously developed. An example of this is plastic floors that extend onto interior ambulance walls to minimize cracks where microbes incubate or cleanable triage covers to protect padding from bodily fluid spills. With a shift in design materials from wood and cloth to metal and plastic, there is a decrease in contamination. The production of specialized chemicals and the enacting of cleaning procedures also effects contamination.

Since WW1 there is evidence of cleaning procedures amongst battalions. Figure 17 is a picture of a cleaning battalion from WW I.The American troops had a Director of Medical Services and each division had a sanitary section. The officers of the sections were specially trained experts on sanitation and as Nelson states, “each of these sanitary sections has a small staff of non-commissioned officers and men and plenty of equipment, such as disinfecting machines, which accompany the division wherever it goes” (Nelson). However, the concept of an advanced cleaning team was harder to apply in civilian life.

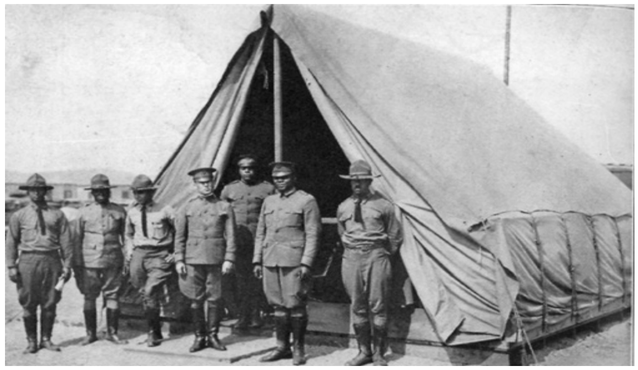


Figure 17: WWI Labor Battalion[63]

In the late 20th century, emphasis is placed on life saving in addition to transport. The speed of ambulance vehicles is increased with advanced motors and technology is invented to treat the patient before even reaching the hospital. The 1970's and 80's introduced communication devices, portable defibrillators, and permanent internal clasps to hold the portable stretchers. The increase in technology caused additional cracks for microbial growth. The transfer of authority from local guidelines to NHS performance standards in 1974 helped to maintain the balance between health standards and the rising reliance upon technology. The invention of cleaning products like Ajax, Tide, Palmolive, and Formula 409 in the 20th century aided in the promotion of cleanliness and performance standards.

In the 21st century, each nation has a standard for cleanliness and regulation of cleaning. The ability to advance as a nation is based on the frequency of opportunity's prevalence. Therefore, even in the modern century, the quality of care varies. In Figure 18, five countries are selected to show the variance of quality in different regions of the world.

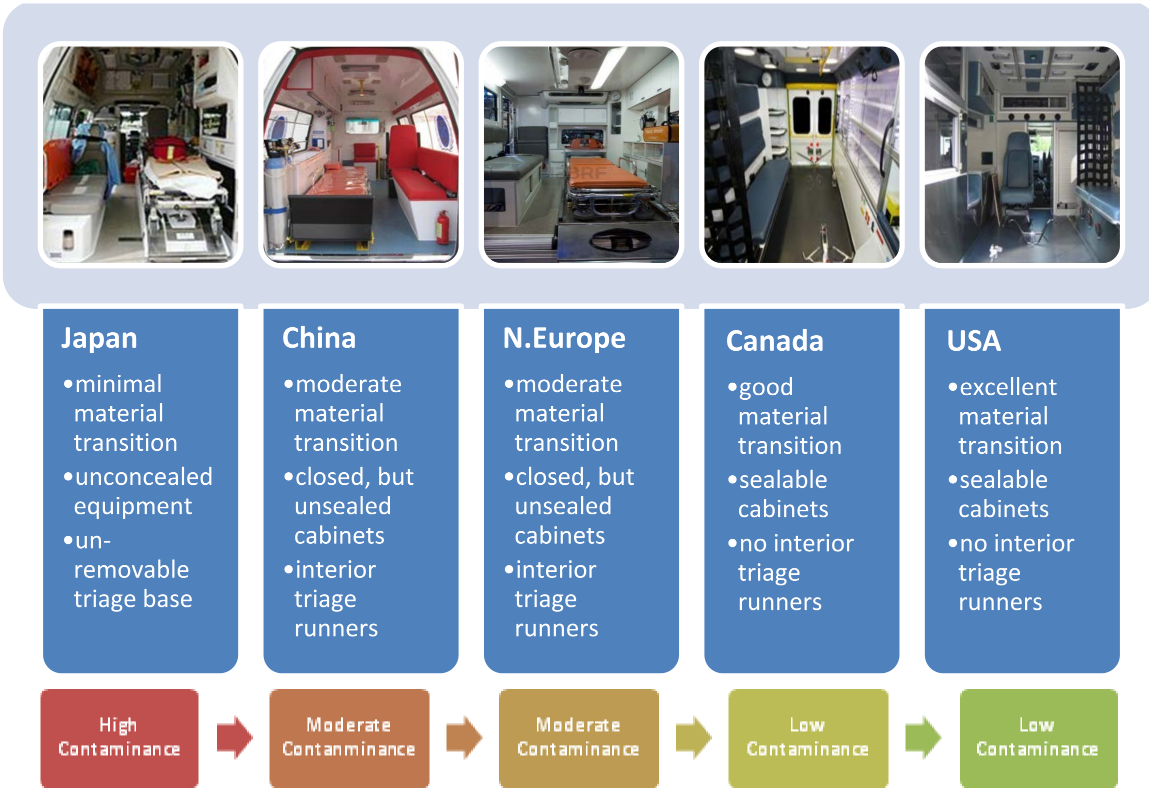


Figure 18: Ambulance Quality Variance

Japan is rated as high contaminance, since the ambulance exhibits minimal design criteria for cleanliness. Though the materials used to furnish the interior are primarily plastics, the way in which the components are configured suggests ample room for microbial growth. There are numerous cracks between the floor base and walls, at adjoining connecting seats, and around cabinets. There are no triage proper cabinet seals and the triage base is complex and un-moveable. Even with extensive cleaning, microbes would still be able to incubate in unreachable corners of the ambulance. The difference between the Japanese ambulance and an ambulance of moderate contamination is the coverage. There are minimal cracks in both the Chinese and Northern European ambulances between wall and floor seems and seat cushions are re-moveable to reach hard to get places. Cabinets are properly enclosed or sealed to prevent fluid splatter from contaminating tools and machinery Though there are interior problems, such as the triage runners, it is much improved from a high contaminance vehicle. Low contaminated vehicles include Canada and USA, as there is a seamless transition between the walls and floors, re-moveable pads, seamless cabinets and no triage runners. Section 2.2.2.1 will further discuss the modern advancements in technology that creates a low contaminated unit.

Noise Reduction

Ever since noise pollution became an issue for society, there has been dedication to researching and developing methods to reduce sound. In the beginning, the only technique used to minimize noise was to eliminate where the source of the sound was coming from. For instance, in ancient Rome, men were not allowed to use their wagons on the pebble roads at night due to the sleep disturbance caused. Since then, knowledge has increased along with technology, and therefore noise reduction devices have improved.

The 1960's was the first time that reverberation time had been utilized in the design process. Reverberation time is the amount time it takes for a sound to drop below 60 decibels from its original level[77]. An auditorium can be used as an example to grasp this concept and its importance. If an auditorium were made out of metal, then the sound produced would reflect off of the walls and chairs, and it would take a very long time for the sound to die down. On the other hand, if the walls were absorbent, the sound would quickly die down since the walls would take in the sound, not allowing it to bounce off.

The origin of time reverberation began with trying to identify how long it took for sound to completely go away. This was nearly impossible to detect since noise depends on how loud the initial sound was as well as the acuity of the hearing of the observer. In order to set a standard, reverberation time was defined as the time it takes for sound to decrease by 60 decibels below its original level. This definition allowed for reproducibility.

Engineers used this classification in designing sound reducing devices. Referring back to the auditorium example, architects would design one so that the reverberation time lasted around two seconds. The shape and materials used in the room would help to achieve this goal. The two seconds was set so that articulation was clear and the music would sound richer. Figure 19 below shows desirable reverberation time for an auditorium.

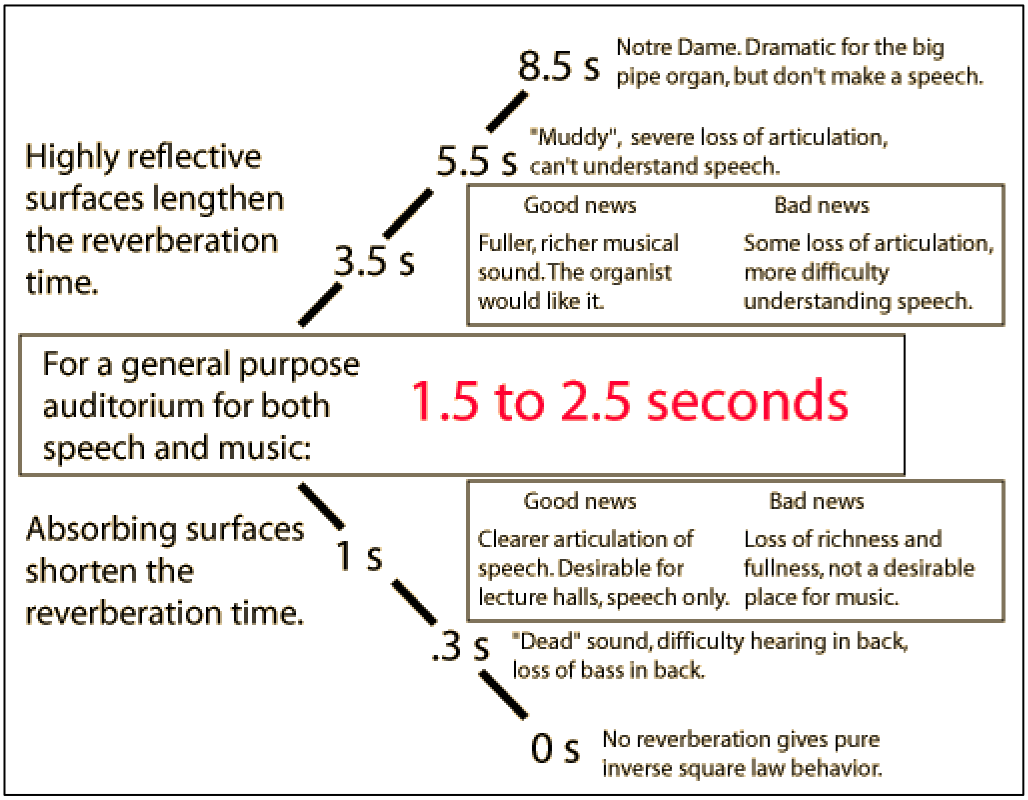


Figure 19: Reverberation Time 77

Reverberation time is dependent on the dimensions of the area and the absorption coefficients of the material used. Besides auditoriums, reverberation time began being used in many public areas. This was a great method for deciding dimensions and material to best reduce noise in a particular location.

Relating reverberation time to the design of an ambulance was highly important for speech to be clearly communicated between EMTs/paramedics and the patient. For speech, the optimum reverberation time is 0.8 – 1.1 seconds[77]. An ambulance could best achieve this by reducing the noise of the siren going into the patient compartment.

In the 1900s, sirens were attached to the roof of an ambulance so that the sound would be projected outward to drivers and pedestrians. This goal was achieved. However, the driver and patient compartments were disturbingly loud. In the late 1900s, the siren was moved from the roof to the front grill of ambulances[96]. Table 12 shows the sound differences before and after the siren was relocated.

Table 12: Ambulance interior sound level according to placement of siren [96]

Location/Condition	Roof Siren (RS)	Grill Siren (GS)	RS – GS
Driver Compartment with Window Open (DWO)	109.1 dB	87.1 dB	22.0 dB
Driver Compartment with Winder Closed (DWC)	96.3 dB	80.0 dB	16.3 dB
DWO – DWC	12.8 dB	7.1 dB	
Patient Compartment	84.3 dB	75.9 dB	7.4 dB

As seen in Table 12, before the relocation of the siren, both the driver and patient compartment exceeded today's regulations. These decibels were unsafe for EMTs/paramedics to be exposed to on a daily basis. Consequently, many workers during the 1900s experienced hearing damage due to the location of the siren, and lack of research and technology developed to reduce noise. To demonstrate the hearing loss during the late 1900s, Figure 20 demonstrates the percentage of EMTs/paramedics who loss hearing over fourteen years of working.

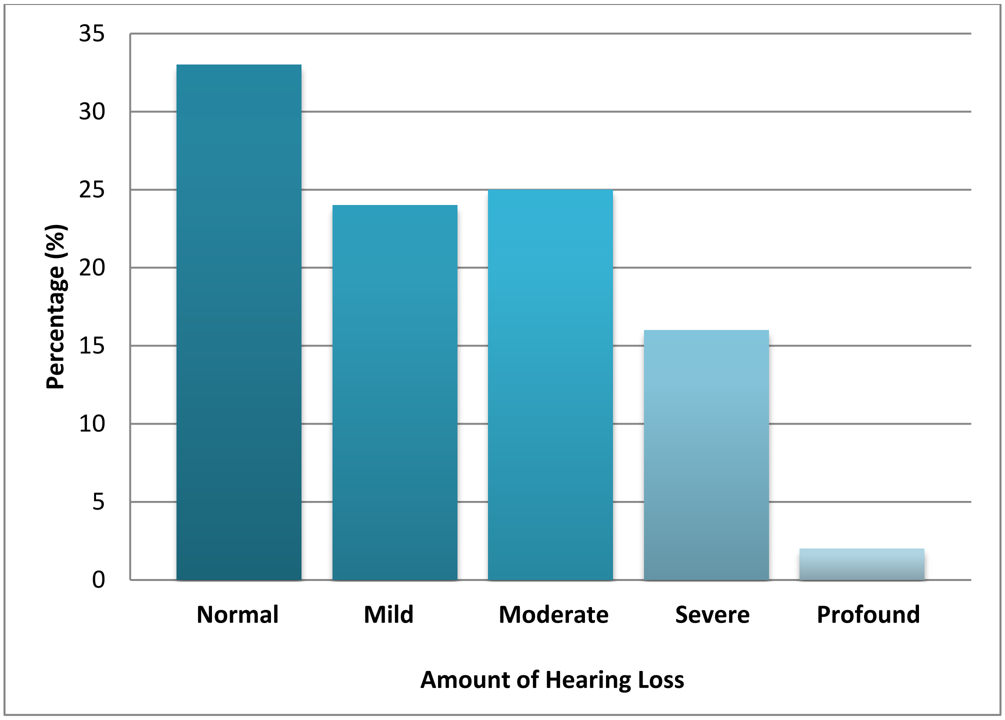


Figure 20: Hearing Loss of EMTs/Paramedics Over Fourteen Years [45]

The figure above is research conducted from 458 EMTs and paramedics from Ohio. The National Institute for Occupational Safety and Health (NIOSH) tested the EMTs hearing in 1984, and again in 1998 the same 458 were retested to determine whether the ambulance caused noise induced hearing loss. Over the fourteen years, hearing loss is to be expected due to aging. The category labeled as "Normal" in the table accounts for 33% of the participants who lost their hearing as an average person would. The other two-thirds had measurable hearing loss. These results indicate that the EMTs exposure to noise was a significant hazard. Hearing loss was caused from the siren, air horn, and apparatus engines.

Three years prior to the conclusion of this test (1995), standards were increased for ambulance noise. These results supported OSHA's stricter noise regulations. At the start of the twenty-first century, all ambulances had relocated the siren and improved wall insulation to meet the 80 decibel maximum noise. Drivers and EMTs/paramedics were highly recommended to additionally protect their hearing with the use of earplugs and headsets.

Many improvements have been made to cabin design compared to the primitive ambulances of the past. Comfort has been one of the greatest advancements. Ergonomics of seats and beds in ambulances have improved from wooden bench designs, to seats with cushions, padding and contouring to best support the patient and technicians [Figure 21]. Early ambulance units focused their efforts on design for transport Up to the Korean War, the ‘scoop and scoot’ method of emergency triage care was common place. Attendees of the 1995 Adelaide symposium saw in-field treatment as the future of emergency triage, and, although the technology was slow to catch up, their lofty goals have been partially met. While the treatment in the patient compartment is not, and cannot be extensive of yet due, primarily, to road vibrations and chassis movement, some procedures are feasible. These procedures include but are not limited to incubation, needle thoracocentesis, pulse oximetry, and resuscitation. A larger cabin which allows a greater range of motion for emergency medical technicians, and an increase in medical devices present within the patient cabin are base improvements which have reduced unintended stresses on technicians and patients.

Figure 21: 1940 New York City Ambulance

Figure 22: 2012 New York City Ambulance- Illustrates the differences to the exterior of New York City ambulances in the past seventy years**.**

2.2.2 Current Technology and Advancements for Decontamination

Since contamination is a real issue of concern for any EMS provider, many researches have been dedicated to prevent or remove contaminants. Below is a summary of recent technology development in this field.

Simple cleaning technology

The most common technology currently used is the simple cleaning method, which combines manual cleaning with disinfectants. The benefit of this method is that it is very simple, as any EMS worker could perform the task as long as he adheres to the specified procedure. In addition, the current manual method is also inexpensive, as it does not require any expensive materials or complicated infrastructure set up. The disadvantage, of course, is that this method does not guarantee 100% decontamination, as it is usually the case that there are many contaminated spaces that could not be reached with manual cleaning[62].

The procedures for manual cleaning that most current EMS providers follow are:

- Use a 5% aqueous solution of a phenolic germicidal detergent (e.g. Lysol, Amphyl) to spray the entire interior of the ambulance heavily then leave the solution on the surface for at least 20 minutes (Figure 23).

Figure 23: Spraying Ambulance Interior Surfaces

- Use a clean and disinfected cloth or a disposable wipes and apply the recommended disinfectants mentioned in section Chemicals used for decontamination and disinfection purposes (section 4.1) to clean all surfaces inside the ambulance and all outside door handles, according to section 4.1 (Figure 24).

Figure 24: Wiping Ambulance Interior Surfaces

- Wash ambulance exterior surfaces with running water (Figure 25)

Figure 25: Washing Ambulance Exterior Surfaces with Running Water

More advanced cleaning technology

Beside the common manual cleaning method, recently more advanced decontamination technologies have been developed. These new methods have been shown to be superior to the manual cleaning techniques in decontaminating ambulances and EMS devices. Thus, these new technologies have been recommended to be used in EMS when possible. However, the major disadvantages of these new technologies are their high cost to set up and operate, and complicated installation. These disadvantages have prevented most EMS providers to adopt the new cleaning technologies; and currently the companies providing these new technologies are still working to eliminate these disadvantages.

The Micro particle disinfecting system

One such new technology is the ZIMEK micro particle disinfecting system from the Safe Air Corporation of Manasquan, New Jersey. This ZIMEK micro particle disinfecting system is a system transporting disinfectant solutions from the recommended disinfectant list (section 4.1) into ambulances to clean interior surfaces of an ambulance and medical devices. What is special about this system is the Dri-Mist Micro-Particle Generator that breaks down the molecular structure of these disinfectants into negatively charged ion particles. Due to the small size of these ion particles, which are less than 1 micron, they can access all the interior surfaces of the ambulance, including those tiny areas that manual cleaning method cannot reach, thus killing all the virus and bacteria inside the ambulance. In addition, the whole process is controlled via a computer system, which assures that the concentration of the disinfectant solution as well as the cleaning step orders follow exactly the requirements[104].

Since the process of this system is automatic, the operation is very straightforward and could be run by any EMS member after a short training. However, a major disadvantage of this system is its high cost so currently only a limited number of public and private EMS providers are using this system. An example of such private EMS providers is the Monmouth-Ocean Hospital Service Corporation in Neptune, NJ, which has been using the ZIMEK micro particle disinfecting system since May 2009. According to the report of the service provider, the ZIMEK micro particle disinfecting system has been very effective in decontaminating ambulances and medical devices and is superior to the traditional manual cleaning methods. Furthermore, the ZIMEK micro particle disinfecting system has also been adopted by many agencies of the Department of Homeland Security for more than three years[54] (Figures 26, 27).

Figure 26: A ZIMEK Micro Particle Disinfecting System in Operation

Figure 27: The ZIMEK System used at Carson Tahoe Regional Healthcare

The vapor generation technology

Similar to the micro particle disinfecting system, the vapor generation system also has a generator in the system. However, instead of breaking down the molecular structure of these disinfectants into negatively charged ion particles, the generator in the vapor generation system transforms the disinfectant solution, in this case being hydrogen peroxide, into gas streams. Then another component of the system, which is the high velocity gas distribution nozzles and fans will provide an even spread of the disinfectant vapor to all interior areas of the ambulances. Thus, utilizing this system, one can be assured that all surfaces are uniformly exposed to the disinfectant vapors and will be decontaminated. In addition, after the cleaning process, hydrogen peroxide vapor will decompose into oxygen and water vapor, making the bio-decontamination process "residual-free". As a result, no further wiping down of surfaces is required up on completion of decontamination. Although this vapor generation technology is superior to the traditional manual cleaning method, similar to the micro particle disinfecting system, this technique is currently still expensive and not affordable for many EMS providers[10] (Figures 28, 29).

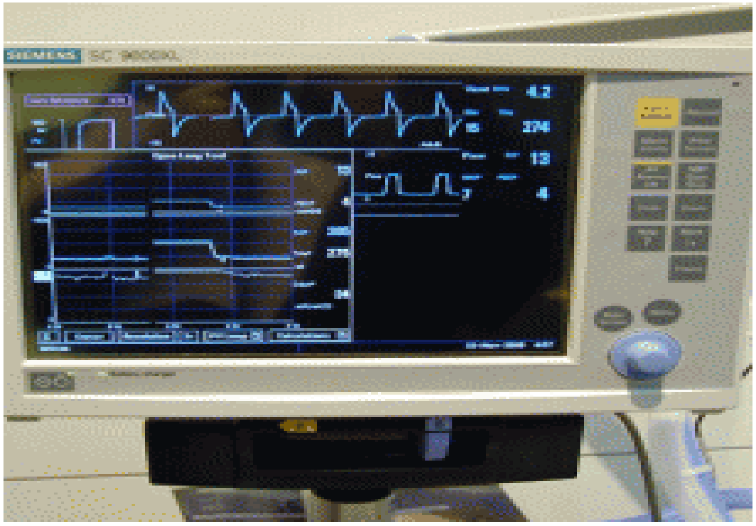


Figure 28: A Bioquell's Vapor Generator in Operation

Figure 29: Hampshire County EMS

Dry steam vapor technology

The dry steam vapor technology is very similar to the vapor generation technology, in the sense that in both technologies, there is a stream of gas materials poured into the interior surfaces for cleaning purposes. However, in contrast to the use of disinfecting chemicals in the case of vapor generation technology, the dry steam vapor technology does not utilize any aggressive chemical; instead it uses a vapor steam heated to 180 degrees Celsius and delivered at 130 PSI to eliminate contamination. The structure of the dry steam vapor system is very similar to that of the vapor generation system. It consists of a generator that produces a vapor steam at the desired temperature and pressure, and a high speed air distribution nozzle and fan system to provide an even spread of the air steam to all the interior surfaces[5].

This dry steam vapor technology has the benefit that, unlike the micro particle disinfecting system and the vapor generation system, it does not require the use of aggressive disinfecting chemicals, which means that it is safer for the cleaning system operators as well as for the environment. However, this benefit is also its disadvantage, as many people still have concern that the lack of aggressive disinfecting chemicals would still leave contaminations in the ambulance after cleaning. Although there exists evidence showing that the dry steam vapor technology achieves a high effectiveness in removing contaminate (such as one study showing it achieves a microbial "kill" rate of 90% in two seconds), whether all the EMS providers should use this technology or not is still very much in debate[5] (Figure 30).

Figure 30: Dry Steam System in Operation

Noise Reduction

Research and education has increased dramatically since the creation of the ambulance. Consequently, technology has significantly improved as well. Regarding ambulances, there have been drastic improvements in all aspects to ensure safety to other drivers on the road, pedestrians, EMTs/paramedics, and the patients. Specifically, noise pollution in ambulances has not only acquired federal standards over time in the United States, but engineers have been able to implement technology to meet these requirements.

Today, the KKK-1822 Standards state that the siren on the front grill or bumper must produce at least 123 decibels, and the patient compartment may only be 80 decibels[97]. In order to meet both of these requirements the walls, ceiling, and floor of each ambulance have materials insulating noise. This reduces the noise emitted from the siren that travels into the patient compartment. The siren's noise may travel two ways into the compartment; (1) the wrap around method which means that as the sound is projected out of the siren, it propels forward and bounces off surrounding objects, and (2) structurally so that the sound travels through the surface that the siren is mounted to and continues through adjacent materials. Utilizing sound insulation reduces the effects of the 123 decibel siren down to 76 decibels in the patient compartment[46]. As previously mentioned, before the sound insulation was implemented, the patient compartment reached noise levels of 85 decibels which translates into being nearly twice as loud.

The chart below demonstrates the effectiveness of sound insulation in the patient compartment as well as in the driver's compartment in type I and III ambulances. In order to meet the current KKK-1822 Standards of the patient compartment maximizing at 80 decibels, sound insulation was necessary.

Table 13: Ambulance interior sound level based on sound insulation [97]

Type I and III Ambulances	Without Sound Insulation	With Sound Insulation
Driver Compartment	120 dB	80 dB
Patient Compartment	115 dB	76 dB

Table 13 indicates that the driver compartment today still reaches 80 decibels with the siren on, and this excludes any speech communication and other noises occurring. Using Equation 30 below, it proves that by adding speech (about 60 decibels) to the existing 80 decibels from the siren, the driver compartment will remain at 80 decibels[35]. Therefore, there is enough sound insulation protecting the driver at all times from any hearing impairment that could have occurred over time with exposure to the siren. In order to calculate the sound pressure level, the equation below in Figure 31 must be used.

$$\mathrm{L} = 10log10 \sum_{i=1}^{n} 10^{\left(\frac{\mathrm{Li}}{10}\right)}$$

Figure 31: Sound Pressure Level Equation [66]

The above formula is necessary in order to determine sound pressures, which aid in quantifying values used for EMT safety. With sound insulation in an ambulance, this equation is utilized. In order for the sound insulation to work effectively, it is composed from three layers that control the sound. The first layer decouples the sound, the second acts as a sound barrier, and the third absorbs the sound[27]. These layers consist of foam and solid panels which are located in the floor, walls, and ceiling of the ambulance. After assembling the three sound insulating layers, the interior layer of the ambulance is put up which is generally made out of aluminum. This is the preferred material due to cost efficiency, ease of cleanup, and the light reflective properties of the material. The last point mentioned is necessary for the EMTs/paramedics to perform their job effectively.

Aside from the sound insulation, EMTs/paramedics have options so that the noise is less of a distraction. Below in Table 14 are the primary choices that are predominantly used in ambulances in the United States. Comparing each of the three devices shown in Table 14, there are advantages and disadvantages to using each one. Although earplugs reduce the most noise being channeled into the eardrum, they are undesirable by most EMTs/paramedics. Earplugs make it difficult to communicate with one another due to how much noise is being prevented. Along with this, some people find earplugs to be irritating to wear. On the other hand, they are extremely cheap and therefore cost effective.

Table 14: Comparison of ambulance noise devices [27, 31, 46]

Device	Advantages	Disadvantages
Earplugs	-Cost effective - Reduces noise by 30 db - Mobile	- Difficult to hear and hold conversation - Insert new pair daily - Uncomfortable
Silent Intercom	- Produces 0 db - Patient is not alerted	- Hands on - No speech communication, less detailed - Reduces noise by 0 db
Intercom Headset	- Reduces 24 db - Hands free - Ease of use - Comfortable	- Cost

A silent intercom is a system of three lights and a beeper used by an EMT/paramedic to advise the driver about the patient's condition. This device is most useful when the EMT/paramedic needs to inform the driver about a patient's negative condition so that the patient and any friend or family member who is riding along will not be alarmed or scared. In order to use the silent intercom, the display in the patient compartment includes a beeper next to a green, amber, and red light. The green light signifies that the patient is in good care and to proceed normally to the hospital. If the ride is too bumpy for the patient then the amber light is signaled to the driver so that he or she can slow down to accommodate the patient's need. The red light is used when the ambulance needs to pull over to the right and stop as soon as it is safe to do so[27]. The silent intercom method is used moderately by EMTs/paramedics depending on the specific scenario. Using this device is not very accurate if the driver or the other EMT/paramedic in the patient compartment needs to know more details.

Lastly, the intercom headset device has become widely accepted in in the United States due to the convenience of being hands free, comfortable and reducing background noises by 24 decibels. While wearing the headset, the amount of decibels entering the ear canal, if one person is speaking through the headset, will be 52 decibels on average[31]. According to OSHA this noise level is extremely safe and a human can be exposed to this decibel level for an everlasting amount of time without having it cause any hearing impairment. Using the headset is also very simple. Once the lightweight, flexible headset is on and plugged into the intercom system, an EMT/paramedic or driver solely needs to speak into the microphone. This hands free approach allows the EMT/paramedic to help the patient to the best of their ability. Also, the headsets have a feature so that the person on the receiving end of the conversation will not hear any background noise coming from the person's end who is speaking. The intercom headsets are more expensive than the earplugs and the silent intercom, but the benefits exceed the withdrawals which is what has made this product's use extremely common.

The current technology reducing noise in the patient compartment has made the EMT/paramedics and the driver's hearing safety increase so that over time they will not have permanent damage. The patients have also benefited from these new devices so that their emergency treatment can be performed without exterior noise distractions. An EMT/paramedic's attention needs to be completely focused on their job, and this can be made possible with the assistance of current technological advances.

Noise levels exceeding 70 decibels cause an annoyance and are undesirable for working conditions. According to research, it is desirable to have 50 decibels of noise or less. Areas of condensed population struggle to keep noise within a desirable level as shown previously in Table 13. In order to lessen noise pollution in these areas, sound reduction techniques have been implemented, as seen previously with the case of an ambulance. The table below shows devices currently used to reduce noise in various public areas in the United States.

Table 15: Devices used to reduce noise in public areas [67, 77, 87]

	Sound Insulating Walls	Sound Absorbing Walls	Headset	Earplugs	Shape of Space	Equipment Modifications
Ambulance	X		X	X		
Hospital	X	X				X
Airplane	X		X	X		X
Classroom		X				
Auditorium		X			X	

Note: Sound insulating walls prevent noise from coming into or leave a room. Sound absorbing walls are used inside a room so that sound will die away quicker.

The table above shows that depending on the public place, different techniques are utilized in order to best achieve noise reduction. As seen, an ambulance utilizes sound insulating walls for relief from the siren, as well as working personnel wearing headsets and earplugs. But, in a hospital it is unnecessary to have workers wearing headsets and earplugs. In this case, it is better for the environment to implement sound insulating and absorbing walls so that a patient is not disrupted by another patient in an adjacent room. Equipment in a hospital is also being modified in ways such that alarms may go off less frequently so that patients may be able to sleep without disruption. Another public area displayed in the table is an auditorium which is where the shape of the room is altered. It is efficient to have non-parallel walls as well as walls with sound absorbing panels and curtains to best reduce noise while allowing it to spread evenly over the entire theater[77]. In conclusion, different sound reducing techniques must be implemented depending on what is best for the particular location.

Unintended stresses

Of all the ambulance improvements throughout the years, reduction in vibration is a major component which has reduced physical and psychological stress on emergency medical technicians and patients alike. Ambulance patients in pain benefit from calmer surroundings, especially after traumatic events where and stress and anxiety compound in the patient cabin[43]. The integration of suspension systems in these vehicles have brought down vibration levels in ambulances to allow for a smoother overall transport. Reducing vibrations have allowed for the administration of on-site medical treatments, allowing for patient care before hospital arrival.

The cubic feet of space within the patient compartment has almost doubled since the 1940 ambulance models. This additional space has allotted for medical storage and increased head room, allowing emergency medical technicians to equip the ambulance with medical supplies to improve patient care. The additional space allows for greater range of motion for the ambulances, improving their ability to contort in the ways necessary to address the patient's medical issues.

Although vibrations have decreased, the addition of electronic, medical devices has added stresses in the form of alarms and various noises associated with machine read-outs and alerts. Although the devices are not permitted to produce noise greater than 80 dB, the beeps and ticks of the medical machinery increase patient anxiety. While vehicle technology has improved the unintended stresses produced in an ambulance, the leap in medical device technology has introduced added stresses within the patient compartment.

2.3 Economic Structure and Limitations

2.3.1 General

Common fee structure of most EMS

Most EMS providers charge three types of fees: flat service fee, mileage fee and extra fee. Whenever EMS is performed on a patient, a flat service fee would occur. Most EMS providers have three levels of EMSs: basic life support (BLS), advanced life support (ALS) and advanced life support 2 (ALS 2). Each level would result in a different level of flat charge with ALS 2 costing the most. Depending on the level of service performed, the EMS provider would charge the corresponding fee at that level only. For example, a patient receiving ALS service would only be charged at the ALS fee level and will not be responsible for the BLS fee, although ALS activities do include BLS activities[39]. The most common definitions of these levels are below:

Besides the three levels of flat charge mentioned above, some EMS services also have some additional flat charges for some extra services. The most common extra flat charge is a flat charge for the supply of oxygen, regardless of the amount applied. An example of the flat service fee for EMS could be seen from the EMS charge table of the public EMS in Chicago[15]:

Table 16: Public EMS with services fees in Chicago

Levels of EMS Service	Fees
Basic life support	$800.00
Advanced life support	$950.00
Advanced life support II	$1,100.00
Oxygen	$25.00 (regardless of the amount)

In Washington D.C the flat service fees are lower for all three levels of service, with no charge for the use of oxygen[22]:

Table 17: Public EMS with services fees in Washington D.C.

Levels of EMS Service	Fees
Basic life support	$428.00
Advanced life support	$508.00
Advanced life support II	$735.00

Beside flat service charges, EMS providers also charge the fee of transporting the patients to hospitals. This charge is usually based on mileages, thus being called mileage fee. Some examples of mileage fees charged are below:

Table 18: Examples of EMS providers with mileage fees

EMS Providers	Mileage Fees
Chicago public EMS	$16/mile[15]
San Antonio fire department EMS	$12/mile[24]
Washington D.C public EMS	$6.55/mile[22]

In addition, many EMS providers also charge extra fees. Usually private EMS providers follow this practice, as they charge these fees for the extra services they provide, such as special doctor arrangements or patient transportation using helicopters. However, some public EMSs also have special charge. For instance, the public EMSs in Chicago charge a flat fee for any service user who is not a resident of Chicago[15].

Figure 32: Patient Helicopter Transportation in Virginia

Payment and insurance coverage

As mentioned above, EMS charges are not low. A simple call for EMS including basic support at the BLS level and ambulance transportation may easily result in a bill of thousands of dollars[6]. As a result, insurance coverage is always important to patients utilizing EMSs. However, the rule for insurance coverage of EMS is complicated and insurance coverage may not be available in every case.

For public insurances, such as Medicare and Medicaid, they will pay 80% of the EMS fees after the specified deductibles and the patient has to pay the remaining 20% along with the deductibles if the insured satisfies the following conditions:

- The patient is in a critical condition or in a condition such that EMS is required. Usually this condition is certified by the EMS paramedics.
- Transportation of the patient to the hospital is necessary and the hospital is chosen based on the patient's conditions, i.e. not being chosen based on the patient's direction.

In some certain cases Medicare will also pay for premium services such as patient transportation using helicopters. However the patient has to demonstrate that such service is necessary (e.g. the patient could show he was in an area not accessible by regular ambulances)[56].

These requirements leave rooms for cases where Medicare and Medicaid would not pay for EMS fees. The most common example is when the patient is determined to be not in critical conditions by the EMS paramedics. Usually in those cases the EMS providers will still provide services, but will ask the patient to sign the "Advance Beneficiary Notice", which indicates that the patient is willing to pay in full if Medicare refuses to cover the cost[56].

For private insurers, they usually follow the same practice as Medicare, i.e. they will cover 80% of the cost of EMS after deductibles if the patients are in emergency situations and patient transportation to hospital is necessary. However things get more complicated for private insurers because of the concepts of in-network EMS providers versus out-of-network EMS providers. What it means is that for most private insurers, each has its own list of in-network providers that these insurance companies are willing to cover 80% of the cost after deductibles. For the rest of the EMS providers, if a patient uses any of them, the private insurer will consider him using an out-of-network EMS provider and the insurance coverage would be much lower. There is an exception, however; if the patient can show that the out-of-network EMS provider is the only option at the time, he will still receive the same rate as in the case of an in-network EMS provider[6].

2.3.2 Contaminants

Economic structure and limitations can affect contamination in ambulances. For example, according to Vogel, in Germany, "studies are still needed to support infection control guidelines at the interface between hospital and community care. This interface is vulnerable for MRSA transmission due to lack of communication and knowledge, financial constraints and understaffing” (Vogel). Germany has over 14 000 cases of nosocomial methicillin-resistant *Staphylococcus aureus* (MRSA) infections a year. The cost of cleaning supplies, uniforms, and preventative gear can add up. Figure 33 displays the average cost of today’s EMT essentials.

Figure 33: EMS Equipment Value

The total cost for uniforms is high, but the $230 investment is reused multiple times. EMT uniforms are washed if contaminated with bodily fluids or other harmful substances. EMT equipment totaling to $310 is reusable until supplies run out and more must be purchased. The worst offenders to cost limitations are EMT infection control and ambulance cleaning supplies. For example, in the city of Boston there are about 100,000 calls per year and for every call one EMT needs one pair of gloves. If there is a minimum of two EMT’s in an ambulance, then the amount of money spent on gloves per year is $10,000. The costs add up, making it difficult to balance economic standing with cleanliness. In Chapter 3, the idea of economic limitations and cost reduction techniques are discussed.

2.4 Review of H.E.E.D. System

Based on the team's background research, a theory is developed on the classification of different types and sources of noise, contamination, and unintended stresses. Each classification type and source can be placed under one of three categories: ICU, PCU, and GCU, otherwise known as the H.E.E.D. system. The placement of classification types and sources will be determined from experimental and theoretical data in Chapter 3. Chapter 2 explains the preliminary theory behind the grouping decisions between the three units. Section 2.4 focuses on explanation of units ICU, PCU, and GCU.

2.4.1 Intensive Care Unit

The intensive care unit (ICU), also known as the critical care unit (CCU) or intensive treatment unit (ITU), is a special unit within a hospital that specializes on providing intensive medical treatments and medicines. The patients who are transferred to the ICU are usually critically ill and require intensive and constant monitoring. Examples of such illness include multiple organ failures, respiratory arrest, or after traumatic or critical surgery. The main focus of the ICU unit is to keep the patients in stable conditions so the underlying illness can be cured[13].

As a result, the ICU is staffed by special trained doctors and nurses who can quickly make decisions on how to keep their patients stable. They usually focus on the major systems of the body, including the cardiovascular system, the gastrointestinal tract, the central nervous system, and the respiratory tract. As the patient's underlying condition is treated, smoothly running bodily systems will greatly improve the patient's health. Mortality rates of ICU patients are higher than other departments due to the entering conditions of its patients.

Figure 34: Intensive Care Unit

2.4.2 Progressive Care Unit

The Progressive Care Unit [PCU] in a hospital serves as a step of continuum critical care and as a transitional phase of medical care between Intensive [ICU] and General Care Units [GCU]. [12] The Progressive Care Unit is often recognized as the Intermediate Care Unit. [24] These units are a cost saving measure for hospitals while not affecting patient care levels. [18] PCUs most often focus on patients recovering from cardiac and pulmonary surgeries. [6] Transfer from an ICU to a PCU is dependent on factors involving patient stability and monitoring. These consist of a decreased risk of potentially fatal events, a lesser need for invasive monitoring, an increase in patient stability, and the ability for patients to administer self-care. [18] The patients in PCUs have a lesser need for complex equipment and do not require nurse monitoring as often as ICU patients do, which decreases overall hospital expenses for PCU patients. The PCU is a solution to the problem of the growing number of patients who need critical care, and it serves as a stepping stone between ICUs and GCUs.

2.4.3 General Care Unit

The General Care Unit (GCU) of a hospital is responsible for children who do not require immediate attention, like the patients in the ICU do. In this unit, the sick are tended to frequently on a daily basis by a team of nurses and doctors who take measurements throughout the day and night to make sure the patients are on track for recovery. As part of the HEED system, the GCU constitutes as a public environment due to the parents and families who come to visit. The population of people visiting combined with the patients, doctors, and nurses leads to contamination, noise, and unintended stresses. These issues cause further complications which can affect the patient in a variety of ways, as seen in REEDIT (section 2.6).

2.5 Classification

2.5.1 Types of Contaminants

Noise, Contaminants, and Unintended stresses are broken into two categories: type and source. Type is the different classifications of noise, contaminants, and unintended stresses. Source is the origin of the types in noise, contaminants, and unintended stresses. Sources can be placed into the three different units (ICU, PCU, GCU) discussed in section 2.4. The source placement process will be described in further detail in Chapter 3. The type and source classifications are described below.

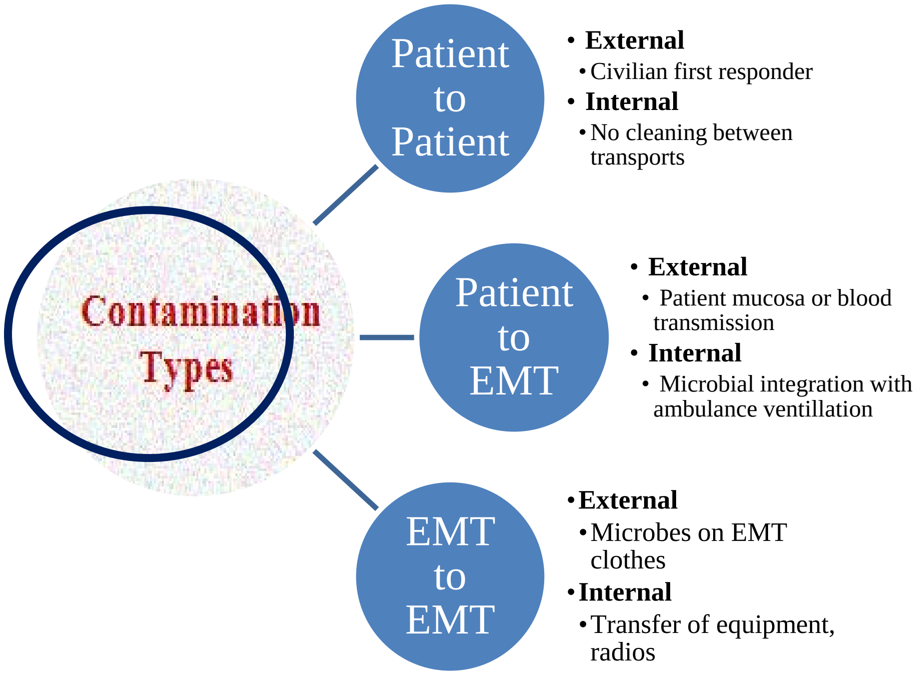


Figure 35: Contamination Types

Patient to Patient

- External (outside of the ambulance): Contamination could spread externally outside of the ambulance from patients to patients. There are usually two situations this phenomenon would occur: when civilians are coming and trying to help the contaminated patients without proper care, thus inheriting the contaminants and becoming a contaminated victims; or patients being placed within close contact of each other and thus spreading contaminants to each other.

An example of the first situation occurred in the case of the release of hydrofluoric accident at the Marathon Petroleum Refinery in Texas in 1987. In this incident, before the EMS teams arrived to help, many local residents and workers, who did not initially get exposed to the acid, tried to help the acid victims without proper safeguarding equipment. As a result, most of them became exposed with the acid on the skin of the victims they were trying to help. Among the 939 acid victims of this incident, it was estimated that about 100 people were exposed to the acid in this way, i.e. from trying to help other victims[72].

External patient-to-patient contamination could also occur in the case when patients are placed close to each other, thus spreading contaminants to each other. This situation could be seen from the Severe Acute Respiratory Syndrome (SARS) epidemic that broke out in Hong Kong in 2003. At the beginning of the outbreak, a common mistake was that patients suspected of SARS were placed together in the same room with very close contacts. Although it was determined that initially only one of them carried the SARS, the disease was spread out among all the patients with close contacts and as a result eventually all of them were contracted with SARS[50].

- Internal (inside of the ambulance): Contamination could also spread from patients to patients inside of the ambulance. In most cases this situation occurs because contaminates from one patients are left on ambulances surfaces or in the interior environment of the ambulance without proper cleaning and sterilization; thus the next patient using the ambulance obtains these contaminates.

  A study by Ro, Shin and No showed that there were many reported cases of patients contracting tuberculosis virus because of being transported in unclean ambulances in South Korea in 2007 and 2008. In most of these cases, evidence was found showing that bodily fluids from previous patients, who already had the tuberculosis virus in their bodies, were left on the stretchers and other ambulance surfaces. Proper cleaning and sterilization methods were not performed accurately, due to budget constraint or emergency situations. As a result, those bodily liquids still existed when the ambulances were used to help other patients; and those patients contracted the virus during the transportation through contact with those body liquids[80]. Infection from patients to patients could also occur because medical tools used for one patient were not cleaned properly before being used for the next patient. In her research, Arias mentioned some popular examples of such contamination. One such instance is Clostridium Difficile, which could cause severe diarrhea, pseudomembranous colitis, toxic megacolon, and death. The number of incidences related to Clostridium Difficile in the United States has been increasing since 1996. The study found out that a major cause of this increase is due to contaminated electronic thermometer used for obtaining rectal temperature was not cleaned properly before being used for the next patient[7].

Patient to EMT

Patient-to-EMT contamination may occur at any point during or after transportation where physical, fluid, or air contact with the patient occurs. The two types of patient-to-EMT contamination are external and internal. External contamination encompasses all contact between the EMT and patient outside of the ambulance, including first responders, patient transport onto and off of the triage unit, and patient transport from the stretcher to the hospital bed. An example of external contamination is MRSA (Methicillin-resistant Staphylococcus aureus) found on stretchers. In the study from Germany, at the University Hospital of Würzburg, ambulance walls and stretchers are tested immediately after patient transport for MRSA. The results showed that MRSA was only present on the stretcher and not on the walls. The parts closest to the patient, the stretcher headrest and handles, had the highest levels of MRSA. This indicates a high potential for Patient to EMT transmission externally. In the same study Vogel includes that, "reports primarily from the USA suggest that MRSA contamination of ambulance cars is putting staff and patients at risk" (Vogel). EMTs touch the handles of the stretchers while moving the patient to an external location, such as a hospital. EMTs now have MRSA on their gloves. If the proper procedures for disinfection and disposal are not followed or if EMTs touch other surfaces with those gloves, the spread of MRSA continues. Figure 36 shows an EMT taking proper precautions in order to avoid patient contamination.

Figure 36: EMT protected against patient contamination

Internal contamination encompasses all contact between the EMT and patient inside of the ambulance, including physical contact with the patient, fluid splatter, and secondhand contamination if machines house microbes from the patient. In a presentation made at the UK Ambulance Service Association conference, a study is described where eight locations within the interior ambulance are swabbed, "including the rails of a stretcher, the track beneath the stretcher, an overhead locker, and the paramedic's utility bag […] organisms [found] included methicillin-resistant Staphylococcus aurous, Bacillus cereus, other staphylococci, and various coliforms"(Pincock). The swabs were taken after extensive cleaning of the ambulance. Results indicated that standard patient transport contaminates commonly touched ambulance surfaces with microbes. Internal surfaces and tools that EMTs use to save lives, like the medical bags and overhead lockers swabbed during the study, are also the reservoirs for transmission of disease from an infectious agent to a susceptible host or from patient to EMT.

EMT to EMT

There is external and internal EMT to EMT contact. External contact can be anywhere outside of the ambulance, including clothes worn in between patient transport, un-washed hands, or lingering coughs. In a study done by Steven Nurkin and covered by CBS news, doctor's neckties were tested for diseases where, "Of the 42 physician neckties sampled, 20 contained one or more microorganisms known to cause disease, including 12 that carried Staphylococcus aurous, five carrying a gram-negative bacteria, one that carried aspergillums and two ties that carried multiple pathogens" (CBS News). The excess of microbial contamination amongst doctors' neckties aids in the promotion of microbial transport by acting as not only a reservoir, but also a mode of transmission between doctors, co-workers, and patients. EMTs do not always wash their uniforms in between patient transports. Most often, clothing is thrown in a washer/dryer system and the end of each work day. Even if there is no visible blood on an EMT uniform, the potential for microbial growth is high and co-worker contamination is even higher. Figure 37 shows a situation where EMT's are interacting with each other. The physical contact increases the risk of disease spread from EMT to EMT.

Figure 37: EMT to EMT physical contact potential spreads disease

Internal contamination from EMT to EMT most often requires a medium or secondary transmission. Machines, equipment and radios constitute good traveling mediums for microorganisms where the primary EMT touches a surface and the secondary EMT must touch that same surface to be contaminated.

Noise Reduction

Although noise regulations have been set for ambulances and hospitals, there are still negative effects on patients and the working personnel from the sound. The different classifications of theses noises can be termed as types. The five types include human, equipment, alarm, external, and internal. All contribute to the rate and excellence of care as well as the recovery of a patient.

Figure 38 depicts the types of noise are highlighted in blue. Furthermore, these can be broken down into sub-categories, and in the table gives only a few examples for each type. For example, human interaction is a form of noise pollution. Humans may consist of doctors, patients, families, custodians, and more. From examining the chart it is evident how much noise is accumulating at once in a particular area in an ambulance or hospital.

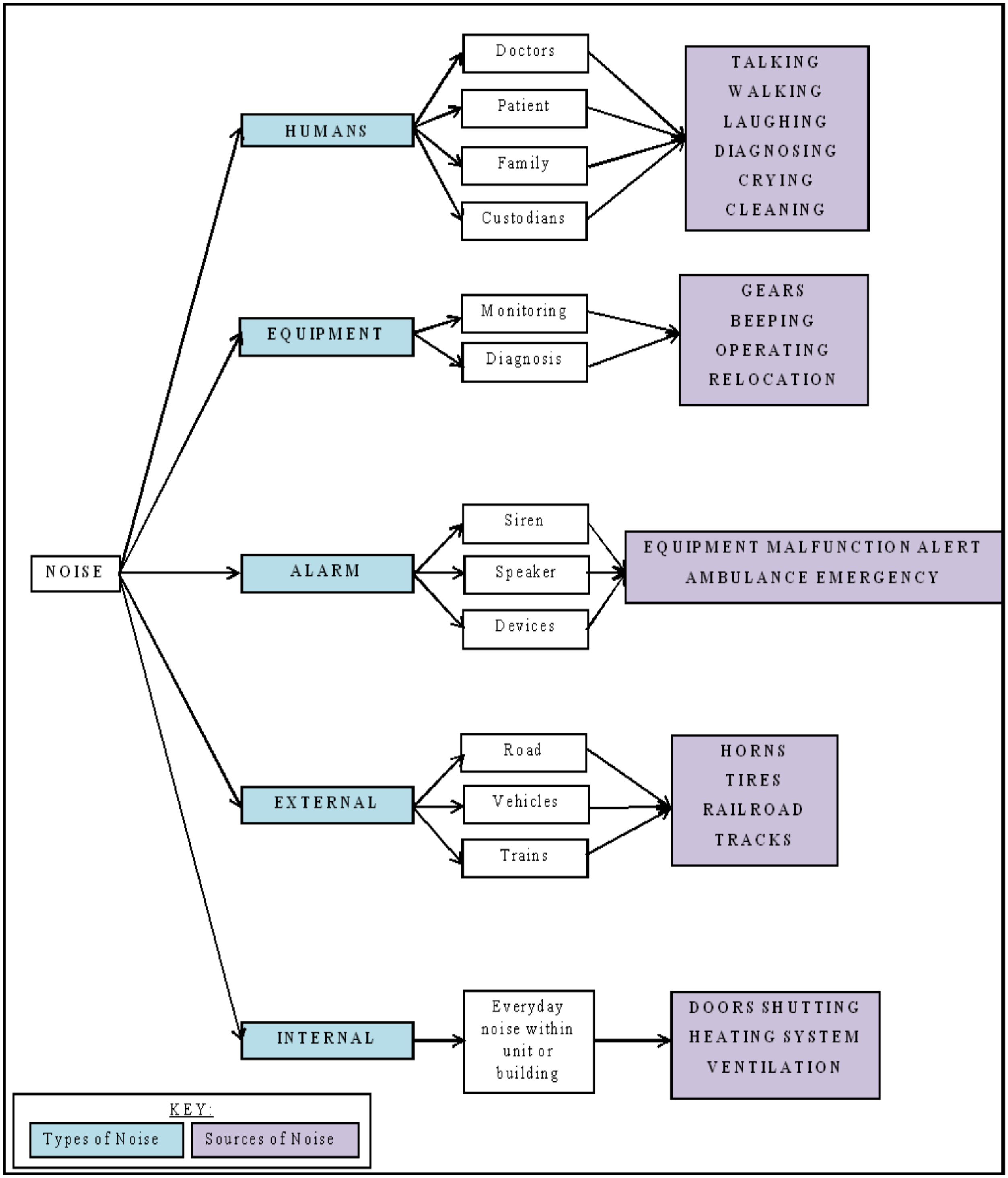


Figure 38: Types and sources of noise in Ambulances and Hospitals

Figure 38

Unintended stresses

The types of unintended stresses most prevalent to ambulances are vibration and patient compartment space limitations. Both of these sources cause patient and emergency medical technician stress which affects pre-hospital patient care, and technician health in the long term. [31]

Vibration due to uneven road surfaces result in harmful vibration of the stretcher, often secured to the ambulance floor. This connection causes a direct transference of vehicle vibration to the patient. The emergency medical technicians standing in the patient compartment also experience these vibrations. [9] Vibrations during acceleration can reach up to 1.5 m/s^2 at speeds greater than 65 miles per hour, and these levels warrant the 'Uncomfortable' rating on the Cotnoir Z-axis and comfort scale. [9] Not only is the patient experiencing discomfort but the emergency medical technician is unable to perform more sensitive medical procedures. These vibrations also affect care since delicate instrument measurements. For example catheterizations and electrocardiograms use piezoelectric metals, which are affected by acute movement. Vibration in ambulances is detrimental to patient care and calmness during transport.

The main problem emergency medical technicians face during their shifts is extended periods of time hunched over the stretcher. Emergency medical technicians have amongst the highest rates of lower lumbar injuries of all emergency responders. [35] The increased level strain on the spine results in early retirement for many emergency medical technicians and chronic back pain. This pain can affect both technician mood and cognition, which can both affect overall patient care. [35] Vibration is a main type of unintended stress on patients and the limitations of patient compartments are detrimental to emergency medical technician health.

2.5.2 Sources

As stated in section 2.5.1.1, there are three types of contamination: patient-to-patient, patient-to-EMT, and EMT-to-EMT. These three categories are included in what the Emergency

Health Services Branch of the Ministry of Health and Long-Term Care considers ‘The Chain of Transmission’, as described in Figure 39. The infectious agent is representative of the patient. The reservoir is the space where the patient is or has been and has high potential for microbial incubation. The susceptible host is anyone who comes into contact with the patient. Based on the regulation of the mode of transmission the chain continues, fueling the entry and exit of disease from host to host. There are three main sources of transmission: gas, liquid, and solid.

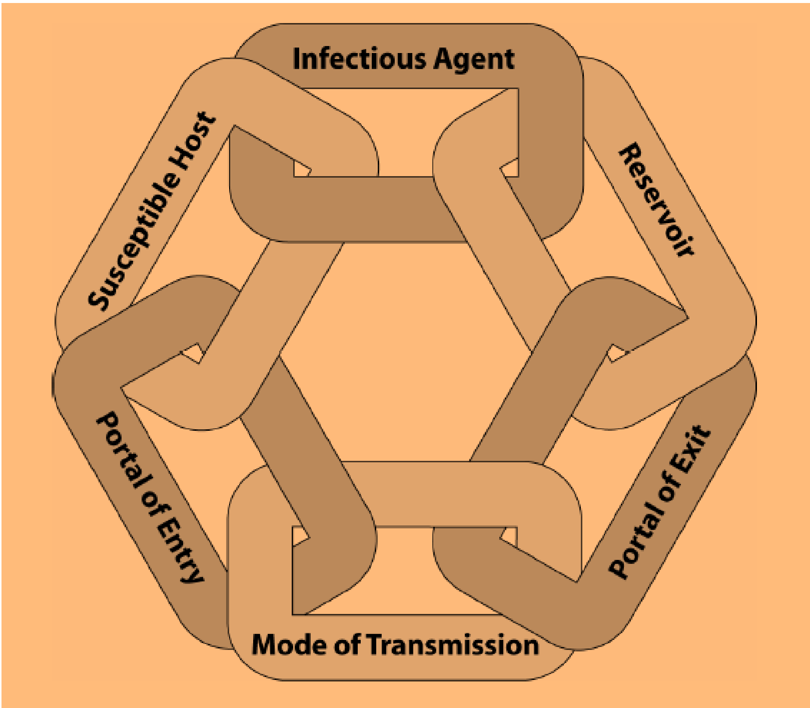


Figure 39: The Chain of Transmission

Gas Transmission

Gas transmission of contaminants is defined as the spread of contaminants through the medium of air. An example of gas transmission of contaminants occurs through breathing. It happens when a patient containing the contaminant spreads that contaminant into the environment through breathing activity and other patients or staff members contract these contaminants also through breathing activity. This phenomenon happened during the outbreak of Severe Acute Respiratory Syndrome (SARS) in Asia. It has been documented that some people were staying very close to SARS patients in small and closed spaces, and therefore contracted the virus through breathing activities[50].

Another example of gas transmission of contaminants happens when the patient spreads the contaminants into the environment through coughing. Similar to the case of breathing, other patients or staff members contract these contaminants also through breathing activity. A common example is the case of tuberculosis. It has been documented that in many cases tuberculosis patients spread the virus to the environment though the liquid that comes out along with their coughing. As a result, anyone who stays near that liquid has a very high chance of acquiring the virus through breathing activity[7].

Liquid Transmission

Liquid transmission of contaminants is defined as the spread of contaminants through the medium of liquid. An example of this type of transmission is via the transferring of bodily liquid, such as blood. It has been known that transferring blood that contains viruses like HIV or Hepatitis C to a patient will result in that patient contracting the virus. As a result, multiple measures have been taken to prevent the transfer of infected blood. However, infection could only happen via blood although no blood transfer is intended. It happens when the blood of an infected patient appears on the medical device and the device is used for the next patient without proper cleaning and wiping out of the blood and the virus. This phenomenon was one of the early causes of the spread of HIV virus[23].

Liquid transmission could also occur through direct contact. This situation happens when the contaminated body fluid of a patient is left unclean on the ambulance or the stretcher surfaces and the next patient or staff member contracts the contaminants by directly contacting with that fluid[80].

Solid Transmission

Solid Transmission is the spread of disease through contact. For example, touching a contaminated machine and then touching a patient or co-worker can result in solid transmission of microbes. In the study, *Risk Stratification-based Surveillance of Bacterial Contamination in Metropolitan Ambulances*, thirteen ambulances are sampled for surface contamination with results presented in Figure 40.

Sites of sampling	Total	Positive, total				Remark, pathogen
	No.	No.	%	95%	CI*,†	
Airway devices*	91	23	25.3	16.7	35.5	1 *K. pneumoniae*[1)]
Critical	26	4	15.4	4.4	34.9	
Semi-critical	52	16	30.8	18.7	45.1	
Non-critical	13	3	23.1	5.0	53.8	
Breathing devices, semi-critical	104	48	46.2	36.3	56.2	1 *K. pneumoniae*[2)]
Circulation devices, non-critical	65	45	69.2	56.6	80.1	
Other devices, non-critical	117	74	63.2	53.8	72	1 MRCoNS[3)]
Ambulance apparatus, non-critical	26	5	19.2	6.6	39.4	
Driver's side (control), non-critical	26	19	73.1	52.2	88.4	I MRSA[4)]
Total	429	214	49.9	45.1	54.7	
Critical	26	4	15.4	4.4	34.9	
Semi-critical	221	64	41.0	33.2	49.2	
Non-critical	208	146	59.1	44.0	57.9	

*Critical airway equipments were intubation tube and laryngeal mask airway cuff. Semi-critical airway equipments were laryngoscope blade, suction tip, water in suction bottle and oropharyngeal airway. Laryngoscope handle was classified into noncritical equipment. All breathing devices were semi-critical group. Circulation, and other devices, ambulance apparatus, and driver's side was non-critical group. 1) One Extended spectrum beta lactamase (ESBL) positive-*K. pneumoniae* was cultured in water of suction bottle among airway equipment; 2) One ESBL positive-*K. pneumoniae* was cultured in BVM bag among breathing equipment; 3) One Methicillin resistant Coagulase Negative *Staphylococcus* was cultured in stretcher car side bar; 4) One Methicillin resistant *Staphylococcus aureus* was cultured in driver's side door handle; †95% confidence interval.

Figure 40: Contamination Results[100]- Prevalence rare of microorganisms according to risk stratification-based sampling sites

The frequency of use of materials, equipment, and surfaces in ambulances increases the chances of solid transmission. The study broke the above table into three categories: critical, semi-critical, and non-critical, based on the chance of direct contact between the EMT and the surface. The critical surfaces had the highest chance of contact and tend to be in high traffic zones like handles and parts of the stretcher. Out of the 429 samples taken, 214 tested positive for bacteria. Contaminants included primarily bacterial flora, though some samples tested positive for MRSA and K. pneumonia. Contamination totals for critical, semi-critical, and non-critical locations were 15%, 41%, and 59%, respectively. This indicated that the ambulances were not being cleaned appropriately if the low-traffic zones or non-critical areas held the most bacteria. The results also solidify that even with proper precautions EMT's are not entirely safe from the sources of solid transmission. Chapter 3 discusses the prevention of solid transmission in both critical and non-critical areas of the ambulance and triage units.

Noise Reduction

Identifying types of noise and their sub-categories allows for direct sources of the noise to be found. In Figure 40, the sources of noise are highlighted in purple. They are the key sources to be targeted with noise insulation solutions. This would enable a quieter ambulance or hospital, and benefit the patients' safety as well as the EMTs, doctors, and nurses.

Below, Table 20 was taken from a survey of patients who stayed in a hospital for an extended period of time. At the end of their stay, patients were asked to fill out a survey asking to rank each sound by percentage as to how much disturbance it caused them. As shown, alarms on equipment were the most disturbing noise since they affected all patients.

Table 19: Percentage of patients reporting disturbance by source of noise in a hospital [20]

Source of Noise In Hospital	% of Disturbance by Noise
Alarms on Equipment	100
Intercom and Paging System	63
Visitors	50
Patient Sounds (ie. coughing, snoring, gagging, moaning)	48
Doors Opening, Closing, Slamming	43
Falling Objects (ie. pans, patient charts)	43
Socializing at Nurses' Station	36
Telephones	36
Equipment Used for Patients (ie. suction or breathing machines)	30
Conversations Between Hospital Personnel at Bedside	30

Unintended stresses

Unintended stresses in medical ambulances, mainly vibration and space limitations in the patient compartment arise from a few sources. The source of ambulance vibration is uneven road surfaces and less than perfect vehicle suspension systems which inadequately counter bumps and grooves in road surfaces. Ambulances must drive over the same roads which contain pot holes that take tires of smaller vehicles. Vibrations of less intensity can also be caused from engine function, emergency medical technician movement, and the manner by which the ambulance chauffer is driving. All space limitations come from ambulance and highway regulations which dictate maximum widths, heights of patient compartments and lanes. Organizations like the

National Fire Protection Association [NFPA] and the Federal Highway Administration [FHA] assign the dimensions available to ambulance companies to manufacture their vehicles. In an ideal patient cabin vibrations are minimal and enough space is allotted for comfortable movement and positioning of all parties. These improvements would drastically improve the ambulance transport process. Until changes are made, emergency medical technicians and patients must cope with the unintended stresses caused by the nature of a mobile emergency triage unit.

2.6 R.E.E.D.I.T.S.

Identified sources in section 2.5.2 are related to R.E.E.D.I.T.S. This is a discussion of source influence on the six aspects of the healthcare system: Recovery, Efficiency, Evaluation, Diagnosis, Intervention, and Treatment. Once established, the six aspects show a direct correlation to the quality of care in the healthcare system. Chapter 3 will look at how to improve upon sources in relation to R.E.E.D.I.T.S. to create a safer environment in Ambulance Care. Figure 41 is a diagram illustrating the overlap of the 6 aspects of R.E.E.D.I.T.S. in ultimate patient recovery.

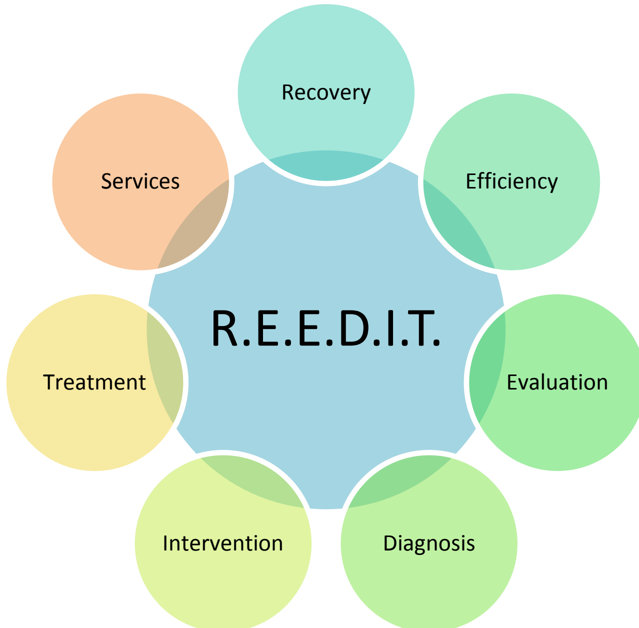


Figure 41: Patient Recovery based on RE.E.D.I.T.

2.6.1 Contaminants Related to R.E.E.D.I.T.S.

Recovery

Gas transmission of microbes affects patient recovery in that airborne diseases further weaken a patient's immune system causing a decreased rate of recovery. Liquid transmission of microbes from an unsterile surgical tube breaks the microbe barrier, allowing for mass entrance and exit of disease to and from a patient. The immediate effect is an additional disease inside of the patient for the immune system to battle, further increasing recovery time. The long-term effect is the release of disease from the patient, creating a new reservoir in the surgical tube that will remain as a means of microbial transition until cleaned properly. Solid transmission, including dirty surfaces and unsterile beds, can also harbor disease and have the ability to further infect the patient.

Efficiency

Work place efficiency of the other five R.E.E.D.I.T. tasks is seriously decreased with an increase in any kind of transmission. Medical personal are forced to retrace their steps in order to re-intervene, diagnose, evaluate, and treat the patient and then the recovery process begins again too. The probability of this process occurring again is high unless medical staff are able to pinpoint the reservoir and means of transmission of the given microbe.

Evaluation

- Gas transmission: Gas transmission of contaminants could significantly affect the evaluation process. For instance, from the discussion of contamination sources above, gas transmission could spread virus such as SARS or tuberculosis through the air medium. Thus, there have been many cases that a patient, who was evaluated to be well based on the treatment procedure of the original disease, actually still carried some diseases caused by the virus they caught through air transmission. These incorrect evaluation results would lead to early dismissal of patients who have not been cured completely. Gas transmission of contaminants also leads to incorrect evaluations of the conditions of medical facilities. There have been many cases in the past that patients were transported in ambulances certified to be clean and safe while in fact there were evidences of tuberculosis virus inside the ambulances[7].
- Liquid transmission: Similar to the case of gas transmission, liquid transmission also significantly affects the evaluation process. For example, at the early stage of the HIV outbreak, many patients contracted HIV through blood transfer while being cured for other diseases. As HIV is known for its ability to destroy the immune system and make all the drugs ineffective, the treatments of the original diseases for those patients were not

effective. Instead of realizing the ineffectiveness of the treatments with the appearance of HIV, many doctors, however, increased the amount of medication given to the patients, making the conditions of the patients worse[23].

- Solid transmission: Similar to the case of gas transmission, solid transmission also significantly affects the evaluation process. For instance, in his study Ulrich showed that dirt from patients' relatives when coming to the hospitals to visit the patients could carry many bacteria that caused complications to the evaluation of patients' conditions[93].

Diagnosis

- Gas transmission: Gas transmission of contaminants could significantly affect the diagnosis process. A common example is in the case of the spread of virus such as tuberculosis through air medium. In this case there are usually two situations that would occur. The doctor would either diagnose the patient with the original disease and ignore the existence of tuberculosis virus, or diagnose the patient with tuberculosis only and ignore the original disease. It would be very difficult to identify both diseases in the case of tuberculosis, especially if the original disease has similar symptoms as tuberculosis does. Either case would lead to incomplete diagnosis and treatment for the patient[80].
- Liquid transmission: Similar to the case of gas transmission, liquid transmission also significantly affects the diagnosis process. For example, for the case of contamination of HIV discussed in the previous section, most doctors only identified the original diseases and tried to cure the diseases using traditional methods. However, without realizing the existence of HIV, it would be very difficult for these methods to be effective, as HIV destroys the immune system of the patients. The appearance of HIV makes the diagnosis process complicated and the results incomplete[79].

- Solid transmission: Similar to the case of gas transmission, solid transmission also significantly affects the diagnosis process. For instance, in his study Ulrich showed that the dirt coming from external environment and staying on diagnosis devices could change the diagnosis results, as the doctors could diagnose the patients with the bacteria coming from the dirt and ignore the true disease[93].

Intervention

- Gas transmission: The existence of contamination through gas transmission could also complicate the intervention aspect. An example is the case of contamination of hazardous air. In this case any CPR practice would be ineffective, as the hazardous air would still cause fatality to the patients, and potentially to the EMS staff. Thus the recommended practice in this case would be to remove the patients from the areas affected by hazardous air and to prevent the contamination. After those actions are carried out, the CPR would then be effective[80].
- Liquid transmission: Similar to the case of gas transmission, liquid transmission could also affect the intervention process. For example, hazardous liquid such as mercury could cause such a quick fatality to the patients that no intervention actions could prevent. As a result, for emergency situations that involve hazardous chemical liquids, the highest priority for EMS workers is to prevent contamination of hazardous chemicals to the patients[1].
- Solid transmission: Similar to the case of gas transmission, solid transmission could also affect the intervention process. For example, hazardous particles such as nix, which is used frequently in many manufacturing industries, could cause fatalities to those who

inhale these particles. Such contamination usually occurs due to industrial accidents. Combating this transmission is one of EMTs primary goals.

Treatment

Gas, liquid, and solid transmission of microbes negatively affect the treatment process. The addition of new diseases into the body can cause the immune system to over-express itself, causing an allergic reaction to the medicine given. The introduction of new diseases can also cause the medicine to not work properly or to fix a different problem then its primary intent. In extreme cases, treatment plans can stop working because the new disease mutates and the body becomes immune to the given drug. Treatment may even increase patient contamination. For example, if a patient is told to inhale a drug, like anesthesia, the patient is ingesting air and potentially other microbes through gas transmission. The same occurs for IV's if the skin surface is not cleaned before puncture or if the patient eats a solid pill, but their hands are dirty. Transmission of all forms can disable, negate, and hinder treatment depending on the circumstances.

Services

The services doctors and nurses supply to their patients include caring, diagnosing, and treating their patients. Contamination negatively affects all of these aspects as the patients' health will only decrease. In turn, this will make the patients' stay increase, and make their time spent in the hospital a worse experience.

2.6.2 Noise Reduction and Unintended Stresses Related to R.E.E.D.I.T.S.

Recovery

A patient staying in a hospital for many days will have to deal with the continuous noise surrounding them being produced from many different sources during the day and night. In order for a patient's recovery to be at its best, the noise level should not be a concern for the patient. However, in hospitals, it is impossible for silence at all times. Therefore, the noise irritates patients such that recover can be hindered. For example, sleep is a necessity for healing the body. If during the night people are talking or alarms are contributing to noise, then the amount of sleep will dwindle. This will cause longer stay in the hospital and an extended recovery period.

Efficiency

Time is a factor for an emergency medical patient. Every extra minute spent by a doctor or EMT deciding what to do could cost the patient their life. Efficiency plays a large role in the outcome of the situation. Due to various types of noises accumulating, it is difficult for the working personnel to have their full attention on what must be done for the patient. This causes time delays, and therefore could harm the patient's life.

Evaluation

A doctor or nurse should have all of their focus on what they are doing while evaluating a patient's condition. An example of this would be a patient who is rushed into the emergency room. The doctor must decide what is wrong with the patient based off of symptoms and what can be physically seen. The doctor must make a quick decision in order to proceed with the surgery or caretaking. Noises cause a distraction, and could give lead to an incorrect patient evaluation which can cause serious complications if the wrong procedure is continued.

Diagnosis

Once a doctor evaluates a patient as to what their symptoms are, the doctor can then diagnose the patient. This includes accumulating the given information and formulating a conclusion. Noise harms the concentration of EMTs and doctors, and this could lead to an incorrect diagnosis. Doing this would harm the patient and lead to further complications.

Intervention

A patient in an ambulance or an emergency room requires the full attention from the EMT/paramedic or the doctor. The working personnel must quickly identify the next step that should be taken in order to save the patient's life. Any noise distraction could cause the EMT/paramedic or doctor's attention to be strained and therefore the best decision for the patient's safety may not be made.

Treatment

Patient treatment can range from performing CPR to a lifesaving surgery. No matter what the circumstances call for, the EMT or doctor must have their undivided attention on the task at hand. With a person's life at stake, any error could cause death or a life threatening injury. Noise created in an ambulance or hospital could cause a diversion for the EMT or doctor thus, patients will not be treated as they would be if there was a noise distraction. Reduction of noise is beneficial to patient care and treatment.

Services

As doctors and nurses care for their patients, noise is a factor that negatively impacts the services supplied. Sound louder than 80 decibels, will only take away the attention from the doctors to perform their job correctly. Also, patients need the area to be quiet so that the services supplied can be done so at its best, therefore making patient stay decrease.

CHAPTER 3: METHODS, PROCEDURES, AND OUTCOMES

3. Introduction

3.1 South Shore Hospital Contaminants

3.1.1 Procedure

Procedural ambulance cleaning processes strive to ensure sterility of ambulance patient compartments. This cleanliness is vital to efficient patient medical care, ensuring minimal cross-contamination between patients and transfer sites. Nosocomial infections are the fourth-leading cause of death in the healthcare field.[1] Figure 42 displays evidence of ambulance contamination in Seoul, Korea where approximately 50% of testing sites in tested positive for bacteria, 2% of which were pathogenic.

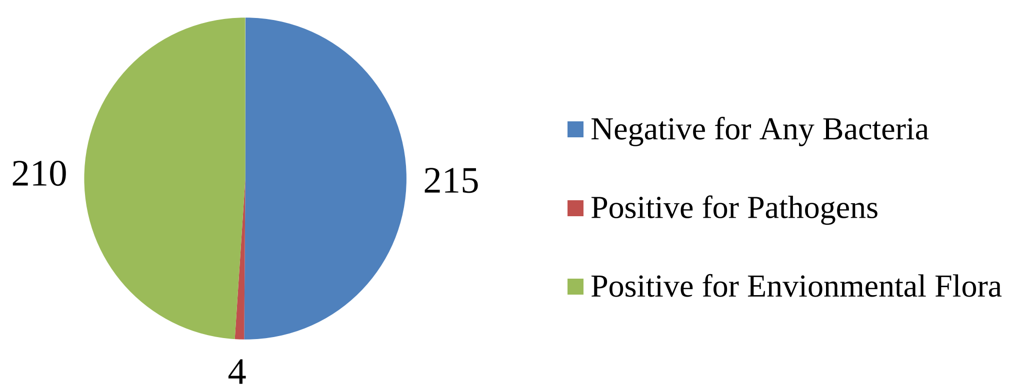


Figure 42: Ambulance Contamination Testing.[2]

From Figure 42, this study suggests that nosocomial infection is not necessarily confined to a hospital environment, but can start in pre-hospital emergency triage care. Identifying potential problems from ambulance contamination is the first step to eradicating the problem altogether. Reducing the risk of infection can shorten hospital stays, improve patient satisfaction, and increase overall quality of patient care. Implementing more effective cleaning practices will reduce future contamination and infection which will lead positive outcomes for both hospitals and patients.

Typical Ambulance Cleaning Procedure

Commonly, the ambulance cleaning procedures will need to fulfill the Occupational Safety and Health Administration's (OSHA) standards to restrain the exposure of contaminants, such as blood and infectious materials. However, there is no standard cleaning procedures for ambulances as the required procedures are varied among different states with ranging level of descriptiveness. Some sample procedures for ambulance cleaning processes, from cursory to descriptive, are shown in the sections below.

Methuen Fire Department, MA 01844 [106]

Standard Operating Guideline

- Ambulance cleaning policy

The ambulance should be cleaned and disinfected after each transport. Every morning the floors should be swept and mopped. On the first day of every month the interior should be cleaned and disinfected.

- Ambulance cleaning procedure

Proper protection must be worn (gloves, face shield etc.). The ambulance will be cleaned after each transport with a cleaning/disinfectant solution (all contaminated surfaces). Floors will be broom swept and washed with cleaning/disinfectant solution every day. On the first day of each month all of the interior surfaces will be cleaned with cleaning/disinfectant solution.

Alton Fire & Rescue Department, NH 03809 [107]

SOP 1.3.13 Cleaning and Decontamination of Ambulances

Purpose: To maintain member and Patient safety, health and welfare

Scope: All department members staffing an ambulance

Overview:

- Providing cleaned and decontaminated ambulances ensures a work environment free form potential airborne and/or blood borne pathogens for members and patients
- Maintains a clean and neat appearance
- Satisfies state requirements

Total Decontamination—To be completed after every transport:

- Disinfect all handles (interior and exterior)
- Disinfect headsets, portable and radio set microphones
- Disinfect patient cot, to include carriage, straps, buckles
- Disinfect any re-usable device used on a patient (ie: monitor, stair-chair, suction unit, etc.)
- Disinfect steering wheel
- Disinfect floor, seats, and walls

Partial Decontamination- To be completed after any non-member enters the ambulance, but is not transported:

- Disinfect anything the person has contacted
- Change linens if they sat or came in contact with the patient cot

Salt River Fire Department, AZ 85256 [108]

Purpose

To insure that ambulances that are being used for patient transport are properly cleaned after every transport in a standardize manner. To provide for the most sterile environment for Fire Department personnel and the patients they serve. This cleaning and disinfecting procedure is required and essential to ensure employee safety as well as that of the patients that are treated and transported daily.

1. Cleaning the vehicle and EMS equipment between calls and at the end of the shift.

(This should be monitored by the station Captain, whenever possible.)

A. Personal Protective Equipment (PPE) is used:

   Isolation gown (if necessary)

   Mask (if necessary)

   Eye protection (MANDATORY)

   Booties (if necessary)

   Gloves (MANDATORY)

B. Cleaning and disinfecting of equipment should be performed at the receiving medical facility as much as possible. Some facilities are equipped with a designated area to remove heavily contaminated equipment. Large items can be taken to this area and the majority of the contaminants hosed off into a containment area. Complete PPE should be worn in this area. The fewer contaminated items on board, the lesser the risk to exposure. Some equipment items may take extensive cleaning and decontamination efforts. These items must be red-bagged and transported back to quarters for immediate cleaning.

C. To clean, deodorize, and disinfect hold the cleaning agent mixture dispenser 10 inches from the surface and atomize with quick short strokes, spraying evenly on contaminated or potentially contaminated areas of the equipment and affected interior patient compartment of the ambulance or other affected portions of the vehicle until wet. Wait 30 seconds and wipe dry with a paper towel. To kill Staph, Strep, and other common types of virus and bacteria strains, repeat as above, wait 10 minutes, and wipe dry. Blood and other body fluids must be thoroughly cleaned from surfaces and objects before application of the disinfectant.

D. Steps in cleaning after each transport:

1. Remove gurney

2. All visible debris and soil contaminants are wiped off with towels

3. Cleaning agent mixture is sprayed liberally on the interior of the transport compartment of the vehicle

4. Cleaning agent mixture is sprayed liberally on the gurney mattress, the gurney frame, including wheels

5. All surfaces are inspected to ensure that no visible signs of debris, soil or contaminants are present. If such signs still exist, then repeat the cleaning process

6. Towels are disposed of appropriately for washing. Paper towels must be placed in a red or properly marked biohazard bag or container if blood-soaked; otherwise, they may be treated as normal trash per Scottsdale Health Care SOG’s.

7. Gloves must be placed in a red or properly marked biohazard bag or container if blood-soaked; otherwise, they may be treated as normal trash per Scottsdale Health Care SOG’s.

2. Special Equipment Cleaning Instructions

a. Patient restraint straps (spine board, gurney); remove immediately when contaminated with blood or body fluids or body substances/secretions and place in a red or appropriately marked biohazard bag.

   1. Straps are washed upon return to the station in an appropriate detergent according to manufactures instruction and recommendations.

   2. Air or machine dry as recommended

b. Equipment bags made of Cordura nylon; remove from service immediately when contaminated with blood, body fluids, or body substances/secretions and place in a red or appropriately marked biohazard bag.

   1. The bags will be washed upon return to the station in appropriate detergent according to manufacturer instructions and recommendations.

   2. Air or machine dry as recommended.

c. MAST/PASG: Before washing, all gauges are removed, using the quick-disconnect tubing and closing all valves. Washing is done by hand in soapy water. DO NOT DRY CLEAN, BLEACH, STEAM CLEAN, OR USE HARSH CHEMICALS. FOLLOW MANUFACTURERS INSTRUCTIONS.

d. Laryngoscope blades and Magill forceps, portable suction units (and any other non-disposable instruments that touch mucous membrane): equipment is cleaned with the cleaning agent mixture insuring complete coverage with the agent mixture and then rinsing. Insure that all needles and contaminated scalpels are placed in a Sharps container.

e. The radio equipment should be decontaminated by spraying cleaning agent on a towel and wiping down the portable radio and microphones/mobile radio.

f. Turnouts that have been contaminated should be removed from the individual, bagged in a red bag or appropriate biohazard container and taken to the station. The turnouts should be first hosed off and brushed using liquid detergent that does not have any chlorine products. Once hosed off, the coat and pants should be separated from the liner (if possible) and placed in a washing machine with soap and hot water. The turnouts and liners should be air-dried. The washing machine should be cleaned using a 10% mixture of bleach and run through a complete cycle.

Swab Collection Procedures

Purpose

The team aims to improve emergency medical health of the patient and staff via identification of contamination in ambulances. The team will be working to measure cleanliness in ambulances.

Method

It is a blinded study powered by up to 30 ambulances. The EMT cleaning staff will be blinded and the team members will collect the contaminant data post-cleaning. Swabs are collected from 12 non-variable locations on the ambulance. Samples are taken at peak hours, 4-6pm, on two given days (Monday and Friday). Swabs are plated and tested for both pathogenic and non-pathogenic organisms in swab culture procedure

Location of Swabs

1. stretcher mattress
2. stretcher tracks or floor
3. stretcher handrail
4. inside and exterior door handles
5. laptops/tablet computers

6. inside modbox
7. radio controls/microphone
8. inside cupboards or drawer corners
9. buttons on cardiac monitor
10. safety equipment- steering wheel or seat belt
11. oxygen flow-control taps
12. stethoscope diaphragm sphygmomanometer cuff internal/surface or inside suction bottle

Materials

1440 Swabs

1440 Swab containers

Gloves, masks, scrubs for all team members

2 hazardous waste boxes

Set-Up

1. EMT's secured area by completing procedure 3.2.1.1.
2. Sample Collectors create a safe and sterile environment by putting on surgical gloves, masks, and doctoral scrubs.
3. Two safe hazardous waste disposal boxes are procured. Box 1 is used as a storage and transit unit for swab samples collected. Box 2 is used a disposal device for any trash procured during the swab collection process. See hazardous waste handling for more details on what is and how to handle hazardous waste.

Procedure

1. Enter ambulance with swab covered in sterile package
2. Open swab package when reach first swab location

3. 4 swabs will be used for each swab location.
4. Follow the Swab procedure described in Figure 43.

   Follow steps 1 and 2 in Figure 44 for swabs 1 and 3.

   Follow steps 3 and 4 in Figure 44 for swabs 2 and 4.

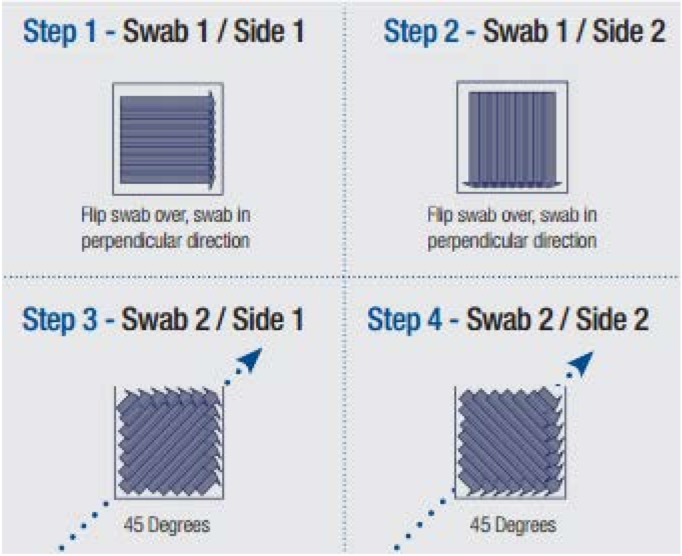


Figure 43: Swab Procedure[3]

5. Follow the swab transfer procedure shown in Figure 44 to place swabs in the swab container. Note that the first swab much be placed in its container before the next swab may take place. Note that each swab location will use 4 swabs and 4 swab containers.

Figure 44: Swab Container Procedure[3]

- Snap the connection between the swab handle and swab head, letting the swab head fall into the collection flask
- Securely cap the collection flask
- Place handle into hazardous waste Box #2.

6. Label each swab container with swab location and swab number (use numbers 1-4 for each location to indicate which swab it is) and ambulance number.
7. Place all swab containers in the hazardous waste Box #1. Place any additional wipes and collection materials in hazardous waste Box #2.
8. Repeat steps 1-8 for all 12 locations in all 30 ambulances
9. Remove gloves, masks, and scrubs using proper lab procedure in section 3.2.1.4.
10. Bring hazardous waste Box #1 to the swab culture facility mentioned in section 3.2.1.3. Bring hazardous waste Box #2 to the appropriate collection site mentioned in section 3.2.1.4.

Swab Culture Procedure

Purpose

To process swabs to allow for analysis of data collected, so the team may determine the types and location of contamination and provides alternate sanitation methods for future prevention and enhancement of patient safety.

Method

Swabs are plated and tested for 7 microorganisms, both non-pathogenic and pathogenic. This part of the study is not blinded. In the above procedure 4 swabs are taken from each of the 12 locations in all 30 ambulances. Each side of the swab is used for a separate microorganism test. There are eight sides available per location, leaving an extra side for the control.

Microorganisms Tested

1. Staphylococci
2. Streptococci
3. Coliforms
4. Bacillus
5. Diphtheroid
6. Pseudomonas
7. Yeast/fungi.

Materials

Swab containers each containing a swab from the Swab Collection Procedure

240 12-well cell culture plates

Serile forceps

Media as seen in Table 21

Table 21: Media per microorganism

Microorganism	Culture Media/Agar	Amount Needed (mL)
Control Media	All-purpose media	828mL
Staphylococci	Blood agar	828mL
Streptococci	Blood agar	828mL
Diphtheroid	Blood agar	828mL
Coliforms	Nutrient media	828mL
Bacillus	Thallous acetate agar	828mL
Pseudomonas	Acetamide nutrient broth	828mL

Set-Up

1. Sample handlers create a safe and sterile environment by putting on surgical gloves, masks, and doctoral scrubs.
2. Media is prepared based on directions from the media bottle and in sterile conditions
3. 1/3 of each well in a 12-well plate is filled with media. Since one well is 6.9 mL, then 2.3 mL is used per well.

Procedure

1. Remove swab containers from Box #1. Order swabs in groups based on ambulance number and location.
2. Take swab 1 from ambulance 1 location 1 and using sterile forceps, rub side 1 of the swab over well plate #1 for 30 seconds. Use proper swab procedure as seen in Figure 45.

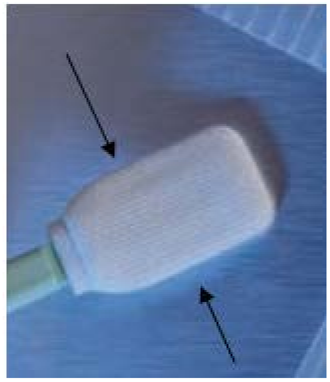


Figure 45: Swab Procedure in well plates[3]

-Swabs must be handles by forceps where arrows indicate, on the sides of swab

-Swab face must be perpendicular with the well-plate surface it is being rubbed on

-Swabs must not be touched by gloves or anything other than sterile forceps

-This procedure must be done in a sterile environment, like a bio hood.

3. Using sterile forceps, flip swab and rub over the second well plate for 30 seconds
4. Replace the swab in the container and place back in hazardous waste Box#1
5. Place cover back on well plate and label the two wells that were swabbed with ambulance #, site location, and swab #.
6. Repeat steps 2-5 for all other swabs.
7. Place well plates in an incubator with atmospheric oxygen concentration and temperature
8. Allow to incubate for 24 hours
9. Remove plates, check for confluence under microscope
10. Place plates back in the incubator for another 24 hours
11. Remove plates, check for confluence under microscope
12. Run tests on plates (this could be manual identification of microbes under the microscope or the application of a chemical indicator)

13. Record Results
14. Dispose of well plates in a biohazard container
15. When finished, turn gloves inside out and place in a hazardous waste container
16. Ethanol the work surface and hands
17. Leave ethanol on work surface to dry

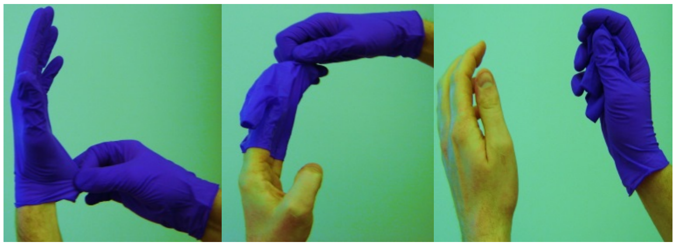
Hazardous Waste Disposal Procedure

What is Hazardous Waste

1. Human bi-products (blood, feces, saliva, etc.).
2. Used Gloves, masks, doctoral scrubs
3. Used Swab collection kits, including swabs, swab containers, and additional collection devices.

Disposal Procedure

1. Hazardous material should be placed in a bag labeled 'hazardous material', sealed, and then placed in a hazardous materials box.
2. The box must be taped shut when filled and placed at a collection site where hazardous waste boxes are removed, emptied, and cleaned.
3. Proper removal of gloves is seen in Figure 46.



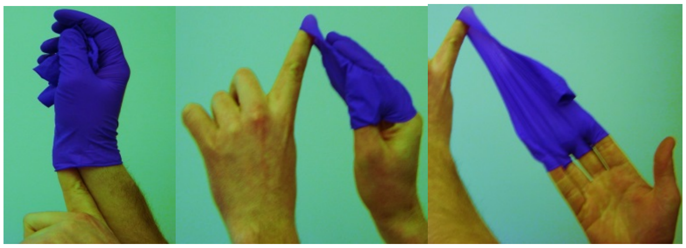


Figure 46: Glove Removal Procedure[4]

- Place one hand at the base of the other glove and pull up over fingers
- Hold removed glove in palm of gloved hand
- Place ungloved finger between in glove and base of hand
- Use the finger to pull up, removing the second glove
- Place gloves in hazardous waste container
- Note that this same format may be used to remove any other equipment from the body

4. All parties involved in sample collection and hazardous waste disposal must sterilize their hands.

3.1.2 Data Analysis Techniques and Potential Results

Upon data collection, results are analyzed by placing all data in a coordination chart, similar to the example in Table 21.

Table 20: Result analysis

Microorganism	% Positive for Microorganism	% Negative for Microorganism	Ambulances Containing Microorganism	Locations Containing Microorganism
Control				
Staphylococci				
Streptococci				

Coliforms	
Bacillus	
Diphtheroid	
Pseudomonas	
Yeast/fungi	

Based on the results analysis, other statistics can be looked at and a pie chart of location prevalence can be created to identify the location with the most contamination. Analysis of data will allow for the team to develop a modified simulated model that better fits the needs and circumstances of the actual ambulance. The team will run further tests on the new model and use those to develop an on-site cleaning environment that can clean the interior and exterior of an ambulance in 5-10min. In addition, the team will look at ways to decrease ambulance contamination within the interior of the ambulance. Potential innovations for cleaning techniques and ambulance design are discussed in section 3.1.3.

3.1.3 Recommended Innovations in Cleaning Techniques and their Application

Ambulances can be easily contaminated with blood and infectious materials; thus, such cleaning procedures, as shown in section 3.2.1, are extremely crucial. However, due to a vast demand from the patients under the EMTs' time constraint, ambulances must be sterilized quickly and thoroughly. It is essential to discover varieties of materials, and equipment to help speed up the ambulance cleaning process and achieve the good result of decontamination. The suggested materials and equipment for ambulance cleaning process can be found in the following sections.

TiO_2

Self- learning materials can be considered as one of new inventions used to save the cleaning time and limit the misuse of cleaning chemicals. Currently, scientists use Titanium Dioxide (TiO_2) as the special catalyst for the self-cleaning processes in some novelties, such as Self- Cleaning Windows and, Self- Cleaning Paint (Catalyst is used to stimulate the reaction between the other substances; its amount will not be changed after the reaction). TiO_2 has been known for its reactivity to sunlight, stability, and cheaper alternative for keeping the surface clean[108] as it costs about 3-10 US dollars for 10-20nm diameters. Besides that, TiO2 can make an excellent reflective optical coating such as paints, plastics, and paper, when being deposited as a thin film, which will not be ruined easily due to its stability and reactivity as a catalyst. This material also has strong UV light absorbing capabilities to stimulate the reaction between organic substance and strong reactive particle. Therefore, the surface with TiO2 thin film will keeps itself free of dirt and grime through natural processes (Figure 47).

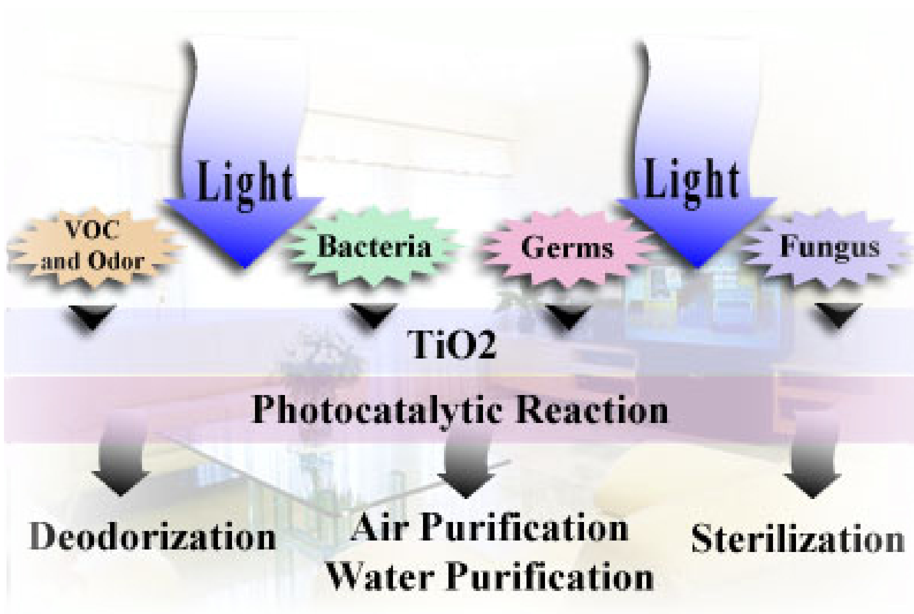


Figure 47: Application of TiO_2

Furthermore, self-cleaning process based on TiO_2 includes two steps: Photo catalytic and Hydrophilic. During Photo catalytic process, all the organic dirt on the surface will be fragmented after TiO_2 absorbs ultraviolet (UVA) in sunlight (even on over cast day). When exposed to UVA radiations, TiO_2 will stimulate the reaction between oxygen and water vapor, in the atmosphere, to form the free particles which are known as cations H^+. As these free particles are very unstable, they have very strong reactivity. Therefore, they will automatically break down the organic dirt to form CO_2 and H_2O. Also, the reaction occurred at the surface of the coating can be written as the followings (Figure 48):

$$O_2 + H_2O \rightarrow H^+ \ (free\ particle)$$

$$H^+ + Organic\ Substances \rightarrow CO_2 + H_2O$$

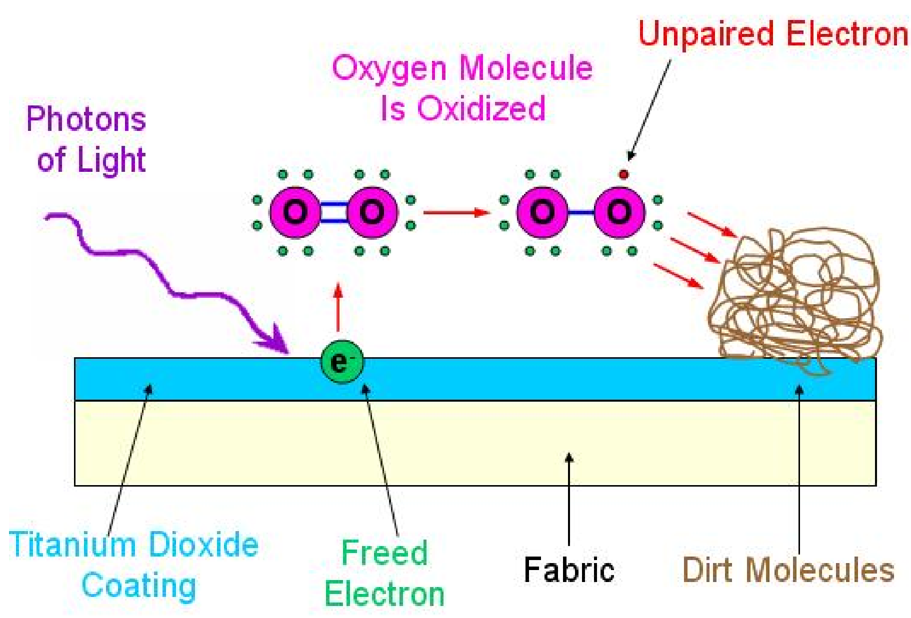


Figure 48: Surface reaction of TiO2

The amount of CO_2 produced is inconsequential so there is no negative effect to the environment when using TiO_2 material. As mentioned before, thin film of TiO_2 is very stable which will not be considered as any kind of toxic impacting harmfully to the environment as well. UV light sources for this process may come from the sunlight or UV machine, which is not a big concern for such self-cleaning innovation.

The second stage of this process is Hydrophilic. Water will rinse the surface and spreads evenly, running off in a sheet and taking all the loosened dirt with it, also drying quickly without leaving streaks. This step is only to clean the surface from unharmed particles since the first step has already decompose all the dirt, blood, and infectious materials to plasma phase. This step is considered to be a big concern for the self-cleaning process as it requires water to clean interior surfaces of ambulances, which cannot be afforded. Therefore, water's substitution, such as steam water, is recommended to use for the process.

Seat belt is known as an essential tool securing not only the EMTs but also the patients transported on the ambulance (Figures 49 and 50) However, due to its size and structure, the seat belt cannot be cleaned easily once it gets contaminated.

Figure 49: Ambulance seat belt

Figure 50: Demonstration of using ambulance seat belt

Elaborately, there are two types of lap seat belts, which are non-retractable and retractable seat belts. The non-retractable one will have the buckle with a push button in a red background with a white “Press” on the push area (Figure 51). Also, the buckle has a metal underside and a hard plastic top for durability. This type of seat belt is generally black in color. Similarly, the retractable seat belt has an underside metal base for mounting flat on to the rear or side of a seat. The buckle is a push button with a red background with a white “Press” on the push area. This type of buckle also has a metal underside and a hard plastic top for durability (Figure 52)[109]. Therefore, the seat belt can be easily contaminated as the buckle structure allows many cracks opening to which requires times and specifics cleaning skills to remove. Additionally, as there is no descriptive instruction for seat belt cleaning process, the EMTs, under the time constraint, can only be able to decontaminate the outer surface of the seat belt, specifically the exterior surface of the buckle. As a result, seat belt buckles are known as sources of irremovable contaminants.

To solve this problem, the seat belt cover, specially designed for the buckle, is highly recommended to use. The plastic cover of the buckle will prevent both sides of the buckle from being contaminated as it blocks all the cracks opening to contaminants (Figure 53). Besides that, as the cover is removable and disposable, the EMTs are expected to simply replace it after each emergency case. Therefore, using the cover will not only reduce one of the sources of contaminants but also speed up the ambulance cleaning process.

Figure 51: Non-retractable seat belt

Figure 52: Retractable seat belt

Figure 53: Buckle cover

Smart materials

Besides self-cleaning material, TiO_2, mentioned in section 3.2.3.1, polymeric smart materials can also be applied to the ambulance cleaning process. This material is designed as new method for the reduction and remediation of wastes like infectious materials and contamination, which are harmful to the environment and human health.

Elaborately, the coatings of polymeric smart material are capable of detecting and removing hazardous contaminants as they involve catalysis chemistry, sensor chemistry, and decontamination methodology. Smart materials are developed to respond to the physical change of the environment such as temperature, pH (stimulated by chemicals), and predetermined hazardous concentration. The coating of smart polymeric material consists of the strippable polymeric composition involving variety types of polymers. This smart- material coating can be easily applied to the surface simply by brushing, painting, or spraying. Then, the surface will be able to indicate the existence of contaminants with its change in color.

Figure 54: Smart material change color when recognizing contaminants

Currently, smart-material technology has been tested with nuclear contaminants as it can recognize and eliminate the nuclear contaminants just by removing smart-material surface after contaminants get indicated. Contaminants are attached to the coating via combination of solvation and chelating effects. As the coating dries, the contaminants get trapped and are removed as the coating is peeled off the surface. Similar technology for indicating decontaminating infectious materials from smart coating has also been developed. Such innovation will be beneficial for the EMTs as it help them recognize sources of contaminants, so the ambulance cleaning process will be more productive.

Related to R.E.E.D.I.T.S. Analysis

The materials and equipment mentioned in section from 3.2.3.1 to 3.2.3.3, contribute greatly to the ambulance improvement through R.E.E.D.I.T.S. analysis, mentioned in section 2.6.1.

- Recovery:

As the gas, liquid, and solid transmissions of microbes weaken a patient's immune system, which causes a decreased rate of recovery, it is crucial to ensure that the ambulance is entirely contaminated. Therefore, improving the cleaning process of ambulance by applying smart materials or equipment will significantly help the patients' recovery process.

- Efficiency:

  As mentioned in section 2.6.1.2, other 5 R.E.E.D.I.T tasks can be improved by a decrease in any kind of transmission. Applying new materials and equipment help reduce the transmission of microbes, which in turn increase the efficiency of all other 5 R.E.E.D.I.T.S.

- Evaluation, Diagnosis, Intervention, Treatment:

  Similarly, the reduction in ambulance contaminants caused by applying new materials and equipment will help enhance the evaluation, diagnosis, intervention, and treatment process for the patients. Therefore, protecting the patients from being infectious during transported in the ambulance will lead to the improvement in R.E.E.D.I.T.S. analysis.

3.1.4 Future Recommendations

It is the hope of the team that future teams will use these procedures to produce results on ambulance contaminants and to utilize them to create a new emergency triage care unit with maximum contaminant prevention capabilities. Additional studies that can be paired with the contaminant procedures in this experiment may include work with artificial contaminants *in vitro*. The comparison of *in-vivo* testing discussed in the above procedures compared to a less variable environment may add validity to future experiments. The 12 selected locations selected based on background research and consulting with UMass Memorial, can be further focused by using *in-vitro* testing to prove if these 12 locations are of optimal priority and to determine the 'spread' of contaminants in its entirety.

Additional contaminant variables yet to be explored include odor, the comparison of air contaminants versus surface contaminants, and the effects of materials and cleaning products on patient and EMT health. Future research on these topics will aid in the discovery of new materials and manufacturing processes to eliminate long and short term contamination in the emergency triage unit.

3.2 South Shore Hospital Noise and Unintended Stresses

3.2.1 Procedures

Sound Collection at Typical Hospital

1. Ascertain three distinct locations for sound collection that will produce three varied sets of sound data. This can be in the form of different departments or different wards.
2. Acquire mounting and data collection permits and hospital access cards to ensure feasibility of project
3. Acquire sound collection devices
4. Acquire mounting boxes to ensure for safe and secure data collection with limited human interference.
5. Install mount boxes
6. Insert sound collection devices
7. Power devices to collect sound data for duration of battery life (approximately three days).
8. Return after devices have ceased operation and transfer data onto hard drive for analysis in excel.
9. Repeat steps six through eight to continue data collection until trial period is complete.

10. Remove mounting boxes from hospital walls.

3.2.2 Recommended Innovations and their Application

Demonstrated in section 3.2.1, the potential noise data collected would likely exceed the standards set by the KKK. Excess noise may create an insecure environment for the patient, which is counterproductive of the health and medical industry. The sound issues stem from multiple departments in hospitals as well as from a variety of sources. Concentrating on the Emergency Department, ICU, PCU, and GCU there are innovations that can be applied to improve the measures of REEDITS to create a safer environment in ambulance care.

South Shore Hospital utilizes an Emergency Department that receives patients from a large geographical area. At any time, the department can quickly become overcrowded and too noisy for patient safety. This section of the hospital consists of emergency dispatcher, EMT's, and nurses who come on site when a patient is rushed into the hospital. Depicted below is the general layout of South Shore's Emergency Department, in Figure 55.

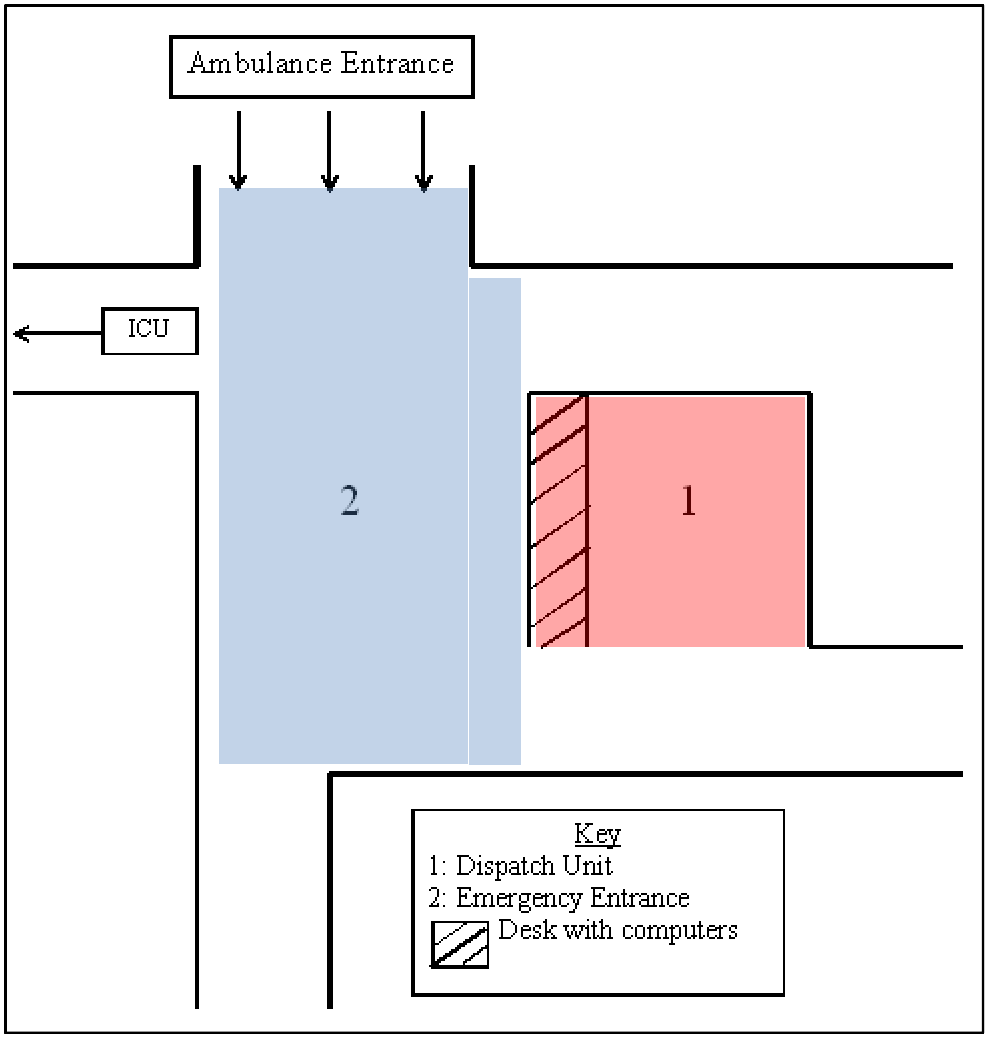


Figure 55: South Shore Hospital Emergency Department Floor Plan

As seen above, there is no barrier between the dispatchers (section 1), and the emergency entrance (Section 2), besides a long desk. This creates an unstable environment. At peak times of emergency, the room can be filled with many people all working on different tasks, and therefore attempting to speak over one another. Since each task is of equal importance for patient safety, this causes an elevation in noise. Not only does this affect the immediate area, but due to the thin walls, tiles, and ceiling type, this noise may travel in all directions disturbing patients in other areas of the hospital.

Applying innovations to South Shore's Emergency Department can reduce noise and aid in improving the measures of REEDITS. Due to the limited space currently in the section, adding Plexiglas between the dispatch and the entrance (sections 1 and 2 in Figure 55) would reduce the noise level. The Plexiglas would allow for dispatchers to still perform their job effectively since they can utilize their computers and headsets, as well as see the patients coming into the hospital and be of assistance if need be. Another advantage to this type of glass is that it absorbs the sounds generated on both sides of it. Sound absorbing floor and ceiling tiles should also be implemented to help contain the noise from spreading to other departments in the hospital.

The ICU, GCU, and PCU have different noise concerns than the Emergency Department. In these cases, the main sources of noise stem from equipment, carts, alarms, nurses, and other patients. Each of these issues has a solution, which is shown below in Table 22. It is important to note that these are not the only resolutions, and that it will take a collaborative effort from the staff in order to make an improvement.

Table 21: Noise reduction recommendations

Source of Noise	Solution
Alarms on Equipment	Background music
Intercom and Paging System	Background music
Patient Sounds (ie. coughing, snoring, gagging, moaning)	1 patient per room, or add a sound barrier (i.e. Plexiglas) in between patients
Doors Opening, Closing, Slamming	Door stoppers, and staff be more conscious of closing doors quietly
Falling Objects (ie. pans, patient charts)	Background music
Socializing at Nurses' Station	Nurses aware and hold each other accountable
Equipment Used for Patients (ie. suction or breathing machines)	Cover machines (i.e. Plexiglas box)
Noise Total	Absorbent ceiling and floor tiles

The table above provides some solutions for the various noise problems. In the table, background music was utilized as a recommendation for numerous sources of noise. Applying soothing background music in the hospital can mask unrelated noises and maintain a safe noise level. Another solution was to have one patient per room, which may be unrealistic for all patients. But, there should be a sound absorbing barrier in between patients who are in the same room instead of only a curtain which does not aid in reducing noise, and instead only prohibits patients from seeing one another. Another source of noise is the nurses socializing at stations.

This action can be improved by making general standards for all nurses in a hospital. Just like nurses have a dress code, they may have a noise code and hold each other accountable for being loud. Being aware of the amount of noise each person is creating will help in reducing it. Equipment that does not need to be changed or touched frequently may be covered by a sound absorbing material. Plexiglas is recommended since it is transparent so the equipment can still be monitored. Lastly, the noise total row suggested adding absorbent ceiling and floor tiles. If this were done throughout the hospital, it would aid in alleviating excess noise from any source, and control the noise spreading from within a room as well as from one floor to another.

Benefits of implementing the innovations outweigh the initial cost inefficiency that may come with some of the solutions. Creating a safer environment for the patients will ultimately allow for a better patient recovery process as seen in the R.E.E.D.I.T.S. method. Applying subtle background music, covering machines, and adding absorbent ceiling and floor tiles throughout the hospital are the three vital components that would immediately impact patient safety. All noise cannot be eliminated, but with further research and improvements, hospitals will have higher success rates with patient care and recovery.

3.2.3 Future Recommendations

As South Shore Hospital continues to expand in the upcoming years, the recommendations mentioned in section 3.3.3 should be implemented in the construction process. If the Emergency Department is extended, the dispatch unit should be moved farther away from the ambulance entrance. This would intensely reduce noise which is significant in an emergency situation where there is no room for miscommunication. An immediate action that should be taken by South Shore Hospital is to purchase noise meters. These can be placed around the hospital and tests run once a month to record noise. This would allow the staff to review the noise that is being produced and make them more conscious of being loud and what other areas can be improved on. Over time, this method should motivate the staff to reduce noise and patient recovery and satisfaction will increase.

Based on the team's conclusions and recommendations, it is evident that there is room for further research and improvement. Future IQP teams studying noise reduction in a hospital and Emergency Department setting should record noise data if possible. Collecting data or sitting in a hospital and listening to the sources of noise will be beneficial. Observing noise disturbances in person would allow for sources of noise to be verified and other possible conclusions can be made. Having multiple teams working on this issue may present other conclusions until the finest solutions to reducing noise are found.

CHAPTER 4: CONCLUDING REMARKS

4 Introduction

Emergency Medical Service (EMS) is an essential part of our medical system as it helps transport people who need immediate medical assistance. With its primary goal as pre-hospital care, the EMS has enhanced their services by continuous incorporating of new technology into emergency system triage units and ambulances. However, under resource constraint and environmental conditions, the EMS providers still face challenges ranging from the controlling of nosocomial infections to monitoring noise and vibration, which have adverse impact on patients and care providers. Therefore, the major focus of this project is to gain knowledge on current methodologies, policies, and procedures for reducing contaminants, noises, and unintended stresses to better improve the medical service processes. The objectives of this project are (1) Evaluate/ Examine noise, contaminants, and unintended stress in ambulance triage units, (2) Control (Methods to control) of noise, contaminants, and unintended stress in ambulance triage units, explain all statistics, and experiments, (3) Establish new ways to eradicate noise, contaminants, and unintended stress. Eencyclopedias, books, credited websites, and the Worcester Polytechnic Institute library database are major resources that are used in the study. First-hand interactions with UMass Memorial Emergency Medical Technicians and South Shore Hospital staff provide an opportunity to expand the background research beyond the two-dimensional world of academic journals. The full three-dimensional experience allowed for a better understanding of the problems and implications of environmental strains on patients and staff in emergency triage units. The background research of chapter two set the foundation for procedural principles and innovations discussed in Chapter 3

In order to strengthen the effort to improve ambulance and hospital safety regarding contamination, noise, and unintended stresses, the IQP team present recommended innovations. Detoxifying the ambulances requires cleaning procedures to be followed exactly in order to effectively remove infectious materials and blood. Applying TiO2, smart material, and a seatbelt cover would aid in ensuring patient safety. Limiting noise and unintended stresses involve implementing materials in a hospital such as sound absorbing floor and ceiling tiles, modifying tennis shoes to muffle step noise, making sound insulation machine boxes, and providing noise limits for staff to follow. Integrating the materials recommended into ambulances and hospitals would provide a better understanding of the measures of REEDITS.

Significant improvements can be made with succeeding interdisciplinary qualifying project groups. Invention, specialization, and focus on specific devices to limit noise and contaminants would produce a final product the team could potentially prototype and present to medical device and hospital supply companies. Using data collected by this and the previous team would allow future groups to start brainstorming on product designs early on in the project process. This database would allow for ample time for the proper design process to yield a novel solution. The group recommends on investigating the feasibility of developing a sound-insulating layer that can be attached to the bottom of hospital staff's shoes to muffle step noises. Advancements and designs that decrease contaminants, noise, and unintended stresses add to the health care industry and ameliorates uncomfortable, even painful and misleading patient care inhibitors.

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Appendix A.1. EMS Certification Levels