Design of a Sensor-Enabled Testing Device for the
TrueClot® Tourniquet Application Trainer
(Technical Paper)

Relationships Between Emergency Medical Services and Marginalized Communities:
Disparities Across High- and Low-Income Areas in the United States
(STS Paper)

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On my honor as a university student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Prospectus

Introduction

The Boston Marathon bombing was just one of the events over the last decade that has highlighted the need for more effective tourniquet training within the United States. Of the 243 people who were injured, 27 had tourniquets applied to them at the scene, and none of the tourniquets used were commercial. They were all makeshift—adapted from belts or other materials that bystanders had on themselves—and they were ineffective (King et al., 2015). This crisis called attention to the lack of training in tourniquet application and heightened platforms for bleeding control campaigns and products. For example, Luna Labs USA developed a tourniquet application trainer called the TrueClot® Tourniquet Application Trainer, which seeks to provide the most realistic training scenarios to emergency medical services (EMS) and military personnel (Luna Labs, 2017). The proposed technical project consists of two parts: (1) a pressure sensor that can be placed within the tourniquet application trainer in order to provide extra feedback to the user and verify that the tourniquets are secured properly and (2) a technical report outlining the processes and success of the project.

In addition to the ability of first responders to properly apply tourniquets, there are many different aspects of EMS that influence effective emergency medical care, including response time. Studies have shown that the greatest disparities in EMS response times occur between richer and poorer communities, with response times being up to 10% longer in the poorer neighborhoods (Hsia et al., 2018). Longer response times lead to increased health complications and higher mortality rates in those specific communities (Johnson, 2018). There have been attempts at justifying such large differences through economic reasoning, such as hospital closures and costs of service (EMSWorld, 2018); however, there is a clear disruption in the sociotechnical relationship between marginalized communities and EMS that must be acknowledged and will be analyzed throughout the science, technology, and society (STS) research paper.

Assessing Reliability of the TrueClot® Tourniquet Application Trainer

Luna Labs USA, LLC has a medical trauma and simulations department that is largely concerned with bleeding control. One of the main medical trauma products produced by Luna is the TrueClot® Tourniquet Application Trainer. Luna was motivated in the development of this product by the growing need for bleeding control training, as highlighted by the events of the Boston Marathon bombing (King et al., 2015). The tourniquet application trainer is primarily targeted to EMS and military personnel, but it can also be purchased and used by any person interested in bleeding control. The trainer consists of a padded arm cuff that can be secured around an individual's left shoulder, internal tubing to simulate the brachial artery, and synthetic blood that is pumped through the tubing and out of a fake wound at the base of the arm cuff (Luna Labs, 2017). The padding within the arm cuff is important because not only does it protect the wearer from the pressure of the applied tourniquet, but it also cushions the tubing in a way that ensures that the correct pressure for full occlusion of the brachial artery is required to stop the synthetic blood flow.

Currently, the only way to verify that a tourniquet is correctly applied to the trainer is to observe the stoppage of synthetic blood flow out of the fake wound. A second feedback mechanism is desirable because it would provide a quantifiable result from the training experience, and it would prove that the trainer can be realistically used for practice scenarios. A pressure sensor that can be inserted behind the tubing within the trainer will provide this mechanism. The sensor will detect the amount of pressure being applied to the trainer via the tourniquet and verify that the applied pressure is within the correct occlusion pressure range.

In order to achieve this additional feedback mechanism, five design specifications must be considered: pressure, length, sensitivity, thickness, and durability. The first step required in the design process is acquiring a useful sensor. The sensor must be able to read pressures within the 2.51-4.06 psi range (Tuncali et al., 2018). This is the range of acceptable limb occlusion pressures. The sensor must also be at least 1.5 inches in length in order to accommodate the widths of different tourniquets (Curtis, n.d.). The sensitivity of the sensor is not as important as the length and the pressure range, but it is still necessary in order to ensure accurate reports of applied pressure. Therefore, the sensor should have a sensitivity within the range of 0.01-0.5 psi. The sensor also requires a hard, flat backing in order to accurately read pressure. It will be important to consider thickness during the design process because if the sensor and its backing are too bulky within the trainer, then the accuracy of tourniquet application will be affected. Additionally, the sensor, the housing for any electronics, and the backing must all be durable. EMS and military personnel trainings tend to place a strain on training equipment, so the design must withstand rough handling and a lot of use.

The design needs outlined above will be met using a working Arduino circuit with a force-sensing resistor, which is the type of sensor that will be used for this design, simply consists of a resistor and a voltage source. The sensor works by increasing the resistance of the circuit when pressure is applied (Ada, n.d.). In order to provide data on the applied pressure, an equation for converting the change in resistance to a change in pressure must be formed. The equation will be determined through calibration of the sensor with an Instron machine, which will allow for different applied pressures to be plotted against any resulting change in resistance. The data will be fitted to the desired calibration equation, which can then be used to output applied pressure in real-time, creating the desired feedback mechanism. The short-term technical deliverables are to design housing and backing for a fully calibrated pressure sensor, whereas the long-term goals are less definitive and may include designs that allow for the sensor to be permanently embedded within the trainer and display pressure readings on a liquid-crystal display (LCD).

Disparities in ERTs between High- and Low-Income Communities

When placing a distress call, it is expected that emergency medical services (EMS) will provide the highest possible level of care. However, it can be difficult for EMS to ensure that all distress calls receive the same level of medical care, especially when the circumstances surrounding each call influence the EMS response times (ERTs). However, there is a trend of increased ERTs when the calls come from specifically low-income areas. Nationally, rural areas are lower-income than urban areas: data from the 2016 U.S. Census showed that the national "median household income for rural households was about 4% lower than the median for urban households" (Bureau, n.d.). A 2017 study that defined rural as having less than 2,500 residents and urban as having more than 50,000 residents found that 4% of rural communities experienced significantly slower ERTs. The 90th-percentile response times were 12 minutes for urban neighborhoods and 26 minutes for rural neighborhoods (Lindberg, 2017). EMS has certain standards to meet with respect to the time it takes for an ambulance to reach the patient after a call has been dispatched to the company. The national expectation is that an ambulance should arrive to urban areas in less than 9 minutes, whereas an ambulance "should arrive in 13 minutes to rural areas, [but up to] ten percent of responses may exceed this time" (Dowd, n.d.).

ERT is a big contributing factor to the rate of health complications and the mortality rate within any given community, especially in lower-income communities where health issues are more prevalent. In the case of out-of-hospital cardiac arrests, which are among the most common and most severe calls to EMS (Jordan, 2021), ERT has a large influence over survival as well as the rate of hospital discharge in affected patients. Faster response times allow for quicker resuscitation and transportation of the patient, leading to a higher rate of hospital discharge with good outcomes (Bürger et al., 2018). Therefore, communities that consistently experience slower response times are subjected to consistently higher rates of health complications and mortality.

Different ERTs are often the direct result of the process by which EMS prioritizes the need of each distress call. The need is determined by factors surrounding the patient's condition as well as the responders available within the area. With an industry-wide shortage of emergency medical technicians (EMTs) and paramedics, EMS availability is often limited, which increases ERT (Wright, n.d.). Other system-level factors that influence ERT include distance to the scene, time of day, previous workload, skill set of responders present in the ambulance, hospital delay times, etc. (Nehme et al., 2016). Rural communities are typically located further from EMS dispatch sites than urban communities, which justifies a slightly longer ERT. However, longer ERTs disproportionately affect lower-income rural communities because higher-income rural communities have more funding for better access to emergency medical care. Additionally, the 2016 U.S. Census data demonstrated that rural and urban median household incomes differ based on region. Specifically in the Midwest and Northeast, rural areas have a higher median household income than urban areas (Bureau, n.d.), yet the lower-income urban areas still experience longer ERTs. This continued disparity in low-income communities explains the need for an examination of the sociotechnical relationships between marginalized communities and EMS.

This STS research involves the analysis of many different aspects of the working EMS system. Therefore, the examination will be performed using actor-network theory (ANT). ANT is a framework that draws connections between different aspects of social and technological worlds, such as "governments, technologies, money, and people" (Cressman, 2009). The actors within a given network determined by ANT are simply different elements that interact with each other, meaning that the overall network is a series of interconnected actors. While ANT is a theory that can be applied to many different sociotechnical questions, it has received some criticism. Common criticisms of this theory are that ANT implies that all actors within a given network "are of equal importance" (Sheldon, n.d.), and there is no distinction between human and non-human actors. ANT can also be relatively subjective; it relies heavily on the judgement of the researcher and how that individual views the influence of specific actors within a network (Sheldon, n.d.). Additionally, ANT has been criticized for dismissing social factors, such as race, economic class, and gender (Pages, n.d.).

Despite these criticisms, ANT can be effectively employed to evaluate the relationships between EMS and marginalized communities. The actors within this particular network are elements that directly influence ERT and/or elements that affect the relationships between first responders and community members. Examples of actors that directly influence ERT are money (e.g., budgetary constraints of EMS and hospitals), first responder availability, distance to the scene, severity of patient condition, and time between the distress call and the ambulance dispatch. Examples of actors that affect the relationships between first responders and the community include money (e.g., median household income), race, gender, and the patient perception of ERT after placing the distress call (Dowd, n.d.; Johnson, 2018). Even the type of insurance possessed by the patient plays a role in how they may view the care provided by EMS (EMSWorld, 2018). These different actors will be analyzed to determine exactly how they interact with each other and if any interactions can be improved.

Research Question and Methods

The above research is centered around one main question: what are the sociotechnical relationships between marginalized communities and emergency medical services?

The scope of this research question allows for the discussion of the multiple problems associated with how EMS interactions differ between communities. The research will be performed using three different methods: documentary research, discourse analysis, and network analysis. Documentary research will be performed by using key words (e.g., EMS, response time, low-income, and mortality rate) to locate primary sources that will provide specific data on connections between slow response times and community health and wellbeing. This will allow relationships between different actors within the network to be identified. The discourse analysis will be used to determine how communities feel about their interactions with EMS. It will be performed primarily using threads provided by Twitter and Reddit users in order to locate discussions about EMS-related problems. Finally, network analysis will be used to provide organization to the actors determined to be within the EMS-community network. It will allow for focus to be placed on the different social structures that arise from the interactions between the actors (Curtin, n.d.). The combination of these three research methods will provide a holistic view of the complex relationships between EMS and marginalized communities.

Conclusion

Bleeding control training is becoming increasingly important, and the TrueClot® Tourniquet Application Trainer provides realistic training opportunities to prepare individuals and organizations, such as EMS and the military, for related emergency situations. A pressure sensor incorporated within the application trainer will allow for more definitive feedback, ensuring that trainees are applying tourniquets with the necessary amount of pressure.

Additionally, the sensor will confirm that the padding and tubing within the trainer provides an accurate representation of the brachial artery, the surrounding tissues, and the pressures required for full occlusion. Creating a more reliable feedback mechanism for the tourniquet application trainer will allow for EMS and military personnel to be more confident in their training programs, thus increasing overall preparedness for bleeding control scenarios.

In addition to tourniquet application training, many different factors impact the success of medical care provided by EMS, and some of those factors affect the ability of EMS to respond to distress calls in a timely manner. Longer ERTs disproportionately affect low-income areas, leading to increased health complications and higher rates of mortality than in high-income areas. A sociotechnical analysis of the relationships between EMS and marginalized communities through the lens of ANT will highlight the circumstances surrounding the increased ERTs to poorer communities. A thorough understanding of these circumstances will create opportunity for improvement in order to ensure that quality medical care is distributed equally among different communities.

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