IS PREHOSPITAL EMERGENCY TELEMEDICINE IMPLEMENTATION FEASIBLE IN NON-TRADITIONAL EMS SETTINGS: A SYSTEMATIC LITERATURE REVIEW

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Abstract

Background and Significance: The rate of technology expansion is rapidly covering even the most remote parts of the globe and in the lowest resource settings. With globalization however, low and middle income areas are facing emerging health issues such as injuries and chronic medical conditions. With these illnesses, there are inevitable demands on emergency services. It has been thought that technology be utilized to augment emergency medical care in such settings where formal Emergency Medical Services. To aggregate and analyze the existing literature on the topic a systematic literature review was conducted.

Research Question: This study analyzed the existing literature on prehospital emergency care in settings in which no formal EMS services were utilized.

Methods: Four databases were searched with inclusion and exclusion criteria, yielding 1782 results. The initial screening excluded all but 21 articles. Of the 21 articles in full review, 15 were included in the final review.

Results: Studies included in the final review were grouped into those reporting outcomes from five categories: Feasibility, Quality of Care, Response Time, Patient Outcomes, and Cost Effectiveness. Only one study was identified to be of high quality. There was a lack of studies with adequate statistical analysis to conduct statistical aggregation. Most studies however reported prehospital telemedicine in settings without EMS to be feasible, provide quality care, are be cost effective. However, the lack of statistical analysis makes it difficult to make conclusions. Also, several studies did show response time of a trained basic life support volunteer to be faster than EMS in many of the settings. But no positive health outcomes were observed in patients treated with projects utilizing technology in the prehospital setting.

Conclusion: The prehospital emergency medicine setting is a young field of study that may have significant hurdles in application. The studies conducted have shown promise in the use of technology in prehospital settings without formal EMS services, but are not robust enough to make strong conclusions or recommendations that could be put into practice. Thus, more robust, statistically oriented research is imperative in the field so that we can fully explore the
potential of technology in the prehospital setting, especially in low resource and rural settings without formal EMS services. With more robust studies, we can hope to integrate new technologies into practice and better serve the populations without adequate EMS coverage to provide more timely emergency care.
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Chapter 1 – Comprehensive Review

Introduction

One of the greatest challenges in health care is providing medical support to those who need it in areas where there are no trained medical expert available. One way to overcome this barrier is to utilize information and communication to provide expert medical advice without the physical presence of the provider. This is telemedicine and while it has many forms, it aims to bring patient and providers together across physical and social barriers. Telemedicine is a not a novel concept, with early reports of smoke signals used in ancient villages to alert of impending disease outbreaks. However, as technology has progressed, the scope and potential of telemedicine have greatly expanded. There are now many areas in which telemedicine is being utilized. However, one of the few areas in which projects and research is relatively new is in the in the prehospital setting.

One of the primary areas in which telemedicine has been found to be particularly useful is in the situations where treatment delays adversely affect patient outcomes. One example of this has been highlighted through early recognition of EKG changes to facilitate early intervention. Similar paradigms have been utilized to connect paramedics to specialists for early stoke recognition and trauma management. Another area in which the feasibility of telemedicine has been explored has been through physicians taking a supervisory role to aid nurses or less experienced physicians by guiding them through an advanced task, and this concept has been extended to include the guidance of layperson in a few cases. This could be an additional area of potential research, however studies at this time are lacking. One of the major opportunities in the field is in reducing the disparities that exist in prehospital emergency care. Considering that the expanse of technology, as seen by mobile phone saturation in even the most desolate parts of the world, is growing much faster than medical care can, there is an opportunity to utilize technology to provide prehospital emergency care to the areas which are most disconnected from it. The majority of prehospital telemedicine studies have focused on the areas of stroke, myocardial infarction, trauma, and cost effectiveness. The amount of
research geared toward identifying the opportunities in the utilizing of prehospital telemedicine is limited.

**Current State of Prehospital Telemedicine**

*Stroke Telemedicine (telestroke)*- Of applications utilized in the prehospital setting, the majority have focused on recognizing stroke. Several studies have shown that stroke telemedicine is indeed feasible arena to attempt telemedical interventions. This is partially due to the importance of early thrombolysis in acute ischemic stroke and the poor rates of successful intervention\(^3\). In 2008, the thrombolysis utilization rates in acute ischemic stroke within the United States were between three and five percent\(^3\). The difficulty in the recognition of the stroke by an expert provider within the gold standard of 3-4.5 hours is a major reason for the low utilization rates of thrombolysis in acute ischemic stroke. Thus, it was thought that faster recognition of stroke by an expert through telemedicine could improve thrombolysis rates. Studies have shown that the assessment of stroke through telemedicine is feasible with adequate technological infrastructure. Additionally, the quality of the National Institute of Health Stroke Scale (NIHSS) assessment is as effective through use of video as it is in person\(^4\). Further evidence for the utilization of telemedicine for stroke thrombolysis is supported by similar outcomes in mortality and quality of care compared to traditional in person interactions between doctors and patients\(^5\)-\(^8\). Conversely studies have shown that telestroke can have higher costs, mostly attributed to initial investment into technology infrastructure\(^9\). Furthermore, some of the greatest challenges in implementing telestroke are technical in nature, specifically overcoming telemedical equipment issues and broadband infrastructure\(^10\),\(^11\).

*Trauma Telemedicine* – One area of telemedicine that has been partially explored is the role of telemedicine in prehospital trauma care. While there haven’t been major studies looking specifically at the topic as a whole, there have been isolated studies examining certain aspects of telemedicine in trauma care. Primarily, it has been shown that trauma care and disaster
medicine can be supported effectively through telemedicine. This was especially true in settings with severe shortages of health professionals\textsuperscript{12}. Several examples of this include successes using video telemedicine for burn evaluation when compared to traditional in person assessments\textsuperscript{13}. Studies showed accurate assessment and reduced rates of admission and subsequent reduction in costs\textsuperscript{14}. Another model utilized for trauma management via telemedicine has been the guidance of paramedics by physicians for trauma assessment and care. This has included guided sonography for trauma assessments (FAST exam), symptom recognition, and clinical decision making\textsuperscript{15,16}. One study’s findings even suggested that utilizing telemedicine could reduced mortality and hospital costs in rural settings\textsuperscript{17}. Most of the studies in this field have either involved a component of simulation instead of real-life scenarios or have had some forms of bias that could affect the validity of results. Thus, this area of research could further benefit from more robust studies.

\textit{Telemedicine for Myocardial Infarction} – Myocardial is one of the emergencies in which rapid diagnosis and treatment can have a meaningful impact on mortality and morbidity. Thus, in cases of ST Elevation MI (STEMI), it is ideal to have coronary perfusion restored to the affected area within two hours of medical contact\textsuperscript{18}. The importance of timely identification of STEMIs makes it an ideal situation to use telemedicine to shorten the time from first medical contact to diagnosis of STEMI. It is unsurprising that using prehospital EKG transmission via telemedicine for evaluation by a physician can reduce time to percutaneous coronary intervention (PCI) and mortality in STEMI cases\textsuperscript{19,20}. Some studies show a drastic benefit from prehospital transmission of EKGs in increasing the percent of patients with STEMI receiving PCI within 2 hours of medical contact, with one study showing an improvement from 14\% to 72\% of patients receiving PCI within 2 hours of medical contact\textsuperscript{21}. However, this study used historical controls that introduce an element of historical bias to the analysis. Furthermore EKG transmission has been highly reliable in the prehospital setting, with studies showing successful EKG transmission in the 90\% range often, alleviating concerns of technical obstacles in the implementation of such programs. Additionally, low cost mobile applications have been shown to send prehospital EKGs
with a reliability greater than 95%\textsuperscript{22}. The potential impact of these findings are even more significant when considering that studies which have examined paramedics’ interpretation of EKGs for STEMI are not reliable enough to enhance patient triage\textsuperscript{23}. It is clear that telemedicine is already having a meaningful impact in the area of STEMI diagnosis in the prehospital setting. Future studies can further validate this model so that more EMS providers are using such technology to provide more timely care to patients suffering from an STEMI.

Summary of the current state of telemedicine – The current literature in telemedicine is not robust enough to draw conclusions to direct care at this point. Mainly due to the lack of studies conducted in real-life scenarios as well as the lack of large randomized controlled studies. The most conclusive clinically applicable studies in telemedicine currently are in the fields of stroke management, showing positive clinical outcomes compared to traditional models. There have also been successes in applying telemedicine to portions of prehospital care, such as the use of mobile phones to transmit EKG images and sensor to send information to a hospital. However, there has not been significant evidence to support the use of telemedicine for myocardial infarction or trauma care for improved clinical outcomes. These lack of findings could be attributable to infrastructural limitations and technical difficulties. As technology improves, it is possible that telemedicine could become a method for improving clinical outcomes in a greater breadth of illnesses in the prehospital setting. It is important to note that most studies have evaluated the role of prehospital telemedicine by utilizing ambulance mounted equipment and EMS providers. There have been few studies exploring the use of prehospital telemedicine by other types of emergency providers such as laypersons and other types of technical equipment such as smartphones.
Lack of Resources and Disparities in Care

Introduction – Access to prehospital care in cases of trauma and emergencies can be relatively expeditious in certain areas of high resource countries; however in reality the majority of the world does not have access to emergency care. Few people suffering injury are able to receive prehospital care, and even fewer have access to an ambulance. Thus, the majority of the world relies on means outside of traditional EMS systems to seek care in emergencies. Long transport times are common in trauma and present a significant danger to patients. Often, dangerous or poor roads further extend travel time. Finally, Ambulances and EMS personnel are often unavailable, with injured patients being transported by private vehicles, commercial trucks or taxis, public transportation, or by animal. Even in areas with service provided by professional Emergency Medical Technicians (EMTs), the response times and patient outcomes can vary greatly. While many disparities in prehospital emergency care may exist in many forms, two significant and previously researched are in the form of geospatial and socioeconomic factors.

Geospatial Disparities – One of the earlier studies areas of study for prehospital care is in the area of trauma and the influence of geospatial factors on response times and mortality. It was established twenty years ago that trauma victims who live in rural areas not only had to wait longer to receive prehospital care, wait longer to reach a hospital, but were also more seven times more likely to die if their transport was longer than thirty minutes. Recent research has shown that disparities in survival continue to exist, with rural residents experiencing mortality rates 14% in cases of trauma than non-rural residents. Unsurprisingly, studies have shown that areas with lower density of inhabitants are subject to longer ambulance response times, likely contributing to these disparities. Additionally patient using private transport, potentially because of poor ambulance utilization or availability are less likely to achieve coronary reperfusion in the recommended time frame for STEMs. A recent study highlighted the importance of such disparities in care, especially in low and middle-income countries.
Geospatial mapping was able to identify that the majority of the population in more than half of the countries studied cannot access emergency surgical services within two hours. Additionally, some countries that had the majority of the population living within two hours of emergency surgical care had major disparities in access to a surgeon due to number of available surgeons. For example, while Sierra Leone has 70% of its population living within two hours of a surgeon, those living within the two hour travel distance of a surgeon had access to ten times as many surgeons per person compared to those living outside the two hour travel distance. The evidence shows that patients suffering from emergencies in rural areas are much less likely to receive timely care and more likely to die from their emergency than those living in more urban areas. They also have much less access to surgical services in cases of emergency. This clearly is an area in which some of the telemedicine interventions previously studied could be applied to investigate if some of these gaps could be addressed.

Socioeconomic Disparities – In addition to geospatial influences there are also socioeconomic factors that can affect prehospital emergency care. For example, one of the studies that found private transport to hospitals in a prehospital emergency is associated with slower treatment for STEMI also found that lower socioeconomic status could have a similar effect. They showed that patients of lower education levels can have a 66% increased chance of not receiving timely care for a STEMI compared to those in higher education levels. One study compared the diagnosis, resource utilization, and mortality of patients from differing zip codes suffering from a STEMI. Interestingly, those from zip codes with lower median household income were less likely to receive reperfusion within the suggested timelines. Furthermore, those patients from less wealthy zip codes were less likely to have more money spent on their care, as measured by mean hospitalization costs and the use of circulatory support devices. Finally, patients from less wealthy zip codes were significantly more likely to die after suffering a STEMI. This phenomenon has also been described in fields outside of cardiology. The findings from a recent study suggested that patients from less wealthy zip codes were more likely to die in the hospital following a traumatic injury compared to patients from wealthier zip codes even after
controlling for insurance status, race, and other comorbidities\textsuperscript{36}. There is some evidence to suggest that these differences in mortality may be resultant from factors as early as the prehospital setting. For example, several studies have shown that socioeconomic status can even have an effect on rates of bystander CPR in out of hospital cardiac arrest and the survival rates from those cardiac arrests\textsuperscript{37-39}. Another study showed several factors that could be contributing to worse prehospital care in areas of lower socioeconomic status. First, they showed that higher socioeconomic neighborhoods were more likely to be serviced by advanced care paramedic crews\textsuperscript{40}. This study also showed that patients with chest pain from wealthier neighborhoods experienced significantly shorter transport times to the hospital than patients from less wealthy neighborhoods\textsuperscript{40}. It is evident from the research present that areas of low socioeconomic status are less likely to survive from a variety of prehospital emergencies and it seems that some prehospital factors may be implicated for the higher mortality seen in this population. If patients are less likely to receive bystander CPR, advanced paramedic crews, and have longer transit times it may explain why they have higher rates of death in these prehospital emergencies. These differences are significant in nature and could be a major target for improvement when addressing potential solutions to challenges seen in the prehospital setting. As previously discussed, there is potential for telemedicine to improve prehospital emergency care globally, but also alleviate some of the existing disparities in the survival of prehospital emergencies. However, first it must be examined whether telemedicine is a financially feasible option for the already low resource communities.

\textit{Cost of Telemedicine} – There have not been many studies evaluating the costs associated with prehospital telemedicine, however some studies have indicated that it could more costly initially with savings in the future. For example some studies showed telemedicine to be more expensive due to equipment purchases required, but it could be argued that shorter hospital stays are associated with decreased long-term costs\textsuperscript{9,41}. The majority of these cost effective studies were conducted in the field of telestroke. It would be valuable to examine whether prehospital telemedicine outside of the telestroke model are economically feasible.
Role of laypersons in the prehospital setting

*Introduction* – Resources in the prehospital setting are poor, especially in the global realm of prehospital emergency management. While telemedicine may have the potential to alleviate some of the financial and logistic burdens of prehospital care in low resource settings, there is still the question of who, especially in the areas without formally developed EMS systems, will carry out the initial assessment and stabilization of a patient. Though the thought of no formal EMS providers in an area may seem daunting for the delivery of prehospital care, it could be an opportunity for novel models of care delivery in the prehospital setting. The increasing prevalence of technology, especially mobile phones, could be harnessed as a tool to make prehospital telemedicine feasible in low resource settings. To render prehospital telemedicine feasible it might be necessary to utilize resources such as community health workers (CHWs) or laypersons.

*Call For Prehospital Laypersons and Evidence of Support* – The initial stabilization and transport of injured individuals is already often carried out by untrained laypersons in low-middle income countries (LMIC). This is so much the reality in LMICs that the World Health Organization has recommended training laypersons for providing first aid in prehospital settings. It is expected that laypersons can help fill the gap in prehospital emergency management in LMICs. There is already strong evidence that layperson can in the prehospital setting reduce physiological severity score and reduce trauma mortality. It appears that there is currently strong evidence supporting the use of laypersons to respond to emergencies in LMICs. However, it is yet to be determined if similar programs can be utilized for training of laypersons for all types of emergencies.

*Specific Examples of Utilizing Laypersons in Emergencies* – There are several examples in which show successes of layperson training programs across the world in LMICs. There have been several unique approaches to training laypersons. For example, in Ghana it was shown that...
truck drivers have almost universally come across caring for injured persons. Thus, it was decided that commercial drivers (taxi, truck, bus) would be good candidates for first aid training. 355 commercial drivers were provided with a 6 hour course on first aid utilizing the Where there is no doctor and Basic First Aid curriculum. Another project worked to create a “Village University” model in which local health care providers in Cambodia and Northern Iraq were trained not only in basic first aid, but also provided direction to train laypersons in their community to provide first aid. These groups were targeted because they lived in communities that had a high number of land mine related injuries. A program in Kampala, Uganda took a similar approach of training commercial drivers, but took a slightly different direction by developing a very simple picture based training curriculum so that it would be at the literacy level of their commercial drivers. Another program in Iran trained over 4000 laypersons to provide first aid after injury. A different approach to this theme was taken by project leaders in Cape Town, South Africa by training laypersons to be emergency first responders in 1 day, but also connecting them regional EMS personnel. This hybrid of model shows how it is possible to have collaborative programs that appropriately augment the existing medical services available. Finally, Nepal used a novel method of providing training through free online modules to laypersons; successful completion of the online didactic portion qualified students to finish the training in-person at a regional center.

Components of Successful Campaigns – While there were several different methods and models for implementing these programs, there were some themes present in most of the successfully implemented programs. First, a majority of programs that trained laypersons first did a “needs analysis” and had significant contributions from key stakeholders. Another key component of these programs was they developed their curriculums based on an analysis of pre-existing resources and the needs of the area. For example, programs with high incidence of traumatic injury focused heavily on initial stabilization of hemorrhage. Many of the programs aimed at utilizing laypersons for prehospital emergency care also did an excellent job of tailoring their education materials toward the literacy of the target population. Among laypersons in LMIC
countries there is generally low levels of literacy and specifically health literacy, so it was important to devise programming that was attuned to this aspect of the training. Many successful projects have implemented training utilizing native language speakers and visual aids rather than written word. These considerations have been meaningful in creating programs that can have a significant impact in their communities. While many projects aimed at utilizing laypersons don’t have patient outcome data to support their efficacy, several projects have aimed to address this question.

Effectiveness/Cost Effective, Future Directions – Programs that utilize laypersons in prehospital emergency care would not be beneficial if these programs did not appear to be effective or cost-effective. Thus, it is important that the effectiveness and cost burden of these programs are evaluated to assess feasibility. The mortality benefit has been shown in several studies. The aforementioned layperson training program in Iran was shown to reduce physiological severity and mortality from land mines. Second, the “village university” study mentioned from Iraq was shown to also reduce mortality in Northern Iraq. These successes show that laypersons can be effective in provide patients with better outcomes. However, there is the question of whether these programs can be cost effective in addition to having positive outcomes since they would not be very useful if their implementation is not financially feasible. While some studies had relatively low costs estimated at $3 per person, others had higher costs around $27 per person. Some of the more expensive programs included the provision of first aid kits along with training. There is the concern that these high costs for program support could hamper efforts to offer a sustainable program for prehospital emergency care. However, a study out of Uganda assessed training of laypersons for prehospital emergency care and found that trainees demonstrate a high level of knowledge after training and that the program can be scaled up cost effectively.
Conclusions – It is encouraging to see that there are several studies which have successful implemented training programs for layperson, however, it is important to note that only a few have measured outcomes related to reduced mortality. Understandably, the environment and inherent deficiencies in monitoring can make such analysis in LMICs difficult. The positive results from the few studies that have measured outcomes and effectiveness are encouraging. This would indicate that future projects in the field are necessary to evaluate whether utilization of laypersons for prehospital emergencies should be encouraged even more. There is a unique opportunity to utilize laypersons in LMICs to address the lack of prehospital emergency care.

Conclusion
It is evident that there is significant unmet need in prehospital emergency care, especially in rural and low socioeconomic areas. There is immense opportunity to reduce mortality and morbidity in the prehospital stage in settings that don’t have robust or formal emergency medical services. With the rapid expansion of available technology, even in lower resource settings of low and middle income countries, an approach that utilizes telemedicine could a be a practical, low-cost solution to address some of the unmet needs in such areas. Some of the major hurdles with this approach are the existing technologic infrastructure, initial investment costs, and sustainability. However, several studies have supported the long-term cost effectiveness of telemedicine, especially in certain settings such as stroke care. There are also several studies that have shown the utility of laypersons in attending to prehospital trauma in low and middle income countries. There is potential that utilizing prehospital telemedicine with laypersons could be a successful model. However, the utilization of lay health workers as care providers and the use of telemedicine in the prehospital setting are very much in the early stages of research. There are very few studies linking the two concepts. While there have been several studies addressing the feasibility, accuracy, and reliability of telemedicine, few have assessed the impact on patient outcomes. Research into the utilization of lay persons in the pre-setting is in an even earlier stage, with Callese et al.’s systematic review yielding only six
studies, which are primarily focused on feasibility rather than impact on patient outcomes. Both telemedicine and the use of laypersons are promising and innovative concepts. Integrating telemedicine into layperson prehospital care programs in under-resourced settings may facilitate safer and more effective patient care. However, more targeted and rigorous research is required in the field. If research and projects in this area are conducted, there could be significant advancement in the quality and accessibility of prehospital emergency care in rural and low resource settings.
Chapter 2 – Systematic Review

Introduction:
The golden hour in the realm of prehospital emergency care is referred to the hour immediately following an out of hospital emergency. It has also been identified as a stage in emergency response that has a significant effect on improving health outcomes, specifically mortality\textsuperscript{24}. The accelerated spread of technology around the world has had a profound impact on health issues, but also presents a novel medium for health care solutions. One of the consequences of globalization is the introduction and proliferation of technologies to communities that may not be equipped to handle the potential injuries resulting from these new technologies. The rapid global integration of motor vehicles in low and low-middle income settings is just one example and is a notable contributor to the increase in high impact traumatic injuries seen in these countries. Ninety-one percent of the world’s fatalities on the roads occur in low-income and middle-income countries, even though these countries have approximately half of the world’s vehicles\textsuperscript{24}. An additional paradoxical burden of these countries is that as their health systems reduce deaths from infectious disease, persons are living longer and thus are more susceptible to chronic disease. Chronic disease has increased 27\% in the past 10 years\textsuperscript{24}. These countries that have seen the relatively recent emergence of traumatic injuries and chronic health issues as a significant health threat are now facing “a triple burden of disease.” The triple burden includes the emerging issues of chronic disease and injuries, as well as the ever-present threat of infectious diseases. While the health systems of low and low-middle income countries have been geared towards addressing infectious disease, their capacity to address the emerging chronic diseases and injuries is not well established. Many of these chronic diseases and injuries cause an estimated number of Disability Adjusted Life Years (DALYs), making them incredibly burdensome on low-resource communities. One aspect of chronic diseases and injuries is that they both often require emergent attention, often in the form of hemorrhage from injury, stroke, or cardiac arrest. Thus, solutions which can address timely delivery of prehospital care to those suffering from an emergency can have improved outcomes the broad area of chronic and injury care. Hence, the delivery of timely care to low-resource areas, specifically rural areas,
is one of the most pressing issues in prehospital emergency care. These areas are particularly susceptible to poor outcomes from emergencies as their long travel times to major hospitals contributes to poorer outcomes30. However, there are several promising opportunities for the low-middle income countries seeing aging populations and increased injuries. First, as emergency services are often not well established in low resource settings, there is more opportunity to influence the development and implementation of these services to ensure that cost effective, evidence based approaches are utilized. Second, the globalization of technology also allows for the opportunity to strengthen emergency care in low and low-middle income countries in a unique way that doesn’t adhere to the same paradigms of settings with highly developed, established trauma and emergency systems. Having a setting in which trauma and emergency care is not established may lend an opportunity for the technology to be utilized differently and flourish in ways not restricted to conventional beliefs and systems.

With prehospital time and transport being such a critical factor in emergencies suffered in resource poor and rural settings, those factors become potential areas of significant improvement with targeted intervention. The improvement in mobile technology is an obvious tool that should be considered in addressing this critical time between the occurrence of a health emergency and access to a health care professional. Telemedicine in the emergency prehospital setting is not a new idea. But, as expected, telemedicine and technology has been most utilized in high income countries with advanced emergency medical service systems. Most studies and interventions have focused exclusively on technological improvements to the ambulance portion of the prehospital. There have been close to one hundred studies on prehospital EKG transmission and telecardiology. Mobile stroke units have also become more popular in higher resource settings1. A systematic review on the topic of prehospital telemedicine summarizes the advances and successes of these interventions1. However, the one aspect of the prehospital phase that has not been studied extensively is the use of telemedicine and mHealth in the absence of EMS. This has primarily accomplished through volunteer or community health worker paradigms. Though some studies on prehospital
emergency care in low resource settings have been conducted. For example, the Murad and his colleagues have studied the use of laypersons as emergency responders and showed that indeed prehospital emergency care can be effective in this form\textsuperscript{52,53}. Another study also focused on improving prehospital emergency training and adding additional dispatch sites with good results\textsuperscript{54}. Some studies, such as the one conducted by Tiska et al, focused their education efforts on commercial drivers, as they were often witness to road trauma\textsuperscript{55}. Some of the other studies assessed the current prevalence prehospital care and the efficacy of existing systems\textsuperscript{56}. Some review studies by Nielsen et al have evaluated several prehospital trauma systems and found the use of laypersons for delivering care to be and effective use of resources\textsuperscript{57}. These are several examples of community health workers and volunteers being utilized in the prehospital setting for emergencies. “Out of hospital cardiac arrest (OCHA)” chest compressions are another major area of research with promising results. However, one area of prehospital emergency care that has not been explored extensively is the utilizing technology to augment efforts of non-professional health workers in low-resource settings. With the proliferation of such technologies, we have a unique opportunity to capitalize on telemedicine in the prehospital setting in low-resource communities. There are a few studies which have started to merge the two concepts in an attempt to provide emergency care to settings without formal EMS with the help of volunteers and layperson. There is great opportunity to reduce the burden of chronic disease and injury emergencies in such settings without formal EMS. A systematic literature review on the topic would explore how effective such strategies could be at improving health outcomes through better care during the golden hour. This opportunity to explore the potential of utilizing telemedicine and mHealth for prehospital care could significantly improve emergency care also in higher income settings, like much of the United States, especially rural areas and those without robust rapid EMS.
Materials and Methods

A systematic review of peer-reviewed prehospital emergency telemedicine and mHealth in settings underserved by Emergency Medical Services (EMS) was conducted in four databases (MEDLINE/PUBMED, EMBase, and Web Of Science), in addition to a grey literature search on relevant organizational websites. The search strategy utilized a combination of terms related to prehospital emergencies and use of technology including tablets, mobile phones, mHealth (full list of search terms listed in Appendix A). Only articles from 1980 to 2016 were included in the analysis as technology prior to 1980 was not sufficient to be included in the scope of this review. “Non-traditional EMS systems” were defined as studies focusing on interventions carried out outside ambulances and not requiring specialized prior medical knowledge. Studies in which EMS providers were trained outside their scope of practice were included, however studies in which EMS providers operated within their scope of practice were not included. Only one study included EMTs which were trained in a skill outside their scope of practice, otherwise all other studies did not include health professionals58. Prehospital studies were defined as those with interventions taking place outside the hospital or health clinic. Finally, telemedicine and mHealth were defined as any technology focusing on electronic communication beyond the traditional audio phone call from the field to an emergency dispatch center.

Initial search engine queries resulted in 2913 entries, of which 1131 were duplicates, resulting in 1782 original studies to be screened. Title and Abstract screening was conducted with one researcher due to study constraints on the following inclusion criteria. Full inclusion criteria are available in Appendix B.

1) Written in English, Spanish, and French
2) Includes a prehospital emergency telemedicine or mHealth intervention
3) The intervention must include electronic communication across a significant distance in a form outside the traditional audio telephone call from the field to an emergency dispatcher.
4) Takes place in prehospital setting
5) Carried out outside ambulances and not requiring specialized prior medical knowledge
6) Intervention must be conducted by laypeople or training included in study which could be performed by layperson (non physician, nurse, EMT)
7) Must report on a feasibility OR effectiveness outcome indicator

The selection process is outlined in Figure 1. Of these references 21 were selected for full article screening according to more rigorous screening and inclusion criteria. Of the 21 articles, 15 were included in the final review. Included studies for review have outcomes measured in four broad categories. Of the studies not included for final review, three were for not taking place in prehospital settings59-61 (Kouidi et al, Mougiakakou et al, and Tillya et al.) One study was excluded for using health professionals within their scope of practice62 (Solla et al.) One study was excluded for not reporting any outcomes as a result of the intervention63 (Van Der Worp et al.) Finally, one study was excluded on the basis of not utilizing any technology beyond the standard phone call method64 (Westlund et al.)

Of the included studies, 7 were poster presentations that were included because they reported outcome in their findings. All the included studies were prospective in design. There were several randomized control studies, longitudinal designs with comparison groups, and pre/post test studies were included in the review. All the studies included, had at least one of the following outcome measures: feasibility of an intervention (non-inferiority in regards to quality of control or previous method), quality of care (i.e. measures of procedural competency), response time to emergency, cost-effectiveness, and health outcomes. Since there were diverse indicators included in our review, there was a broad range of indicators included. Thus, studies in which “feasibility” was the outcome measured, it could include outcomes such as, “quality of ultrasound images using video transmission” or “acceptance of two-way video conferencing for guided chest compressions.” Examples of “quality of care” measurements included studies that
**Figure 1 Article inclusion flow chart**

- **Initial Search Query** of 4 databases and grey literature
  - n=1782

- **Excluded Articles**
  - n=1761

- **Title and Abstract Screen on inclusion and exclusion criteria**

- **Articles selected for full-text review**
  - n=21

- **Full Paper Screening**

- **Papers included in analysis from full paper screening**
  - n=15

- **Papers Excluded from Analysis**
  - n=6
evaluated CPR quality through quantification of depth of compressions, “time off CPR,” and rate of compressions.

All included studies met the inclusion criteria and did not satisfy any exclusion criteria, but their quality and strength varied greatly. Thus, each study was ranked as low, medium, high, or insufficient quality using a method described by an AHRQ article on this topic\(^6\). See Table 1 for classification of studies. With this method, RCTs and those with control groups were considered higher level studies, those with an observational design were generally regarded lower. The magnitude of effect was considered and the width of confidence intervals was also considered in ranking quality of studies. Though posters were included in the final analysis due to satisfying all inclusion and exclusion criteria, but by their nature of not being subject to peer review were ranked lower in quality. As no studies consistently reviewed the same variable, meta-analysis was not conducted.
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<td>Ringh et al. 2015 (Sweden)</td>
<td>Bolle et al. 2009 (Norway)</td>
<td>Ota et al. 2012 (Japan)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Macbeth et al. 2013 (Canada)</td>
<td>Ngabo et al. 2012 (Rwanda)</td>
<td></td>
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<tr>
<td></td>
<td>Bolle et al. 2009 (2) (Norway)</td>
<td>Maes et al. 2015 (Belgium)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Morgenstern et al. 2015 (USA)</td>
<td>Henriksen et al. 2014 (Denmark)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ringh et al. 2011 (Sweden)</td>
<td>Henriksen et al. 2013 (Denmark)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ringh et al. 2010 (Sweden)</td>
<td>Henriksen et al. 2014 (Denmark)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Roth et al. 2000 (Israel)</td>
<td>Grasu et al. 2013 (Romania)</td>
<td></td>
</tr>
</tbody>
</table>
Results

Feasibility of Use:

Four studies in this review reported on factors related to feasibility of use. Three of the four studies measured the clarity or usability of video transmission of either human-human contact or ultrasound images to human contact. All either found the telemedicine (experimental) groups to be of similar or improved quality of communication in their own measures. Table 2 below summarizes the findings of each study. The Bolle study examined the clarity of instruction and the confidence of layperson in CPR training in either video and audio or only audio groups. There was no difference in the clarity of instruction in the two groups, but video group felt more confident in their abilities. The McBeth and Ota studies both examined ability of ultrasound naïve providers to obtain adequate ultrasound images with telemedicine guidance. Both studies show feasibility of ultrasound guidance through telemedicine, however neither study conducted a statistical analysis and the McBeth study did not include a control group. The Ngabo study simply looked at the feasibility of SMS text messages sent by community health workers to summon emergency response in remote areas. The study reported cases of successes and noted 24 times in which the SMS system was used in emergencies, but does not offer any statistical analysis.
### Table 2 Feasibility of using telemedicine or mHealth in reviewed studies

<table>
<thead>
<tr>
<th>Quality/Study</th>
<th>Indicator(s)</th>
<th>Feasibility findings</th>
<th>Description of Comparison/Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medium</strong></td>
<td></td>
<td></td>
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</tbody>
</table>
| Bolle et al. 2009 (poster) | 1) Clarity of instruction  
2) Belief in correctly applying CPR | Yes (p=0.85) No difference between groups in quality of instruction  
2) p=0.01 More confidence in applying CPR with video instruction | Video vs. Audio only for CPR training of high school students in simulated cardiac arrest |
| Macbeth et al. 2013 | 1) Ability to identify ultrasound abnormalities  
2) Concordance between ultrasound naïve examiners and experts | Yes. However, no statistical analysis. No control group. | No Control group. Concordance between expert reviewers and naïve examiners with guidance, but not true control |
<table>
<thead>
<tr>
<th>Low</th>
<th>Ota et al. 2012 (poster)</th>
<th>1) Ability to obtain adequate ultrasound images</th>
<th>Yes. However, no statistical analysis. Showed video guided exams were successful (100% vs 55%)</th>
<th>Guidance vs no guidance for ultrasound images</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ngabo et al. 2012</td>
<td>1) Number of SMS messages sent in emergencies</td>
<td>Undetermined. Study shows that SMS can be feasible for emergencies by community health workers</td>
<td>No comparison group.</td>
</tr>
</tbody>
</table>
Quality of Care:

Two studies in the final review measured outcomes regarding quality of care. Both of the studies measured the quality of CPR/resuscitation performed by layperson when guided by video or a telemedicine equipped AED. However, since the Maes et al. study did not include a control group, their results are not considered strong. The Maes study did summarize the characteristics of providers using an AED with telemedicine capabilities. The outcomes reported from that study do not significantly contribute to the scope of this study beyond 62% of participants delivering an electrical shock when appropriate and a mean time of 2min and 29sec for shock delivery. The Bolle et al. 2009 study did include controls and their findings do support some use of video guidance in simulated layperson OHCA, but the magnitude of their effect was weak, therefore not considered a “high” quality study for the purposes of this review. The Bolle study primarily reported decreased time off CPR in the video assisted group versus the audio only control group. Table 3 below summarizes key findings.
### Table 3 Quality of care findings in reviewed studies

<table>
<thead>
<tr>
<th>Quality/Study</th>
<th>Indicator(s)</th>
<th>Quality of Care findings</th>
<th>Description of Comparison/Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medium</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolle et al. 2009</td>
<td>1) Time off CPR</td>
<td>1) p=0.05. Found to have significant improvement.</td>
<td>Video vs. Audio CPR guidance Groups of randomly assigned high school students with controls from same school using only audio.</td>
</tr>
<tr>
<td></td>
<td>2) Time to first compression</td>
<td>2) p=0.29. No significant improvement</td>
<td></td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maes et al. 2015</td>
<td>1) Use of AED</td>
<td>No Control Group.</td>
<td>No control group.</td>
</tr>
<tr>
<td></td>
<td>2) Mean time to defibrillation</td>
<td>Only descriptive statistics available.</td>
<td></td>
</tr>
</tbody>
</table>
Outcomes in health:

Two studies in the final review measured health outcomes. The Morgenstern study measured the loss of healthy days following the use of a wearable medical alert device in women with at least one stroke risk factor\(^7\). While the study did have qualities such as randomization, there were no positive findings supporting the use of a wearable medical alert device. The Ringh et al. study was very strong in that there was a robust study design including blinding and randomization, as well as a large study size (>300) in each group. The study examined whether SMS based notification of an out of hospital cardiac arrest (OHCA) to a registry of CPR trained volunteers could improve response time and patient outcomes\(^7\). In the Ringh study, the primary outcome was response time, which is discussed later in the results section. The secondary outcomes however focused on health outcomes. The study did not however find strong association with SMS based notification of volunteers to provide CPR with improved health outcomes, with those secondary outcomes showing no differences between the two groups. Table 4 below summarizes key findings.
Table 4 Outcomes in health findings in reviewed studies

<table>
<thead>
<tr>
<th>Quality/Study</th>
<th>Indicator(s)</th>
<th>Outcomes in Health Findings</th>
<th>Description of Comparison/Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Return of Spontaneous Circulation</td>
<td>1) p=0.28</td>
<td>Randomized emergency calls to either SMS dispatch of volunteers or volunteers were not dispatched.</td>
</tr>
<tr>
<td></td>
<td>2) 30 day survival post cardiac arrest</td>
<td>2) p=0.93</td>
<td></td>
</tr>
<tr>
<td>Ringh et al. 2015</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>Loss of healthy days</td>
<td>1) p=0.213</td>
<td>Randomized for wearing medical device or not. Good randomization.</td>
</tr>
<tr>
<td>Morgenstern et al. 2015</td>
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</tbody>
</table>
Response Time and Bystander Initiated CPR:

One of the reviewed articles, seven measured the response time or rates of bystander initiated CPR as an outcome measure. Bystander initiated CPR was considered along the same idea as response time because it indicated faster emergency care. The Ringh study strong indicated that the rate of bystander initiated CPR is improved significantly when an SMS dispatch of an OHCA is sent to pre-registered CPR trained volunteers. The Grasu study was not of highest strength because the results reported were not quantitatively reported and it was not in the form of a peer review journal. There were three posters or oral presentations found in grey literature from Henriksen et al. focusing on response time for AED placement with volunteers utilizing an SMS based service. Their results showed that a volunteer service with SMS based dispatching could arrive prior to the ambulance 95% of the time. The Ringh studies from 2010 and 2011 did not show such high rates of volunteers arriving before EMS, but they still did show that the majority of calls had a volunteers responding prior to EMS if an SMS was sent. They also conducted a simulation in which SMS dispatched volunteers arrived on average more than 2 min prior to EMS providers. Table 5 below summarizes key findings.
### Table 5 Response time findings in reviewed articles

<table>
<thead>
<tr>
<th>Quality/Study</th>
<th>Indicator(s)</th>
<th>Response Time findings</th>
<th>Description of Comparison/Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ringh et al. 2015</td>
<td>1) Rate of bystander CPR</td>
<td>1) 62% experimental vs 48% control (p&lt;0.001)</td>
<td>Randomized emergency calls to either SMS dispatch of volunteers or volunteers were not dispatched.</td>
</tr>
<tr>
<td><strong>Medium</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ringh et al. 2011</td>
<td>1) Simulated Response time. 2) First on scene with volunteer vs EMS</td>
<td>1) 2m58sec experimental vs 5m18sec EMS. P&lt;0.001 2) Descriptive statistics showing majority of cases volunteers were on scene before EMS.</td>
<td>In simulation, there was volunteer team for experimental with SMS dispatch and a control group of normal EMS team and procedures.</td>
</tr>
<tr>
<td>Ringh et al. 2010 (poster)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Low</strong></td>
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<tr>
<td>Henriksen et al. 2013/2014/2014 (Poster/Oral)</td>
<td>1) Response time. 2) Percent of cases with volunteers</td>
<td>1) Prior to ambulance 95% of time. No statistical</td>
<td>1) No groups were formally studied. Solely the response times within the experimental</td>
</tr>
<tr>
<td>Time of response</td>
<td>Faster in SMS directed volunteer service</td>
<td>Did not compare groups in analysis.</td>
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<tr>
<td><strong>Grasu et al. 2013</strong> (Poster)</td>
<td>1)</td>
<td>1)</td>
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</table>
Cost Effectiveness:

Our search efforts found one study that examined the cost effectiveness of utilizing a telemedicine service rather than ambulance costs if avoidable. This study, while not randomized or controlled, did conduct a model showing the expected costs saved by avoiding emergency transfer when avoidable. However since there was no randomization and described statistics based on model, this was not a robust study design to place into mathematical analysis. Table 6 below summarizes key findings.
### Table 6 Cost effectiveness findings in reviewed articles

<table>
<thead>
<tr>
<th>Quality/Study</th>
<th>Indicator(s)</th>
<th>Outcomes in Cost Effectiveness</th>
<th>Description of Comparison/Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>1) Savings per member by introducing telemedicine service</td>
<td>1) Estimated $83 saving per member</td>
<td>Compared based on mathematical models of cost if not offered telemedicine.</td>
</tr>
<tr>
<td>Roth et al. 2000</td>
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</table>
Discussion

It is apparent that with increasing technology, more researchers are considering avenues in which technology can be utilized for better patient care, especially in the prehospital setting. This review aimed to systematically review the literature describing the use of telemedicine and mHealth in the prehospital setting for emergencies in non-traditional EMS settings. Our review of the 21 articles consistently found that mHealth tools and telemedicine are feasible, effective tools that improve the quality of care for patients as well as response times. Some of the primary outcomes measured in studies included in this review include feasibility, health outcomes, response time to patients in the field, quality of care and cost effectiveness.

Primary findings of studies that we reviewed show that the use of telemedicine and mHealth in the prehospital setting is feasible. While research in the past faced technical challenges in implementing such interventions, the studies reviewed showed successes with utilizing technology. The Bolle study clearly showed that users had no problem with the clarity of the information; however the study was conducted in a more controlled testing setting than would be done in the field. Similarly, the other studies included in the review also conducted their studies in fairly controlled settings. While the results were encouraging, it is likely that the research will have to be conducted in the field.

The studies reviewed which measured the quality of the interventions such as time off CPR and patient health outcomes had somewhat interesting results. A general theme tended to be that studies that measured the quality of the intervention did have non-inferior or improved measures in the groups that used a form of telemedicine. However, when applied to a field clinical setting, there were no discernable mortality or patient health outcome differences. This is most evident in the high quality study by Ringh in 2015 showing that while response times are improved, there are no measureable improvements in patient outcomes. Theoretically, with increased bystander CPR rates and faster response times reported in these studies, the survival of OHCA should improve as more patients are getting more rapid CPR. However factors such as volunteer CPR training could affect the applicability of theory to measureable results in
reality. The other factor that could have contributed to the lack of measureable results is the small number of participants in most of these studies other than the Ringh study in 2015. In general, few of these studies measured patient outcomes as many of them were conducted in simulation or training settings. This could suggest that this field is yet emerging or could represent the major challenge in researching this field.

The nature of this topic likely makes studying it difficult because of the differing natural speeds of research and technology. For example, technology is a dynamic field in which new ideas can become obsolete in only a few years due to newer innovations. But research is a methodological process that requires extreme vetting and thorough examination before the intervention can be put into practice in the field. Thus, it can be incredibly challenging to research such an evanescent topic as technology. Another challenge of research in this topic is that technology and connectivity vary greatly across different settings; thus it would be difficult to generalize results regarding feasibility between regions with differing technological capabilities. However, as alluded to earlier, globalization and the rapid spread of communication capabilities across the globe may alleviate some aspects of this hurdle.

With those challenges considered, there are several areas in which this field of research could be bolstered. One of the major gaps in many of the studies reviewed was the general lack of statistical analysis. The majority of studies didn’t carry out or report statistical analysis, even when they had sufficient data to do so. Other studies could have made meaningful contributions to the field of study had the included control groups. For example, the Maes study is a great example of one that didn’t have a control group using a normal Automated External Defibrillator (AED) instead of the experimental telemedicine AED. Having a control group in that study as well as others would have greatly improved the quality of the studies included in this review. The other major area of improvement in this topic of research would have been the application of these interventions in a field setting. The main outcome that was studied in field settings was the response time using an SMS based system to dispatch volunteers. However, beyond that measure most of the other studies did not include field
research of the hypothesis. It is understandable that there are many political and logistic barriers to conducting such studies in the field, but to have meaningful impact, studies must be conducted in such a manner in that they can be applicable to real-life situations.

This review had several limitations that could affect the quality and applicability of its findings. Stemming partially from the studies not having statistical analysis, this review could not conduct statistical analysis or group the results from the studies. The review would be more meaningful if it could provide statistical reference to support the findings of value from prehospital telemedicine in informal EMS settings. Second, this review was conducted by only one reviewer; thus not allowing for disagreement and a more robust screening methodology. Third, by limiting studies to only English, French, and Spanish there could have potentially been articles which would have been included in the review that were excluded. Logistic and cost issues were the primary reasons for these limitations.

As research in this field carries forward, there are several overarching themes that must be considered. As discussed earlier, much of the research is limited by technological factors and the results may not be well generalizable. But another factor to consider is the use of such technologies in rural or urban areas. While many of the studies in this review were done in simulation settings, the field studies were mostly conducted in higher resource settings in which the study augmented pre-existing EMS systems. Thus, for future research, it would be interesting if these technologies were applied to lower resource settings without any EMS services. These technologies could be combined with other programs utilizing laypersons in the prehospital setting. A recent systematic review by Callese et al. is an example of how laypersons are being utilized in the prehospital setting for emergencies. The incorporation of some of these technologies with those programs relying on layperson could turn out to be a perfect combination for lower resource and potentially rural areas.
Conclusion

Technology in the prehospital emergency medicine setting is a young field of study that may have significant hurdles in application. The studies conducted have shown promise in the use of technology in prehospital settings without formal EMS services, but are not robust enough to make strong conclusions or recommendations that could be put into practice. Thus, more robust, statistically oriented research is imperative in the field so that we can fully explore the potential of technology in the prehospital setting, especially in low resource and rural settings without formal EMS services. With more robust studies, we can hope to integrate new technologies into practice and better serve the populations without adequate EMS coverage to provide better and more timely emergency care.
References


Appendices

Appendix A:

Total Results: 1782 De-duplicated (2913 total)

Pubmed: 732 Results

(Prehospital[Title/Abstract] OR Pre-hospital[Title/Abstract] OR ambulance[Title/Abstract]) AND (Technology[Title/Abstract] OR Telemedicine[Title/Abstract] OR electronic[Title/Abstract] OR phone[Title/Abstract] OR Tablet[Title/Abstract])

Embase: 1290 Results

'prehospital':ab,ti OR 'pre-hospital':ab,ti OR 'ambulance':ab,ti AND ('technology':ab,ti OR 'electronic':ab,ti OR 'phone':ab,ti OR 'tablet':ab,ti OR 'telemedicine':ab,ti)

Web of Knowledge: 1852 results

TS=(prehospital OR pre-hospital OR ambulance) AND TS=(technology OR electronic OR phone OR tablet OR telemedicine)

Cochrane: 38 results

Prehospital or pre-hospital or ambulance:ti,ab,kw and phone or tablet or technology or electronic:ti,ab,kw
Appendix B:

Inclusion and Exclusion Criteria:

Is pre-hospital emergency telemedicine implementation feasible in non-traditional EMS settings: A systematic literature review

**Inclusion Criteria:** The studies selected for review must

- Focus on pre-hospital care
- Occur in settings without formal EMS settings OR have components which could be applicable to settings without EMS systems
- Must have conducted an intervention or evaluated an intervention performed with the above criteria
- Must have a focus on telemedicine or new medical communication technology used in pre-hospital care
- Report an a resulting variable as a result of the intervention

**Exclusion Criteria**

- Non-English, French, Spanish language article
- Non-human study; example would be a study only examining a technology without application to pre-hospital emergency care
- Evaluation of technology or outcomes from technology are not the main focus of study
- The technology used is not used for communication
- Non-emergency situations studied; examples would be studies which use paramedics to provide primary care

**Inclusion Criteria**

- Includes a pre-hospital emergency telemedicine or mHealth intervention
- Intervention must be conducted by laypeople or training included in study which could be performed by layperson (non physician, nurse, EMT)
- Must report on a feasibility OR effectiveness outcome indicator (to be defined)
  - Response time
  - Time to care

**Outcome Indicators**

- Effective
  - Improved health outcomes
  - Improved quality of care (time to care)
- Describe feasibility/program characteristics