Heart Attacks in Rural America
Reducing ST Segment Elevation Myocardial Infarction Mortality in Northwest Wyoming

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List of Abbreviations
ACS Acute Coronary Syndrome  GAO Government Accountability Office
AMI Acute Myocardial Infarction  ICD International Classification of Disease
CAD Coronary Artery Disease  NCD Non-communicable Disease
CCL Cardiac Catheterization Laboratory  OMB Office of Management and Budget
CDC Centers for Disease Control  RACE Reperfusion of Acute Myocardial
CVD Cardiovascular Disease  Infarction in Carolina Emergency
ED Emergency Department  Departments
EKG Electrocardiogram  STEMI ST Segment Elevation Myocardial
EMS Emergency Medical Services  Infarction
EMT Emergency Medical Technician  WHO World Health Organization
Heart Attacks in Rural America: Reducing ST Segment Elevation Myocardial Infarction Mortality in Northwest Wyoming

Executive Summary

Cardiovascular diseases currently account for roughly 33 percent of deaths in the United States and the rate of disability and dependency due to heart disease is still on the rise. Chronic diseases, such as cardiovascular diseases, represent a significant challenge for public health officials because they have no cure and represent an entire life-course of interconnected variables. However, acute forms of cardiovascular disease, such as heart attack, represent an opportunity for targeted health policy intervention to save lives and reduce disability in the American population.

ST Segment Elevation Myocardial Infarction, or STEMI, currently affects an estimated 500,000 Americans every year and is considered the deadliest form of heart attack because STEMI represents a complete blockage of the coronary artery for a prolonged period of time. Although recent advancements in medical technology and public health strategies have reduced overall STEMI mortality in the United States, there remains a significant geographic disparity in mortality. Rural regions tend to have diminished access to healthcare resources due to financial and geographic barriers which limit potential medical interventions during STEMI and increase heart attack mortality.

This memorandum evaluates the potential of three established STEMI systems of care to reduce STEMI mortality in rural northwest Wyoming. As the least populous state in the country, Wyoming experiences high STEMI mortality rates. The state’s unique geography and limited access to surgical intervention are key sources of prolonged treatment times and explain why too many individuals in Northwest Wyoming die in the hospital following admission for ST Segment Elevation Myocardial Infarction because they are unable to obtain timely coronary reperfusion therapy. Because time is the greatest factor in determining STEMI mortality, the evaluated interventions focus on improving treatment times within the highly rural context of Big Horn, Hot Springs, and Washakie counties.

Studies on established systems of care regionalization, helicopter transport, and field IV therapy are used to project reductions in STEMI mortality for the proposed solutions. Cost-benefit analysis is also utilized to quantitatively evaluate the cost-effectiveness of each system. Upon extensive evaluation of the potential interventions, this memorandum recommends the continuation of status quo treatment of STEMI within the region due to the high cost of program implementation and the low number of lives to potentially be saved in the region. While this does not preclude small or localized interventions, the establishment of a comprehensive STEMI system of care is not currently feasible.
**Problem Definition**

Too many individuals in Northwest Wyoming die in the hospital following admission for ST Segment Elevation Myocardial Infarction because they are unable to obtain timely coronary reperfusion therapy.

**The Historical Treatment of Heart Attack**

Time is muscle. This has been the mantra of heart-focused public health organizations such as the American College of Cardiology and the American Heart Association since the groundbreaking study of Reimer et al in 1977 that first demonstrated a relationship between the length of heart muscle ischemia and irreversible heart damage during a heart attack. This important discovery prompted numerous subsequent public health studies exploring the effectiveness of different medical interventions at restoring blood flow to the heart and reducing heart attack mortality including aspirin tablets, intravenous fibrinolytics, and percutaneous coronary intervention (PCI). More recently, the impact of heart attacks on future health outcomes has even been associated with increased one-year mortality rates for every additional minute of ischemia. Together, these advancements in heart attack knowledge have encouraged public health officials to design systems of care that expedite medical interventions for individuals suffering from heart attacks.

Advancements in the routine management of heart attacks has prompted a national decrease in total acute myocardial infarction (AMI) mortality rates that has been extensively documented beginning as early as 1975 and continuing through 2008 with specific negative trends in STEMI mortality being

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observed since 1990\textsuperscript{5,6,7,8,9,10,11}. This significant progress in the treatment of heart attacks in the United States is primarily attributable to effective use of aspirin, beta-blockers, and other medications; advancements in fibrinolytic therapy and PCI technologies; and decreased average door-to-treatment times for medical interventions\textsuperscript{12,13,14,15}. Additionally, the development and widespread use of the GPS in United States ambulances between 2006 and 2007 further decreased total ischemic time for heart attack patients by reducing the average EMS response time by roughly five minutes\textsuperscript{16}. However, the recent decline in heart attack and STEMI mortality rates has not been associated with a decline in heart attack hospitalization rates and national STEMI 30-day mortality remains near 20 percent\textsuperscript{17,18,19,20}. A modern STEMI triage schematic can be seen in Figure 1 below. Additional STEMI triage and hospital protocol information is available in Appendix A.


\textsuperscript{12}Rogers et al, 2000.

\textsuperscript{13}Heidenreich and McClellan, 2001.

\textsuperscript{14}Fang et al, 2002.


\textsuperscript{17}Fang et al, 2002.

\textsuperscript{18}Rosamond et al, 1998.


The Geographic Burden of STEMI

These recent advancements in technology and public health strategies have created a disproportionate geographical shift in the burden of STEMI mortality. According to the American Hospital Association, there are 4,999 community hospitals in the United States of which 1,980 are located within rural settings\textsuperscript{21}. These hospitals are less likely to have PCI capabilities and are a significant reason why almost 60\% of United States adults live in a region where the closest hospital is incapable of performing PCI\textsuperscript{22,23}. This results in higher STEMI mortality rates in rural regions because PCI is more effective at restoring blood flow to the heart than fibrinolytic therapy and presents a decreased risk of

bleeding and other treatment complications\textsuperscript{24}. In fact, fibrinolytic therapy possesses significant contraindications, or reasons to withhold medical treatment, that are estimated to exclude 20-30\% of heart attack patients\textsuperscript{25}.

Rural regions are also subjected to significant geographic barriers to rapid medical care for heart attack patients because the majority of rural Americans, 52.2\% percent, live more than sixty minutes away from the nearest hospital and may experience more than thirty minutes of additional delay if the nearest hospital is not PCI-capable\textsuperscript{26}. Finally, many rural regions lack coordinated systems for STEMI treatment that could minimize time before treatment by synchronizing EMS transport, physician tests and evaluations, and performance of or transport for PCI\textsuperscript{27}. For the rural regions surrounding Vanderbilt University Medical Center, similar delays constituted a 7.5\% percent increase in STEMI mortality for every additional thirty minutes of ischemia which would result in a 15\% percent increase in mortality for the most rural American regions\textsuperscript{28}.

**The Cost of STEMI**

In addition to the disproportionate burden of STEMI on rural populations, cardiovascular diseases (CVDs), in general, have significant financial impacts on Americans. Current estimates suggest that CVDs cost the United States $315.5 billion annually, including $108.9 billion from coronary heart

\textsuperscript{25} Stys, 2010.
\textsuperscript{26} Nallamothu et al, 2006.
diseases, due to the cost of health care services, medications, and lost productivity\textsuperscript{29,30}. Additionally, in-hospital STEMI mortality is associated with roughly a $10,000 increase in hospital costs per patient than those who survive fatal heart attacks and are discharged based on the National Inpatient Sample and patient’s who survive fatal heart attacks with significant heart damage have also been shown to incur an additional $38,000 in medical costs over the remainder of their lifetime\textsuperscript{31,32}. These significant medical costs are indicative of the rising prominence of medical bill-related bankruptcy which accounted for over 60 percent of all bankruptcies in the United States as recently as 2008\textsuperscript{33}. Ultimately, the diminished quality of STEMI systems of care in the rural United States presents an additional financial burden on rural regions in addition to increased STEMI mortality and survivor heart damage.

\textbf{Figure 3: Projected Direct and Indirect Costs of all CADs, 2008}

Total Cost of CADs in 2008

\begin{itemize}
  \item Direct Costs = $87.6 Billion
  \item Indirect Costs = $68.8 Billion
\end{itemize}

\begin{itemize}
  \item Home Healthcare
  \item Hospital Care
  \item Physician Visits
  \item Nursing Home Care
  \item Prescription Drugs
  \item Lost Productivity due to Mortality
  \item Lost Productivity due to Morbidity
\end{itemize}

**Wyoming’s Geographic Barriers to Healthcare**

Wyoming has the smallest state population in the United States with 584,153 citizens and posts the second lowest population density in the country of 5.8 people per square mile. According to both the United States Census Bureau and Office of Management and Budget (OMB), Wyoming has only two urban regions immediately surrounding the cities of Cheyenne and Casper which qualify Laramie and Natrona counties respectively as the only urban counties in the state based on OMB metrics. The Wyoming department of health additionally recognizes 17 frontier counties, defined as counties with fewer than six people per square mile, which account for 47 percent of the state’s total population.

The highly rural geography of Wyoming is representative of the rural challenges to effective STEMI systems of care. Wyoming ranks 14th in heart attack mortality rate, at 97.5 deaths per 100,000, despite being the 17th healthiest state in the country according to the United Health Foundation.

Wyoming particularly faces considerable obstacles in its provision of emergency medical services (EMS) and emergency hospital care. Although Wyoming is fourth in the nation in emergency department (ED) access, it also has the second lowest hospital occupancy rate largely due to its rural geography where only 33 percent of the population lives within sixty minutes of a trauma center. This is particularly troubling in the case of STEMI treatment because distance relates to time and time is associated with increased STEMI mortality. The challenge of geography is amplified in the case of Wyoming’s STEMI systems.
of care because the state ranked second lowest in the nation in PCI facilities per 100,000 square miles at 2.04 in 2011 and additionally lacks a uniform system of pre-arrival, triage, and destination policies for STEMI patients once they reach the ED\textsuperscript{41,42}. Finally, EMS agencies tend to be poorly supported. Volunteer agencies are most common in highly rural states and Wyoming does not provide a state EMS medical director or state funding for EMS quality improvement; making EMS improvements difficult within the state\textsuperscript{43,44}. Additional information regarding the emergency medicine climate in Wyoming can be found in Appendix B.

**Figure 4: Wyoming STEMI Burden Map**

![Wyoming STEMI Burden Map]

**STEMI in Rural Wyoming**

Wyoming as a whole is considered a Class 5 STEMI state by the American Heart Association due to its high mortality rates; however, there is also significant variation in heart attack mortality throughout

\textsuperscript{41} Ibid.
\textsuperscript{42} Hirshon et al, 2014.
\textsuperscript{43} Ibid.
\textsuperscript{44} Langabeer et al, 2013.
the state. Based on heart attack mortality data from the CDC, the counties of Washakie, Hot Springs, and Big Horn exhibit some of the highest AMI mortality rates in Wyoming and also represent some of the most rural counties in the state as they are all considered frontier (Figure 4). Even by Wyoming’s standards, these counties have minimal access to PCI with no PCI-capable hospitals located in the northwestern portion of the state (Figure 4). Together, these geographic and structural challenges explain why too many individuals in Northwest Wyoming die within 30 days of admission to a hospital for ST Segment Elevation Myocardial Infarction because they are unable to obtain timely coronary reperfusion therapy. However, these challenges also present an opportunity for public policy intervention to reduce reperfusion times and thus reduce STEMI mortality in frontier Wyoming.

**Background**

*Communicable Diseases vs. Non-Communicable Diseases*

Throughout history, the majority of human deaths have been caused by communicable diseases. A communicable disease is defined by the United States Centers for Disease Control and Prevention (CDC) as any “illness caused by an infectious agent or its toxins that occurs through the direct or indirect transmission of the infectious agent or its products from an infected individual or via an animal, vector or the inanimate environment to a susceptible animal or human host.” These diseases include influenza, malaria, smallpox, cholera, polio, and many others. However, modern advancements in sanitation, food safety, vaccines, antibiotics, and nutrition, in addition to global disease eradication efforts, have greatly reduced the burden of communicable diseases worldwide since the start of the 20th century.

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46 Centers for Disease Control and Prevention, National Center for Health Statistics. Underlying Cause of Death 1999-2012 on CDC WONDER Online Database, released 2014. Data are from the Multiple Cause of Death Files, 1999-2012, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program. Accessed at http://wonder.cdc.gov/ucd-icd10.html on Jan 16, 2015 7:06:40 PM


In fact, non-communicable diseases (NCDs) overtook communicable diseases and other causes of death such as maternal, perinatal, and nutritional conditions as the leading causes of death and disability in most countries in the period between 1990 and 2010\(^9\). A breakdown of causes of death in the United States at the beginning and end of the 20\(^{th}\) century is shown in Figure 5. According to the CDC, a NCD is defined as any “chronic condition that does not result from an acute infectious process and has a prolonged course, that does not resolve spontaneously, and for which a complete cure is rarely achieved”\(^{50}\). NCDs currently kill more than 36 million people each year worldwide with 80 percent of total NCD deaths occurring in low- and middle-income countries and over 25 percent of total NCD deaths being considered premature because they occur before the age of 60\(^{51}\). Additionally, over 80\% of NCD deaths are attributed to cardiovascular diseases, cancers, respiratory diseases, and diabetes and collectively share risk factors of tobacco use, physical inactivity, the harmful use of alcohol, and unhealthy diets\(^{52}\). This advent of NCDs as the primary cause of death globally represents a significant challenge for policymakers as NCDs are now a major cause of poverty worldwide and will represent the greatest cause of death in all regions of the world sometime between 2017 and 2022 according to the United States’ Department of Health and Human Services’ National Institute on Aging\(^{53,54}\).


\(^{52}\) Ibid.

\(^{53}\) Byfield and Moodie, 2013.

The Burden of Cardiovascular Diseases

Because industrialized countries have been particularly effective at controlling infectious diseases, countries such as the United States experienced a disproportionate rise in non-communicable diseases over the course of the twentieth century. Cardiovascular diseases alone represent a significant public health challenge as CVDs, which include coronary heart disease, stroke, congestive heart failure, and peripheral artery disease, became the leading cause of chronic disease morbidity and mortality in industrialized countries over the same time period. The World Health Organization (WHO) additionally recorded significant increases in death rates from what it called arteriosclerotic, ischemic, and coronary heart diseases in developing countries during the first two decades following World War II. Multiple attempts have since been made to evaluate the trends in CVDs worldwide, including a groundbreaking ten year longitudinal study by the WHO called the multinational monitoring of trends and determinants in cardiovascular disease project commissioned in 1979. Varying diagnostic practices and criteria in different regions and countries have complicated the evaluation of CVD trends in the past half century; however, it appears that both overall CVD mortality and CVD mortality rates peaked in the United States at the end of the twentieth century and have been decreasing in most populations and in both genders worldwide since 1970. A detailed background on the global burden of cardiovascular diseases as recorded by the WHO is listed in Appendix C.

But despite significant progress in reducing heart disease mortality, other health status indicators, such as disability and dependency, suggest that the total impact of CVDs has actually increased in the

60 Male CVD Mortality was increasing in Eastern Europe during the study period (Uemura et al, 1987)
62 Luepker, 2011.
United States during the latter half of the twentieth century\textsuperscript{64,65}. CVDs remain relatively abundant in affluent industrialized countries, such as the United States, where calorie-dense food is common, labor-saving devices reduce physical activity, and tobacco products are prevalent. All of these factors contribute to CVD-related diseases such as high blood pressure (hypertension), high cholesterol (hyperlipidemia), diabetes mellitus, and obesity\textsuperscript{66}. A list of physical and physiological risk factors for CVDs is displayed below in Figure 6. As of 2010, CVDs alone were responsible for roughly 33 percent of all deaths in the United States, of which 34 percent were before the average American life expectancy of 78.7 years\textsuperscript{67}.

**Figure 6: Risk Factors for CVDs**

![Risk Factors for CVDs](Image taken from Dekou.com)

**Coronary Artery Disease Background**

According to the World Health Organization, Cardiovascular Diseases include “a group of disorders of the heart and blood vessels that include diseases that affect the blood vessels supplying the heart muscle, the brain, or the arms and legs, damage to the heart muscle and heart valves from rheumatic fever, malformations of the heart, or blood clots in the leg veins that dislodge and move to the heart and


\textsuperscript{66} Luepker, 2011.

\textsuperscript{67} Go et al, 2014.
lungs". Of these disorders, a subset of diseases of the blood vessels supplying the heart muscle, known as coronary heart diseases, are responsible for nearly half of all CVD deaths. Coronary artery diseases (CADs) develop when the coronary arteries, the major vessels responsible for supplying the heart with blood, narrow and eventually decrease blood flow to the heart muscle. CADs are particularly dangerous because they can ultimately lead to a sudden, life-threatening condition known as an acute coronary syndrome (ACS), or colloquially a heart attack, if the blood supplied to the heart muscle is completely blocked. The relative prominence of CADs, coupled with the severe and acute onset of ACSs, makes CADs responsible for over 7 million deaths annually worldwide each year including 380,000 deaths within the United States.

The Pathology of Acute Ischemic Heart Diseases

Cardiovascular Diseases and Public Health

The majority of chronic diseases, including CVDs as a whole, represent a significant challenge for public health officials because these diseases present an entire life-course of related variables that range from genetic factors to childhood socioeconomic status to lifetime educational attainment which have all been extensively documented in the International Journal of Epidemiology since the turn of the century.

The complex, life-long, pathology of CVDs has prompted the CDC to release multiple comprehensive action plans, most recently revised in 2008, that envision numerous levels of societal intervention including environmental change, population behavioral change, improved risk factor

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72 Types of Cardiovascular Disease. (n.d.).
75 Example of variables attributable to adult chronic respiratory disease can been found in Appendix D (Int Jr Ep).
detection and control, improved acute case management, improved chronic case management, and improved end-of-life care\textsuperscript{76}. Further information on population health strategies is supplied in Appendix D.

**Pathology of Heart Attack**

Although policy addressing the entirety of CVDs in the United States clearly requires numerous extensive and coordinated public policies, the underlying pathology of specific acute coronary syndromes may provide an opportunity for targeted policy intervention with the potential to save a significant number of lives. Acute coronary syndromes are also termed acute ischemic heart diseases due to their impact on the blood vessels of the heart muscle. Ischemia, by definition, is a decrease of blood flow due to a partial or complete blockage of an artery that reduces the oxygen supply to a muscle or other region of the body\textsuperscript{77}. Ischemia is harmful in any part of the body because prolonged blood loss can result in tissue death; however, this is particularly dangerous in the heart because myocardial ischemia can cause damage to the heart muscle, known as an infarction, and, in the case of a severe, sudden blockage, lead to a heart attack\textsuperscript{78,79}.

The Mayo Clinic lists the primary conditions that cause cardiac ischemia as the narrowing of coronary arteries from progressive plaque accumulation, the dislodging of blood clots from narrowed coronary arteries or other parts of the body, and the temporary tightening of the artery walls due to a coronary artery spasm\textsuperscript{80}. Any permanent damage caused by these ischemic conditions can, at minimum, reduce the heart’s ability to pump efficiently or, at maximum, lead to heart failure or cardiac rupture depending on the size of the infarction\textsuperscript{81,82}. In addition to reduced heart function, patients who survive

\textsuperscript{76} A public health action plan to prevent heart disease and stroke. (2003). *US Department of Health and Human Services, Centers for Disease Control and Prevention, 13.*

\textsuperscript{77} Ischemia | deficient supply of blood to a body part (as the heart or brain) that is due to obstruction of the inflow of arterial blood. (n.d.). Retrieved January 4, 2015, from http://www.merriam-webster.com/dictionary/ischemia


\textsuperscript{81} Myocardial Ischemia.
heart attacks with resulting permanent heart damage are at an increased risk for additional medical problems such as respiratory diseases, kidney failure, sleep apnea, diabetes, and depression\textsuperscript{83,84}. Not only are these heart attack co-morbidities associated with decreased health but they are also known to increase future patient medical costs\textsuperscript{85}.

**Pathology of STEMI**

The CDC estimates that 720,000 Americans experience a heart attack each year, of which 500,000 are classified as ST Segment Elevation Myocardial Infarction or STEMI\textsuperscript{86}. STEMI is considered the deadliest form of heart attack because STEMI represents a complete blockage in a major coronary artery that results in a prolonged period of blood loss to a large area of the heart muscle\textsuperscript{87}. Although STEMI mortality rates have been declining over the last three decades, national mortality rates remain at 20 percent between patients who die prior to emergency medical service (EMS) arrival, patients who die in the hospital, and patients who die within 30 days of discharge from the hospital\textsuperscript{88,89}. Timely medical intervention is important in the treatment of STEMI because permanent heart damage can begin within 20-30 minutes of ischemia and total infarction size has been shown to significantly decrease with prompt restoration of blood flow\textsuperscript{90,91}.

Diagnosis of STEMI is relatively simple and reliable for emergency department personnel or emergency medical technicians (EMTs) due to its visual presence between the S and T segments on an electrocardiogram (EKG; Figure 7); producing diagnostic EKGs for nearly 94 percent of STEMI


\textsuperscript{86} Go et al, 2014.

\textsuperscript{87} Mission: Lifeline Glossary. (2013, August 23).

\textsuperscript{88} Wilson and Douglas, n.d.

\textsuperscript{89} EMS Incidence Data Reports: Cardiac Events. (n.d.).


\textsuperscript{91} Burke and Virmani, 2007
sufferers\textsuperscript{92,93}. Restoration of blood flow to the heart muscle, known as reperfusion, is most commonly achieved through the administration of clot-breaking drugs, known as fibrinolytic therapy\textsuperscript{94}, or the surgical insertion of a balloon into the blocked artery, called Percutaneous Coronary Intervention (PCI)\textsuperscript{95}. While PCI remains the preferred treatment for STEMI by the American College of Cardiology and the American Heart Association due to its superior effect on blood flow and lower risk of complication, fibrinolytic therapy is recommended when a hospital is not equipped to perform PCI and the nearest PCI-capable hospital is too far away to achieve treatment within two hours of symptom onset\textsuperscript{96,97}. But despite the clear advantage in reduced mortality rate and reduced heart damage from rapid reperfusion, 30 percent of STEMI patients fail to receive PCI or fibrinolytic therapy and only 40 percent of those who do receive treatment get it within the recommended 90 minutes following symptoms onset\textsuperscript{98,99}.


\textsuperscript{93} Appendix E provides general background information on EKG testing and STEMI.

\textsuperscript{94} Fibrinolytic Therapy and Thrombolytic Therapy are used interchangeably in this memo. While fibrinolytic and thrombolytic medications differ slightly in their physiological mechanism of action, their purpose and effect during acute myocardial infarction is the same; rendering the differences beyond the scope of this memo.

\textsuperscript{95} Levine, G. (2012). The 2013 STEMI Guideline: Data-driven recommendations that reduce morbidity and mortality. \textit{Cardiovascular Daily}.

\textsuperscript{96} Grines, Serruys, & O’Neill, 2003.


\textsuperscript{99} Burke and Virmani, 2007.
Public Health and STEMI

STEMI, as well as other CVDs, will likely remain a significant public health issue in the foreseeable future as the prevalence of CVD mortality risk factors such as high blood pressure, smoking, poor diet, insufficient physical activity, and abnormal blood glucose levels remain high among American adults, at 40.6%, 13.7%, 13.2%, 11.9%, and 8.8% respectively\textsuperscript{100}. Roughly one third (31.8%) of American children are also listed as overweight or obese and nearly 14 percent of high school students report no significant physical activity\textsuperscript{101}. While it is clear that the reduction of CVDs in the American population will require significant behavioral and structural changes within the current population healthcare system, the reduction of ACS and specifically STEMI mortality might be obtained in the short run by improving systems of care for individuals suffering a heart attack.

Issue Analysis

STEMI Systems of Care

Due to the recent emergence of heart diseases as the number one cause of death in the United States, public health officials in numerous states have developed different STEMI systems of care to try and reduce heart attack mortality\textsuperscript{102}. A major player in the development of dedicated STEMI systems of care is the American Heart Association’s Mission Lifeline. Mission Lifeline aims to “create STEMI systems of care and improve existing ones to ensure prompt, seamless, effective treatment to STEMI patients”\textsuperscript{103}. This has involved the creation of an extensive accreditation program for heart attack receiving and referring hospitals that meet specific structural, organizational, and protocol standards as

\textsuperscript{100} Go et al, 2014.
\textsuperscript{101} Ibid.
well as the promotion and support of STEMI systems of care in regions throughout the United States\textsuperscript{104}. The general aim of STEMI systems is the reduction of reperfusion time through patient education and EMS, hospital, or procedural interventions.

**STEMI Systems of Care Stakeholders**

Figure 8: Stakeholders in STEMI Systems

![STEMI Systems of Care Stakeholders Diagram](image)

The three major stakeholders in the establishment and implementation of STEMI systems of care are emergency medical services, hospitals, and health insurance companies. While pre-hospital emergency care is an essential part of any medical system, emergency medical services are particularly important in rural areas where the average distances between patients and hospital services tend to be greater than in more populated regions\textsuperscript{105}. However, significant financial and organizational barriers created by high operating costs and lack of qualified personnel have caused many rural EMS agencies to affiliate with local hospitals or suspend operation entirely\textsuperscript{106}. An EMS system may receive revenue from a combination of local governments, insurance companies, and private payments; although many EMS agencies in very rural areas rely almost entirely on donations and function as primarily volunteer


organizations. Rural EMS systems also experience higher average transport costs than urban EMS systems, with average costs of $538 and $409 respectively, and most EMS reimbursements fall short of covering the cost of transport. Together, these financial constraints make any additional financial requirement for EMS agencies important in the development of deduced reperfusion times through improved STEMI systems of care.

Significant costs to hospitals must also be considered with any public health policies regarding changes to PCI services. X-ray generators for cardiac catheterization laboratories (CCLs) can range between $1 million and $2.4 million and the catheters used to perform the procedures can range from $1,000 to $115,000. In addition to equipment costs, some PCI hospitals may need to expand their CCL operation hours, and thus their personnel budgets, to avoid an increase in STEMI reperfusion time and resulting mortality during hospital off-hours. While there are also cost-reducing measures that CCLs can employ, such as performing catheterization through the wrist instead of the femoral artery, many of these measures would also impact hospital budgets through additional physician training or equipment changes.

Finally, health insurance agencies and their contracted physician groups play a major role in the development and execution of STEMI systems of care. In regions with multiple competing physician groups, precious time can be lost during the navigation of complicated insurance referral systems and, in regions with a dominant physician group, legally mandated separation of hospital financial resources and

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interests can inhibit the development of streamlined systems within a single hospital\textsuperscript{113}. The lack of a universal transfer system between medical facilities and the frequent county-level funding of EMS agencies can further complicate STEMI systems and delay reperfusion especially if patients need to be transported over county lines\textsuperscript{114}.

**Memorandum Scope**

This memo will examine how different STEMI system of care program interventions might impact the 30-day mortality rates for STEMI patients living within Washakie, Hot Springs, and Big Horn counties, Wyoming. The proposed solutions will include adaptations of STEMI models from domestic and international contexts to frontier Wyoming. Cost effectiveness will be very important in the recommendation of a specific STEMI system of care intervention due to the constraints of EMS agency budgets and the high costs of CCLs.

**Methods**

**Population Examined**

This memorandum analyzes the effects of regional STEMI systems of care on 30-day STEMI mortality rates in Big Horn, Hot Springs, and Washakie counties in northwest Wyoming. These three counties were chosen due to their proximity to one another as adjacent counties, their relatively high STEMI mortality rates, and their frontier population designation. Rural and frontier counties in the United States experience higher STEMI mortality rates compared to urban counties due to geographic and structural barriers; and Wyoming is no exception\textsuperscript{115}. Big Horn, Hot Springs, and Washakie all have heart attack mortality rates (97.2, 118.8, and 159.4 respectively) that are near or higher than both the Wyoming


\textsuperscript{114} Ibid.

state average of 97.5 and the average of Wyoming frontier counties of 103.46\textsuperscript{116}. A summary of Wyoming’s heart attack mortality data as recorded by the CDC is summarized in Table 1. A complete table of Wyoming’s heart attack mortality rates by county can be found in Appendix F.

### Table 1: County Data

<table>
<thead>
<tr>
<th>County</th>
<th>Population Density (Per Square Mile)</th>
<th>AMI Mortality Rate (Per 100,000 Population)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Horn</td>
<td>3.82</td>
<td>97.2</td>
</tr>
<tr>
<td>Hot Springs</td>
<td>2.42</td>
<td>118.8</td>
</tr>
<tr>
<td>Washakie</td>
<td>2.78</td>
<td>159.4</td>
</tr>
<tr>
<td>Wyoming State Average</td>
<td>-</td>
<td>97.5</td>
</tr>
<tr>
<td>Wyoming Frontier Average</td>
<td>-</td>
<td>101.43</td>
</tr>
</tbody>
</table>

### Analytical Framework

Because reperfusion time is associated with changes in mortality and total heart damage during a heart attack, numerous systems have been implemented across the United States to reduce reperfusion time for heart attack patients. While reducing time before treatment is the ultimate goal of STEMI systems of care, this memo will measure the effects of different regional STEMI systems of care on reducing STEMI mortality within 30 days of hospital admission rather than reducing treatment times. The purpose of the distinction between reperfusion time and mortality is two-fold. First, limits in national and state-wide STEMI registries and EMS reporting make consistent measurement of reperfusion time difficult in most regions. Second, a portion of STEMI systems involve the administration of fibrinolytics or other reperfusion agents in the field by emergency medical personnel rather than transport to a hospital for PCI. While this form of treatment is designed to provide reperfusion through intravenous pharmaceuticals and ultimately reduce STEMI mortality, the reduction in reperfusion time cannot be directly compared with systems utilizing PCI because of the varying success rates between fibrinolytic...

\textsuperscript{116} Centers for Disease Control and Prevention, National Center for Health Statistics. Underlying Cause of Death 1999-2012 on CDC WONDER Online Database, 2014.
and PCI reperfusion methods. However, measuring 30-day mortality can effectively capture the relative impact of both types of STEMI intervention systems and provide a means of direct comparison.

Measuring STEMI mortality within 30 days of hospital admission specifically controls for several important variables. 30-day mortality only includes individuals who reach the hospital and conversely excludes patients with severe forms of heart attack, such as the five percent of STEMI patients who experience cardiac rupture, who would be included in total heart attack mortality but would not survive even if treatment was provided. However, due to limitations to STEMI registries and available data, measuring 30-day mortality will also include a number of individuals who arrive to the emergency department without calling 911 and thus will not be affected by some aspects of the proposed interventions. Measuring 30-day mortality also minimizes the variable of patient education about heart attack symptoms that would be more impactful in total reperfusion time. The average heart attack patient waits 120 minutes before calling 911 and 40 percent of patients fail to call 911 either because they are not aware of the symptoms of myocardial infarction or because they do not understand the significance of every minute of ischemia during a heart attack. Finally, measuring patient mortality at one month from hospital admission places value on the total infarction size, and thus co-morbidities, in STEMI survival while also minimizing the effect of unrelated diseases or complications that would influence mortality in a longer time horizon such as one or five years.

Data

The data used for population selection was obtained through the CDC Wonder public health information database. The information provided through this database is limited to the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) codes which

119 Widmer, 2011.
are used to categorize and track diagnoses and mortalities by the WHO\textsuperscript{121}. The ICD-10 codes limit the categorization of all heart attacks as either acute myocardial infarctions or subsequent myocardial infarctions via the I21 and I22 codes and are thus unable to differentiate STEMI from other forms of heart attack\textsuperscript{122}. While the use of ICD-10 prevents the evaluation of STEMI-specific data within Wyoming, the CDC Wonder database provides an important foundation for the assessment of heart attack trends within the state.

**Table 2: ICD-10 Codes for Myocardial Infarction**

<table>
<thead>
<tr>
<th>ICD-10 Code</th>
<th>Sub Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>I21 (Acute Myocardial Infarction)</td>
<td>I21.0</td>
<td>Acute Transmural Myocardial Infarction of Anterior Wall</td>
</tr>
<tr>
<td></td>
<td>I21.1</td>
<td>Acute Transmural Myocardial Infarction of Inferior Wall</td>
</tr>
<tr>
<td></td>
<td>I21.2</td>
<td>Acute Transmural Myocardial Infarction of Other Sites</td>
</tr>
<tr>
<td></td>
<td>I21.3</td>
<td>Acute Transmural Myocardial Infarction of Unspecified Site</td>
</tr>
<tr>
<td></td>
<td>I21.4</td>
<td>Acute Subendocardial Myocardial Infarction</td>
</tr>
<tr>
<td></td>
<td>I21.9</td>
<td>Acute Myocardial Infarction Unspecified</td>
</tr>
<tr>
<td>I22 (Subsequent Myocardial Infarction)</td>
<td>I22.0</td>
<td>Subsequent Myocardial Infarction of Anterior Wall</td>
</tr>
<tr>
<td></td>
<td>I22.1</td>
<td>Subsequent Myocardial Infarction of Inferior Wall</td>
</tr>
<tr>
<td></td>
<td>I22.8</td>
<td>Subsequent Myocardial Infarction of Other Sites</td>
</tr>
<tr>
<td></td>
<td>I22.9</td>
<td>Subsequent Myocardial Infarction of Unspecified Site</td>
</tr>
</tbody>
</table>

The data obtained through the Wonder database was intentionally restricted to individuals aged 35 and older. Almost all American heart attacks between 2007 and 2010 occurred in individuals aged 40 and older with the incidence of heart attack being significant only after the age of 35\textsuperscript{123}. Finally, the data used for population selection includes all Wyoming heart attack mortalities data from 2005 to 2012. This relatively wide range of mortality types and dates was necessary to procure a minimum amount of population mortality data for analysis within the CDC Wonder system for each of Wyoming’s counties, including crude death rates per 100,000 citizens, due to the state’s small total population.


\textsuperscript{122} Ibid.

The projected effects of the proposed solutions on Big Horn, Hot Springs, and Washakie counties is obtained through studies on similar systems in different regions of the United States. Published relationships between reperfusion times, in-hospital mortality, 30-day mortality, and five year mortality are used to convert all study results to 30-day mortality rates for easy comparison. Shadow pricing is utilized to measure the costs and benefits of different aspects of STEMI system provision and mortality reduction in all the proposed solutions.

Criteria for Success

This memorandum will utilize a cost-benefit analysis to evaluate the ability of three proposed interventions to reduce STEMI mortality in northwest Wyoming. Success in this memo will be defined as cost-effective reduction of 30-day STEMI mortality in the context of Big Horn, Hot Springs, and Washakie counties. The analysis will help determine if each individual solution’s impact on STEMI mortality is worth the associated costs to Wyoming hospitals and healthcare consumers. This study will hopefully contribute to the current policy debate surrounding the effectiveness of different STEMI systems of care models in frontier counties with limited healthcare resources.

Proposed Solutions

General Recommendation

Public health officials across the country and even across the world have developed numerous unique STEMI systems of care designed to reduce heart attack mortality. As summarized by the goal of the American Heart Association’s Mission Lifeline, any STEMI system of care implemented in rural Wyoming would be designed to deliver prompt, seamless, and effective medical treatment to STEMI patients\textsuperscript{124}. Additionally, any successful solution to Wyoming’s high STEMI mortality needs to address the financial and organizational realities of rural emergency medicine that limit the capabilities of STEMI

\textsuperscript{124} Learn About Mission Lifeline, n.d.
systems of care. Because the length of cardiac ischemia during a heart attack is positively correlated with total heart damage and one-year mortality, any solution should focus on reducing reperfusion times and limiting total heart damage. This memorandum evaluates three proposed solutions in addition to the current Wyoming emergency medical system at reducing 30-day STEMI mortality in a cost effective manner.

**Proposed Solutions**

As discussed above, Wyoming’s unique geography and low population density create unique public health challenges. Limited medical resources and long distances between hospitals contribute to long reperfusion times for heart attack patients and high STEMI mortality rates. This memorandum proposes possible interventions for improving rural Wyoming’s STEMI mortality rates. All three alternatives are taken from national or international public health systems and are purposed with reducing STEMI mortality in Big Horn, Hot Springs, and Washakie counties. The proposed solutions include: the regionalization of STEMI care with direct routing of patients to PCI-capable hospitals; delivery of patients to a central PCI hospital via air ambulance; and the utilization of fibrinolytic therapy in the field without immediate transport to a hospital. These solutions will be evaluated using cost benefit analysis; comparing their effectiveness at reducing 30-day STEMI mortality in rural Wyoming.

**Status Quo**

Wyoming recently posted the 14th highest heart attack mortality rate in the United States with 97.5 deaths per 100,000 residents between 2005 and 2012. The average mortality rate in Big Horn, Hot Springs, and Washakie counties was 28 percent higher than the state rate of 97.5 deaths per 100,000 population over the same span. The three counties are very rural with an average population density of 3.34 citizens per square mile and provide minimal access to hospital services with only four hospitals

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125 Freeman, Patterson, & Slifkin, 2008.
128 Centers for Disease Control and Prevention, National Center for Health Statistics. Compressed Mortality File 1999-2012 on CDC WONDER Online Database, released October 2014.
129 Ibid.
between the three counties providing a total of 193 hospital beds\textsuperscript{130}. Residents in these counties also have limited access to emergency PCI because none of the local hospitals have cardiac catheterization capabilities; making Sheridan and Casper, Wyoming in neighboring Sheridan and Natrona counties the closest PCI centers\textsuperscript{131}. This is particularly troubling because Wyoming ranks second to last in the United States for average time waited before transport to another facility at 178 minutes\textsuperscript{132}. This places Wyoming among the least-served states for average distance to the nearest hospital as well as access to cardiac catheterization; even by rural standards.

In 2014, the American College of Emergency Physicians rated the national emergency care environment, which includes access to emergency care, quality, patient safety, medical liability, public health strategies, and disaster preparedness, as near-failing with a D+ grade which had decreased from an overall C- grade in 2009\textsuperscript{133}. Even considering the general failure of the emergency care environment throughout the United States, Wyoming still ranks last in the country with the only F grade in emergency medical care\textsuperscript{134}. A major part of this low ranking is due to the rural nature of the state because only 33 percent of the population lives within 60 minutes of a trauma center even though the state is ranked fourth in the nation for total emergency room access\textsuperscript{135}. Additionally, Wyoming struggles in STEMI care because the state lacks a uniform system for pre-arrival, triage, and destination policies for STEMI patients and the government does not provide any funding for quality system improvements or employ a state EMS medical director\textsuperscript{136}. The combination of reduced hospital access due to geography and minimal EMS coordination at the regional or state level is descriptive of Wyoming’s current rank as 14\textsuperscript{th} highest in STEMI mortality in the nation. With age as a significant risk factor for STEMI, the context of an aging

\textsuperscript{130} Hospital Search, 2015.
\textsuperscript{131} Ibid.
\textsuperscript{132} Hirshon et al, 2014.
\textsuperscript{133} Ibid.
\textsuperscript{134} Ibid.
\textsuperscript{135} Ibid.
\textsuperscript{136} Ibid.
American population only promises to exacerbate the severity of heart attack mortality in the state of Wyoming.\textsuperscript{137}

**Recommendation 1: Regionalization of STEMI care with direct routing**

**Model Background**

Despite being the ninth most populated state in the United States, North Carolina faces a significant urban-rural divide with 85 of its 100 counties considered rural based on the 2010 Census\textsuperscript{138}. 80 of these counties have an average population under 250 residents per square mile; however, Hyde county is the only county considered frontier by OMB metrics with 4.1 residents per square mile\textsuperscript{139,140}. The state also has unique geographical features with mountains and national forests throughout the western part of the state\textsuperscript{141}. Coupled with the rising burden of cardiovascular diseases, these features contributed to high STEMI mortality rates which are commonly seen in rural and frontier counties throughout the United States\textsuperscript{142,143}.

In North Carolina, healthcare providers attempted to reduce STEMI mortality by coordinating physicians, hospitals, and EMS on a regional level in a program called Reperfusion of Acute Myocardial Infarction in Carolina Emergency departments or RACE\textsuperscript{144}. The RACE program regionalizes STEMI care and decreases average reperfusion time by designating hospitals throughout the state as either primary PCI, transfer, lytics, or mixed providers and directly routing STEMI patients to PCI facilities when possible\textsuperscript{145} (Figure 9). The system utilizes 21 primary PCI hospitals throughout the state which receive patients from 52 surrounding PCI transfer hospitals and 15 mixed hospitals that transport patients to PCI

\textsuperscript{137} Mozaffarian et al, 2015.
\textsuperscript{139} Ibid.
\textsuperscript{142} Nallamothu et al, 2006.
\textsuperscript{143} Nudell et al, 2013.
hospitals when transportation is available\textsuperscript{146}. Patients located in counties within the mountains or far away from PCI centers who are unable to receive timely PCI are delivered to designated “lytic” hospitals that provide fibrinolytic therapy\textsuperscript{147}.

**Figure 9: North Carolina RACE Design**

Standard EMS destination and treatment plans coordinated through regional EMS directors in all North Carolina counties allows the system to function at a statewide level and decrease reperfusion times for STEMI patients throughout the state\textsuperscript{148}. In fact, the number of STEMI patients who received PCI within the recommended 90 minutes after symptom onset increased from 3.4 percent to 36 percent following the implementation of the RACE program\textsuperscript{149}.

**Wyoming Context**

In Wyoming, the greatest obstacle to adequate STEMI care is also long reperfusion times and limited health resources. Although Wyoming currently lacks a state EMS medical director or uniform STEMI

\textsuperscript{146} Ibid.
\textsuperscript{147} Ibid.
protocols, the state could coordinate its thirty hospitals with emergency departments in a similar fashion to North Carolina by designating different hospitals as PCI, transfer, or lytics hospitals. However, successful coordination of Wyoming’s hospitals would require a number of significant organizational changes. All hospitals would first need to devise and accept a uniform set of protocols for transfer or treatment of STEMI patients.

In PCI hospitals, this would involve pre-ambulance arrival emergency department protocols, post-ambulance arrival rapid evaluation protocols, and CCL transfer protocols. In non-PCI hospitals, necessary protocols would include rapid evaluation of potential STEMI patients by emergency department staff and streamlined transfer procedures to the nearest PCI receiving center. The state of Wyoming began this process in 2011 through the establishment of statute 35-2-101 which provides for the designation of state stroke and receiving centers and many hospitals have since achieved Mission Lifeline accreditation based on their individual protocols. However, hospital designation and protocols would still need to be universalized for a regionalization program to be established.

Although the majority of ambulances nationwide are currently equipped with 12-lead EKG technology, providing additional training to emergency medical technicians (EMTs) to ensure accurate and reliable EKG results is important for diagnosis of STEMI in the field so that patients can be directly routed to PCI-capable hospitals. Despite studies by the Journal of Emergency Medical Services estimating that 90 percent of ambulances surrounding the 200 largest cities in the United States carry EKG equipment, it is well documented that the overwhelming majority of chest pain patients do not have an

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150 Hospital Search, 2015.
151 An example of a universal protocol can be found in appendix A
EKG obtained. Lack of training may explain why fewer than 10 percent of EMS patients have a pre-hospital EKG obtained.

In North Carolina, the RACE program benefits from a coordinated emergency call center that provides a rapid relay of EMS routing information to PCI, transfer, or lytics hospitals based on the ambulances’ location. A similar system would be necessary in Wyoming to implement an effective regionalization system. Finally, the majority, if not all, of the hospitals in Wyoming would need to agree upon hospital designations and cooperate with the regionalization structure to minimize reperfusion times through the proper routing of STEMI patients.

County Implementation

In the context of Big Horn, Hot Springs, and Washakie counties, the regionalization of STEMI care would involve the designation of Sheridan Memorial Hospital in neighboring Sheridan County as a STEMI receiving center because it is the closest hospital with established PCI capabilities. Although Sheridan Memorial Hospital might prove convenient for EMS agencies operating in the northern half of Big Horn County, the hospital is simply too far away from Washakie and Hot Springs counties and poses too many transportation complications due to significant elevation changes along its western border to provide timely surgical intervention for STEMI patients. Therefore, Washakie Medical Center in Worland, Wyoming, would also be designated a PCI receiving center and would require the establishment of a CCL to provide PCI services to patients living in Washakie, Hot Springs, and southern Big Horn counties.

157 Map Locator and Downloader, 2012.
Washakie Medical Center was chosen as a PCI receiving center due to its high emergency room traffic, central location between the three counties, and relatively high capacity for medical services. North Big Horn Hospital District, South Big Horn County Hospital, and Hot Springs Memorial Hospital would act as transferring hospitals due to their lack of cardiac catheterization capabilities. These hospitals were chosen to be PCI transferring hospitals due to their relatively limited service capacity and the high cost of establishing and staffing a new cardiac catheterization lab. North Big Horn Hospital District, despite being the largest hospital in the three-county region with 100 beds and a greater number of medical staff, was not chosen as a PCI receiving center due to its geographic location in northern Big Horn County far away from Washakie and Hot Springs Counties. In total, the regionalization of STEMI care to reduce reperfusion time in these three counties is visualized in Figure 10.

**Figure 10: Suggested Regionalization of STEMI Care**

*Potential Outcomes*

Regionalization of STEMI care in Big Horn, Hot Springs, and Washakie counties based on the North Carolina RACE model would be effective if it increased the number of patients who receive PCI during

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158 Hospital Search, 2015.
STEMI and reduced the average reperfusion time for patients presenting to hospitals within the region. Nationwide, an average of 70 percent of STEMI patients receive PCI or other reperfusion therapies but only 40 percent of those receiving treatment get it within the recommended 90 minutes following symptom onset\textsuperscript{159}. In North Carolina, despite its geographical challenges, the RACE program was able to increase the number of patients receiving PCI within 90 minutes from 3.4 percent to 36 percent in the first year\textsuperscript{160}. It is possible for a similar program to be effective in Wyoming where the rural profile of the state is also the major barrier to timely STEMI treatment\textsuperscript{161}.

However, it is also possible for the regionalization of STEMI care in northwest Wyoming to fail to reduce average reperfusion times within the region. It is clear that the North Carolina RACE program benefits from the large number of hospitals participating in the regionalization system. The RACE program integrates 119 participating hospitals into its system across the 53,819 square mile area of North Carolina; whereas Wyoming possesses a total of 30 hospitals across an area nearly two times as large at 97,818 square miles\textsuperscript{162,163}. Not only does this reduce the quantity of advanced medical technology available to Wyoming citizens but it also produces significant travel times from both homes to hospitals and between hospitals. Longer travel times directly to PCI receiving centers or from PCI transferring hospitals to PCI receiving hospitals might reduce Wyoming’s improvements in PCI treatment rates and reperfusion times compared to the results observed in North Carolina. Finally, competition between hospitals and physician groups could preclude the establishment of a coordinated STEMI routing system based on complicated transfer protocols, ambiguous leadership roles and responsibilities, and prioritization of reimbursement over cooperation\textsuperscript{164}.

\textsuperscript{159} Messenger, 2014.
\textsuperscript{160} Studnek et al, 2010.
\textsuperscript{161} Langabeer, 2013.
\textsuperscript{162} State and County Quick Facts, 2014.
\textsuperscript{163} Reperfusion of Acute Myocardial Infarction in Carolina Emergency Departments - Emergency Response (RACE-ER) Project. (n.d.).
\textsuperscript{164} Jollis et al, 2006.
**Recommendation 2: Wheel-and-Spoke Air Transport Model**

Another STEMI system model is the wheel-and-spoke transfer system implemented in central and southern Illinois. In the rural regions surrounding Springfield and Carbondale, Illinois, a group called Prairie Cardiovascular established a system to “meet the goal of providing [PCI] within 90 to 120 minutes from a patient’s arrival at the community hospital”\(^{165}\). The system initially involved six rural hospitals clustered around Springfield, designated as STEMI referral centers, and two hospitals within the city that were designated the STEMI receiving centers\(^{166}\). The hospitals developed universal STEMI protocols that minimized the delivery time of STEMI patients to the referral hospitals and then accelerated their transfer via air or ground ambulance to a waiting team of cardiologists for PCI\(^ {167}\).

Illinois’ unique population distribution with numerous concentrated population centers of 50,000 or more residents surrounded by vast regions of rural lands (Figure 11) was foundational to the establishment of the Prairie Stat Heart wheel-and-spoke model of STEMI patient care. Prairie Cardiovascular was able take advantage of the advanced surgical resources and superior staff capabilities of St. John’s Hospital and Memorial Medical Center in Springfield and Memorial Hospital of Carbondale that are not available in the surrounding rural counties\(^ {168}\). The PCI receiving hospitals were teaching hospitals with inpatient capabilities capable of performing 2,500-3,500 PCI operations each year\(^ {169}\). The model then incorporated 31 smaller hospitals with long-standing referral relationships throughout rural Illinois that were incapable of performing PCI but were close enough to Springfield or Carbondale to allow timely transport by air ambulance, or occasionally ground ambulance, to the PCI-capable hospitals\(^ {170}\).

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\(^{165}\) Prairie Stat Heart. (2010).

\(^{166}\) Ibid.


\(^{168}\) Hospital Search, 2015.

\(^{169}\) Agguire *et al.*, 2008.

\(^{170}\) Prairie Stat Heart, 2010.
Similar to the North Carolina RACE model, the Prairie Stat Heart program utilizes pre-hospital EKG data collected by EMS personnel in the field to activate protocols in both the transferring and receiving hospitals. After receiving a suspected STEMI EKG from EMS, an emergency physician at a transfer hospital activates the CCL at the associated PCI receiving hospital by calling a central operator via a dedicated phone line that is available on a 24 hour a day, seven day a week basis. Protocols within the transfer hospital streamline the transfer of STEMI patients to the PCI receiving centers by reducing time spent in the transferring hospital’s emergency department and providing air transport for all patients who would otherwise experience a >40 minute transit time by ground ambulance. When immediate transfer to a PCI hospital is not available, patients receive fibrinolytic therapy and are transported to a PCI hospital as soon as possible in case rescue PCI is needed. Cardiac catheterization laboratory staff is available within twenty minutes of the call from the transferring hospital and are ready to perform PCI as soon as a patient reaches the PCI receiving center. In total, this program achieved PCI in less than 90 minutes from first emergency department contact for 12.2 percent of all patients and treatment in less than 120 minutes for 58 percent of patients with no adverse clinical events occurring due to transport.

Figure 11: Illinois Population Distribution

171 Agguire et al., 2008.
172 Ibid.
174 Ibid.
175 Ibid.
Figure 12: Prairie Stat Heart Map

Wyoming Context

As discussed throughout this memorandum, one of the greatest barriers to effective STEMI care in Wyoming is the limited access to healthcare services due to long distances between hospitals. The Prairie Stat Heart wheel-and-spoke model presents an opportunity to overcome these geographical barriers by providing a means for rapid transfer to surgical resources in a rural region. Wyoming only has two cities large enough to qualify their respective counties as urban and the majority of its advanced hospital resources are distributed within these two regions\textsuperscript{176}. Accordingly, two of the state’s three PCI centers are located within the cities of Casper and Cheyenne and their respective Wyoming Medical Center and Cheyenne Regional Medical Center together have more than double the hospital beds than all of the hospitals in Big Horn, Hot Springs, and Washakie counties combined\textsuperscript{177}. The establishment of a Prairie Stat Heart style STEMI system in Wyoming would involve extensive coordination with these large hospitals.

\textsuperscript{176} Wyoming Rural Definitions, n.d.
\textsuperscript{177} Hospital Search, 2015.
In addition to establishing referral relationships with the state’s large hospitals, small transporting hospitals would also need to develop universal protocols for the evaluation and transport of STEMI patients once they reach the emergency department. Streamlining STEMI patient transport from a small emergency room begins with reliable EKG testing in the field by EMS and consistent communication between the PCI transferring and receiving centers. Once a patient reaches a transferring hospital, transportation services in the form of ground or air ambulances are needed to deliver the patient to the PCI center. Although the operation of an air ambulance is expensive compared with a ground ambulance, the long distances between Wyoming hospitals would necessitate air transportation between PCI transferring and receiving hospitals.

**County Implementation**

Due to proximity, the hospitals in Big Horn, Hot Springs, and Washakie counties could utilize the PCI facilities of Wyoming Medical Center in Casper, Wyoming. Wyoming Medical Center is one of the largest hospitals in the state of Wyoming and has the capacity to provide surgical services that are not available in most small hospitals.\(^{178}\) The long distances, sparse population, and long ground transport times associated with EMS transport in these rural counties also favors the use of helicopter ambulances for rapid delivery of STEMI patients to PCI centers.\(^{179}\) Helicopter ambulance transportation is known to be expensive, with airlift costs ranging between $5,000 and $10,000; however, the number of helicopter ambulances in the United States has been rising at fast pace.\(^{180}\) Cost aside, helicopter ambulances provide faster transport than ground ambulances over long distances and can conservatively service a 100 mile radius; although other estimates suggest a 200 mile radius is possible.\(^{181,182}\) This combination of rapid transit and long range makes helicopter ambulances desirable in Northwest Wyoming due to the sparsely

\(^{178}\) Ibid.
\(^{181}\) Ibid.
\(^{182}\) Ibid.
populated, large, land area and the small number of hospitals.

Figure 13: Wyoming Wheel-and-Spoke Design

However, implementation of a coordinated helicopter STEMI transport system in Big Horn, Hot Springs, and Washakie counties would require the hospitals to establish expensive contracts with helicopter EMS providers that cover the long distances between the small county hospitals and Wyoming Medical Center in Casper on a 24/7 basis. Wyoming Medical Center would also need to contract additional cardiac catheterization personnel that would handle the increased STEMI traffic at all hours of the day.

Potential Outcomes

In total, a coordinated helicopter-based EMS transport system for STEMI patients in rural Wyoming is desirable due to the geographic challenges associated with rural emergency medicine. If implemented successfully, Northwest Wyoming could experience an increase in the rate of PCI and a significant reduction in reperfusion times for STEMI patients. A similar improvement in reperfusion rates as seen with the Prairie Stat Heart program would result in an 84 percent reduction in STEMI mortality.\(^{183,184}\)

\(^{183}\) Berger, P. B., Ellis, S. G., Holmes, D. R., Granger, C. B., Criger, D. A., et al. (1999). Relationship Between Delay in Performing Direct Coronary Angioplasty and Early Clinical Outcome in Patients With Acute Myocardial Infarction Results From
However, it is likely that STEMI patients in Wyoming would realize a smaller gain in mortality reduction due to the long average transport times from the location of symptom onset to the primary emergency facility for helicopter transport. A more realistic outcome of helicopter EMS program would be a 42 percent reduction.

There are also potential scenarios for failure of a Prairie Stat Heart model system. The Prairie Stat Heart system benefits from its access to large teaching hospitals with high capacity for additional PCI procedures. Wyoming, on the other hand, may have difficulty obtaining the additional staff and resources necessary to establish a high-volume PCI center because the state has a very low per capita rate of specialist physicians and minimal investment in cardiac catheterization capabilities throughout the state. The establishment of expensive helicopter EMS contracts might also represent a barrier to successful implementation of the Prairie Stat Heart model in a state where ground EMS is already underfunded with no assistance from the state government. Finally, the greatest logistical barrier to a wheel-and-spoke transfer model is the complication of multiple medical insurance providers within the state. In Illinois, the Prairie Stat Heart network negotiated inter-institutional policies that permitted rapid patient transfer regardless of insurance carrier, hospital volume, or the time of day. The hospitals in Big Horn, Hot Springs, and Washakie counties are currently run by two different healthcare networks which may prove problematic in implementing a coordinated wheel-and-spoke transfer model to Wyoming Medical Center in Casper if similar inter-institutional arrangements are not created.

**Recommendation 3: Field Fibrinolytics with Rescue PCI Model**

**Model Background**

Although PCI remains the preferred method of STEMI treatment by most medical professionals due to its high efficacy at restoring blood flow to the heart and its associated low risk of complication,

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184 Agguire et al., 2008.
185 Hospital Search, 2015.
186 Hirshon et al., 2014.
187 Agguire et al., 2008
fibrinolytic therapy remains a viable treatment option especially when a patient cannot reach a PCI-capable hospital within two hours of symptom onset\textsuperscript{188,189}. Fibrinolytic therapy represents the intravenous administration of clot-breaking drugs designed to dissolve the blockage in the coronary arteries that is causing a heart attack. The standard procedure for fibrinolytic therapy in the case of STEMI involves intravenous administration of the clot-breaking drugs in a non-PCI capable emergency department followed by patient transfer to a PCI-capable facility for immediate cardiac catheterization if the therapy fails to completely remove the blockage or for non-emergent angioplasty to determine if additional surgical intervention is needed\textsuperscript{190,191}. Although it is estimated that roughly 30 percent of all patients receiving fibrinolytic therapy will require rescue PCI to resolve their blockage, fibrinolytic therapy remains desirable in rural areas because it can be administered in the field or at non-PCI hospitals and provides additional time to transfer patients the long distances to PCI hospitals by initiating a minimal level of treatment prior to transport\textsuperscript{192}. However, it should be noted that fibrinolytic therapy carries an increased risk of complications including bleeding in the brain, rupture of major arteries, and increased platelet activation which precludes treatment for roughly 20 to 30 percent of STEMI patients\textsuperscript{193,194}.

Despite the increased risk of complication among STEMI, fibrinolytic therapy has proven effective in many regions across the globe including France where the treatment of heart attacks is recorded in French Registry of Acute ST-elevation or non-ST elevation Myocardial Infarction or FAST-MI. In an attempt to evaluate the real world management of patients with acute MI, the FAST-MI database showed that patients receiving pre-hospital fibrinolytic therapy rather than in-hospital PCI exhibited lower 30-day mortality rates (2.1%) and lower 5-year mortality rates (12%) compared to their

\textsuperscript{188} Grines, Serruys, and O’Neill, 2003.
\textsuperscript{192} ElGuindy, 2014.
\textsuperscript{193} Ibid.
\textsuperscript{194} Stys, 2010.
PCI counterparts (3.1% and 16% respectively\textsuperscript{195,196}. The success of pre-hospital fibrinolytics is partially associated with the presence of physicians on ambulance teams who were able to expedite the STEMI diagnosis, especially in the case of atypical symptomatic presentations, and provide initial evaluation for fibrinolytic therapy candidacy based on patient risk factors\textsuperscript{197}. It is also important to note that the average age of STEMI patients within the FAST-MI had decreased within the study years which reduced the total number of patients unable to receive fibrinolytic therapy; although elderly patients were still least likely to receive fibrinolytic therapy\textsuperscript{198}. However, the model of dispatching physicians in ambulances to provide rapid fibrinolytic therapy to potential STEMI patients remains an attractive option for rural healthcare services because it significantly reduces the variable of travel time by delivering initial treatment to the patient in the ambulance and increasing the timeframe for transfer to a PCI receiving center if necessary.

**Wyoming Context**

Because only 33 percent of Wyoming’s population lives within 60 minutes of a hospital, the implementation of a coordinated pre-hospital fibrinolytic therapy system could provide significantly better treatment for patients living in highly rural areas\textsuperscript{199}. However, the risks and contraindications of fibrinolytic therapy would require a physician to evaluate STEMI patients in the field before they could receive intravenous intervention. In theory, Wyoming could assign a number of emergency physicians to dispatch with EMS ambulances on chest pain and other STEMI-related calls in order to provide the necessary evaluation before fibrinolytic therapy is administered. STEMI patients would then be evaluated in the nearest emergency department and transferred to a PCI receiving center for additional treatment within three hours if necessary.

\textsuperscript{195} ElGuindy, 2014.
\textsuperscript{196} Danchin, N., & Crea, F. (2012, August). *FAST-MI Programme: Decrease in early mortality in STEMI is related to changing patient profile and behavior, as well as improved organization of care: Data from 4 French nationwide surveys over 15 years.* Presentation presented at the Acute Coronary Syndromes, European Society of Cardiology.
\textsuperscript{198} Danchin and Crea, 2012.
\textsuperscript{199} Hirshon et al, 2014.
County Implementation

In Big Horn, Hot Spring, and Washakie counties, the implementation of a field fibrinolytics program would require new contracts with EMS agencies to allow physicians to ride in ambulances, additional emergency medicine physicians to accompany EMS, and establishment of patient transfer contracts with either Wyoming Medical Center in Casper or Sheridan Memorial Hospital in Sheridan for PCI services.

Potential Outcomes

If effective, a field fibrinolytics program has the potential to reduce 30-day STEMI mortality by nearly 75 percent based on the results seen in France\textsuperscript{200}. However, roughly 20 to 30 percent of STEMI patients would be unable to utilize the new system, due to medical complications that would prevent the use of fibrinolytic therapy, and would receive the reduced level of care currently observed in highly rural areas\textsuperscript{201}.

Although the implementation of a field fibrinolytics program might be desirable in rural regions based on the presence of significant geographic and resource barriers, the consideration of a similar program in Wyoming is not included in the cost-benefit analysis portion of this memorandum due to potential legal and legislative barriers that cannot be solved in the context of northwest Wyoming in a timely manner. The utilization of triage lesion physicians and pre-hospital ambulance-based physicians are anecdotally present in a small number of EMS agencies throughout the United States; however, these agencies required significant, individualized, insurance policy changes for even small patient care changes\textsuperscript{202}.

\textsuperscript{200} Danchin and Crea, 2012.
\textsuperscript{201} Stys, T. (Lecturer) (2010, November 4).
Cost-Benefit Analysis

General Approach and Implementation Timeframe

The purpose of the cost-benefit analysis is to evaluate the financial effectiveness of two different STEMI systems of care models implemented in North Carolina and Illinois at reducing 30-day STEMI mortality in the context of rural northwest Wyoming. Adjustments are made to apply the costs and benefits from the comparison systems to the geography, population, and resources of frontier Wyoming. These adjustments will allow for a more accurate comparison of STEMI system effectiveness at reducing 30-day mortality in the subject region of Big Horn, Hot Springs, and Washakie counties.

Because the focus of this memorandum is the reduction of 30-day STEMI mortality, the costs and benefits listed in this analysis are limited to those directly related to heart attack deaths. Studies assessing the outcomes of the proposed intervention models were used to estimate the outcomes of similar programs if they were implemented in Wyoming. Although these studies varied in methods and measurements, additional studies were utilized to convert all results to 30-day STEMI mortality data. Total costs are estimated based on average hospitalization costs for patients who die or survive STEMI and the additional costs of healthcare resources necessary to provide each STEMI program such as ambulance use, cardiac catheterization laboratory supplies and staffing, and additional emergency physician salaries. Total benefits are estimated using the value of a statistical life after heart attack survival and expenditure reductions for hospitals.

The timeframe for implementation of all the proposed interventions in northwest Wyoming is set at one year. Studies involving the model interventions reported results as early as one month following implementation and were both recorded within the first year. A similar timeframe for results is expected in the studied counties due to the minimal capital changes necessary for total implementation of each intervention.
Stakeholders in STEMI Care

The costs and benefits outlined in this analysis are presented in relation to Wyoming healthcare providers and STEMI patients. The healthcare providers category includes physicians, hospitals, and EMS agencies. The STEMI patients category comprises the value of a statistical life saved from a heart attack and direct costs imposed on consumers of healthcare resources. While this distinction helps to delineate immediate costs and benefits to healthcare providers and patients in terms of intervention implementation, the division of stakeholders in this case is arbitrary because costs sustained by hospitals or EMS providers are ultimately transferred back to healthcare consumers in the form of increased health insurance premiums, various consumer cost sharing methods, and direct patient billing\textsuperscript{203}. However, the division of stakeholders serves the purpose of this memorandum by presenting the origin of costs and benefits involved in STEMI care.

In general, states have a direct financial stake in the survival of STEMI patients in terms of tax revenue. However, the state of Wyoming is not included in this analysis because the state does not levy any income tax on its citizens. Other taxes, such as property tax, are also omitted from this study because their variability within the population and their potential relationship to STEMI patients is beyond the scope of this analysis.

Cost-Benefit Analysis Methodology

The total number of STEMI in Big Horn, Hot Springs, and Washakie counties was estimated based on population estimates from the United States Census Bureau, heart attack mortality data from the United States Centers of Disease Control and Prevention, and national STEMI incidence rates from the National Institutes of Health. Expected STEMI hospitalization numbers were calculated after controlling for occurrence of instantly fatal heart attacks and average dead-on-arrival heart attack patients in Wyoming between 2005 and 2012. The cost of hospitalization for both STEMI mortalities and survivors was estimated using national average costs of STEMI hospitalizations based on outcome which was

\textsuperscript{203} Additional information on modern consumer cost sharing in healthcare is exhibited in Appendix G.
adjusted to reflect higher average medical costs in rural areas. Finally, the value of a statistical life saved from a fatal heart attack was assigned based on the United States Food and Drug Administration’s estimation for heart attack survival which projects an average of 13 years of life gained from a fatal heart attack averted discounted at 7 percent for the reduction in quality over the additional years saved. Additional personnel, service, and equipment costs of STEMI care related to each specific intervention were calculated based on current literature and adjusted for rural area application if necessary.

All costs and benefits were estimated based on the projected STEMI incidence, hospitalizations, and patient outcomes as outlined in the status quo. These numbers were adjusted for changes in STEMI outcomes for each proposed alternative based on previous studies on the original models that were adapted to the context of rural Wyoming.

**Cost and Benefit Discounting and Price Inflation**

This cost-benefit analysis will not discount any of its values or utilize a significant time horizon within the analysis because all of the original proposed alternatives were implemented and produced benefits within one year. Additionally, the proposed interventions require minimal capital investment in terms of new equipment, training, or design and each system is projected to reach its projected level of benefit immediately after implementation.

Additionally, all prices utilized in this analysis are inflated to 2015 values using the United States Department of Labor’s CPI inflation calculator as published by the Bureau of Labor Statistics. This allows for effective comparison of costs and benefits between the proposed interventions.

**Cost-Benefit Matrix and Discussion**

The matrix below (Table 3) represents the quantification of the cost and benefit inputs listed above as well as the sums of the costs and benefits for each proposed intervention. The Net Present Costs are subtracted from the Net Present Benefits to realize the Net Present Value for each intervention as shown at the bottom of the matrix. The alternative with the highest net present value represents the greatest collective benefit for Wyoming stakeholders in relation to associated costs. The second
alternative is presented in two different columns, one labeled high estimate and one labeled low estimate, to account for variation in helicopter ambulance prices and implementation strategies. The high estimate quantifies implementation costs observed in the Prairie Stat Heart model of rural Illinois and the low estimate represents a resource-reduction model that utilizes fewer helicopters with diminished capabilities. Additional information regarding the creation of the cost-benefit analysis, including inputs, sources, and calculations, is available in Appendix H.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frontier STEMI Patients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value of statistical life for fatal heart attacks prevented</td>
<td>$20,128,596</td>
<td>$22,953,662</td>
<td>$26,484,994</td>
<td>$26,484,994</td>
<td>$22,953,662</td>
</tr>
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<td><strong>Healthcare Providers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs saved by STEMI survival vs mortality</td>
<td>$130,460</td>
<td>$148,771</td>
<td>$171,659</td>
<td>$171,659</td>
<td>$148,771</td>
</tr>
<tr>
<td>Total Benefits</td>
<td>$20,259,056</td>
<td>$23,102,432</td>
<td>$26,656,653</td>
<td>$26,656,653</td>
<td>$23,102,432</td>
</tr>
<tr>
<td><strong>Frontier STEMI Patients</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average cost of frontier land ambulance use</td>
<td>$10,315</td>
<td>$17,752</td>
<td>$10,540</td>
<td>$10,540</td>
<td>$12,912</td>
</tr>
<tr>
<td>Average cost of frontier air ambulance use</td>
<td>$229,321</td>
<td>$229,321</td>
<td>$229,321</td>
<td>$229,321</td>
<td>$229,321</td>
</tr>
<tr>
<td>Medical cost of STEMI survival</td>
<td>$508,476</td>
<td>$582,814</td>
<td>$672,477</td>
<td>$672,477</td>
<td>$582,814</td>
</tr>
<tr>
<td>Cost of PCI</td>
<td>$435,965</td>
<td>$390,074</td>
<td>$390,074</td>
<td>$390,074</td>
<td>$98,092</td>
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<td><strong>Healthcare Providers</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average cost of STEMI mortality</td>
<td>$271,465</td>
<td>$210,576</td>
<td>$142,876</td>
<td>$142,876</td>
<td>$214,315</td>
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<tr>
<td>Average cost of STEMI survival</td>
<td>$276,737</td>
<td>$315,578</td>
<td>$364,128</td>
<td>$364,128</td>
<td>$315,578</td>
</tr>
<tr>
<td>Outfitting air EMS</td>
<td>$1,912,341</td>
<td>$598,985</td>
<td>$2,987,385</td>
<td>$2,987,385</td>
<td>$598,985</td>
</tr>
<tr>
<td>Operating air EMS</td>
<td>$5,974,770</td>
<td>$653,258</td>
<td>$5,974,770</td>
<td>$653,258</td>
<td>$5,974,770</td>
</tr>
<tr>
<td>PCI equipment</td>
<td>$2,613,033</td>
<td>$653,258</td>
<td>$2,613,033</td>
<td>$653,258</td>
<td>$2,613,033</td>
</tr>
<tr>
<td>EMS EKG equipment</td>
<td>$6,408</td>
<td>$6,408</td>
<td>$6,408</td>
<td>$6,408</td>
<td>$6,408</td>
</tr>
<tr>
<td>EMS EKG training</td>
<td>$11,700</td>
<td>$11,700</td>
<td>$11,700</td>
<td>$11,700</td>
<td>$11,700</td>
</tr>
<tr>
<td>Ambulance Physician Salary</td>
<td>$3,847,716</td>
<td>$3,847,716</td>
<td>$3,847,716</td>
<td>$3,847,716</td>
<td>$3,847,716</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td>$1,066,994</td>
<td>$4,193,826</td>
<td>$10,367,895</td>
<td>$6,067,154</td>
<td>$5,089,534</td>
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<tr>
<td><strong>Net Present Value</strong></td>
<td>$19,192,062</td>
<td>$18,908,606</td>
<td>$16,288,758</td>
<td>$20,589,499</td>
<td>$18,012,898</td>
</tr>
</tbody>
</table>

Due to the relatively high value of a life saved from a heart attack in comparison to hospitalization and implementation costs, the net present values of every alternative, including the status quo, are found to be positive. No alternative is able to completely eliminate STEMI mortality in northwest
Wyoming due to the severe acute nature of heart attack; however, annual projected STEMI deaths range from eight under the status quo to four under the wheel-and-spoke model of alternative two. The low-cost wheel-and-spoke model intervention returns the highest net present value and is the only intervention with a net present value higher than the status quo. The high-cost estimate for alternative two has the highest implementation cost due to the greater amount of capital investment, including four helicopters and their associated crews, that is required to provide routine air transport from Big Horn, Hot Springs, and Washakie counties to Casper, Wyoming. By reducing these capital investment costs, the low-estimate wheel-and-spoke model obtains the only net present value that is significantly higher than the status quo. However, these capital reductions would likely be associated with a change in total outcome that is assessed in the following sensitivity analysis.

**Sensitivity Analysis and Discussion**

In order to consider the impacts of underlying variables that are not accounted for in the cost-benefit analysis, a sensitivity analysis was performed to more thoroughly evaluate the projected outcomes of the low-cost wheel-and-spoke model alternative. Time between onset and treatment is the key determinant in the outcome of STEMI treatment and Wyoming’s unique geography in terms of land area and population density makes the direct application of STEMI system results from other regions of the United States imprudent. Because the value of lives saved is the driving force of the cost-benefit analysis by means of its relative magnitude to other costs and benefits, additional high and low projections on STEMI mortality rates following implementation of the low-cost wheel-and-spoke model were conducted.

The predicted value shown in the sensitivity analysis represents the projected net present value of the low-cost alternative two listed in the original cost-benefit analysis matrix. This value accounts for the low population density and limited healthcare resources of Wyoming by projecting a two times higher mortality rate compared to the results accomplished in Illinois. The sensitivity analysis adds additional high and low projections for STEMI mortality to account for other possible translational changes. The
best case scenario represents values based on STEMI mortality rates that are identical to the Illinois values. While this may not seem like a best case scenario, Illinois started their program with a base STEMI mortality rate of 14 percent compared to a base rate of roughly 40 percent in Wyoming. Finally, the worst case scenario attempts to capture the effects of increased driving times to hospitals and the reduction of system resources compared to the Illinois model. The resources outlined in the low-cost wheel-and-spoke alternative, while appropriate for Wyoming’s low total healthcare spending and low STEMI volume, could lead to increased wait times for patients being transported to the central cardiac catheterization hub in Casper due to a reduced number of helicopters and the limited helicopter capabilities associated with cheaper models. Coupled with long driving times, these potential delays could lead to increased mortality rates compared to the average calculation. The results of the sensitivity analysis are outlined in Table 4.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Net Present Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best-Case</td>
<td>$22,378,053</td>
</tr>
<tr>
<td>Predicted</td>
<td>$20,589,499</td>
</tr>
<tr>
<td>Worst-Case</td>
<td>$18,800,945</td>
</tr>
<tr>
<td>Status Quo</td>
<td>$19,192,062</td>
</tr>
</tbody>
</table>

**International Comparison: Fibrinolytic Therapy in France**

As mentioned in the proposed solutions, several European countries, such as France, improve their STEMI systems of care by placing physicians in their ambulances. Physicians are able to evaluate a patient’s candidacy for fibrinolytic therapy and administer treatment in the field by weighing the risk of negative side effects based on the patient’s medical history. By administering intravenous clot-breaking therapy.
pharmaceuticals in ambulances, the French healthcare system produced a significant drop in STEMI mortality that was in many ways more effective than routing patients to the nearest hospital for PCI\textsuperscript{206}.

If similar results were achieved in Wyoming, STEMI patients would see a 25 percent reduction in heart attack mortality and a net present value of $18.1 million in a rural context. However, the quantification of many costs and benefits for a field fibrinolytics model are only speculative because no model system for pre-hospital physician care exists for comparison in the United States. There are many legal issues surrounding the provision of pre-hospital care and the resulting compensation for medical providers that have not yet been determined and could significantly affect the financial reality of pre-hospital fibrinolytic therapy in the United States. An estimated cost-benefit matrix for the implementation of a field fibrinolytic program in northwest Wyoming is available in Appendix J.

**Cost-Benefit Analysis Assumptions and Limitations**

- **CBA Methods:** This memorandum utilizes an ex-ante cost-benefit analysis and therefore uses results and estimations from past studies to project the outcomes of programs that have not yet been implemented in the context of northwest Wyoming. The use of this system requires significant assumptions that similar programs and studies can be directly translated to the local characteristics of the study area.

- **Data Limitations:** The projection of STEMI mortality and survival in this study is limited by the available mortality data. STEMI incidence and mortality were inferred from total myocardial infarction data provided by the United States Centers for Disease Control and Prevention because state or county STEMI registries are not available in the study area.

- **STEMI Incidence:** This cost-benefit analysis assumes that the incidence rate of STEMI in Big Horn, Hot Springs, and Washakie counties is similar to the United States average STEMI incidence rate of 77 STEMI per 100,000 persons per year.

- **STEMI Mortality:** This cost-benefit analysis also assumes that the STEMI mortality rate in Wyoming is twice the national average of 20 percent due to the state’s limited healthcare resources, geographic challenges, and total heart attack mortality rate near 50 percent.

- **Walk-In Patients:** The current analysis does not correct for STEMI patients who present to the emergency department as walk-ins rather than through EMS. While this form of

\textsuperscript{206}Danchin and Crea, 2012.
current data are limited in their capacity to differentiate patient presentation in Wyoming and it is assumed that the severe nature of STEMI with its total occlusion of the coronary artery would necessitate the overwhelming majority of patients to call EMS for transport rather than transporting themselves.

- **Patient Education:** Nationally, it is estimated that 40 percent of heart attack patients fail to call 911 or present to a hospital due to a variety of reasons. This cost-benefit analysis is limited because it does not control for patient education and willingness to call EMS during STEMI. There is currently no data available on the percentage of STEMI patients who fail to call EMS but it is assumed that the majority of STEMI patients seek care due to the severe and acute nature of the event.

- **Geography Impacts:** Although the majority of inputs in this analysis are adjusted for rural regions, this memo must assume that Wyoming’s specific geography and population distribution do not significantly alter projected results based on other rural and frontier studies.

- **Healthcare Costs:** The cost-benefit analysis assumes that healthcare costs in the state of Wyoming are similar to costs in other rural regions of the United States.

- **EMS Resources:** EMS data are limited in this analysis. This memorandum assumes that EMS resources are similar to their 2002 levels because this was the last year of quantification. Projecting changes in EMS resources to present day is beyond the scope of this memorandum.

- **EKG Resources:** 90 percent of EMS agencies surrounding the United States’ 200 largest cities were found to have 12-lead EKG capacity in 2006. In order to control for a reduction in healthcare resources in rural settings, this analysis assumes that only 80 percent of ambulances carry EKG equipment in the study area.

- **Secondary Effects:** This cost-benefit analysis does not attempt to capture any secondary economic impacts of the proposed solutions. There may be positive and negative spill-over effects of resource utilization, job creation, and mortality reduction in the study area that are beyond the scope of this analysis.
Strategic Recommendation

As mentioned throughout this memorandum, time between the onset of STEMI and treatment to restore blood flow is the most important factor in determining both the likelihood of mortality and the extent of permanent damage from a heart attack\textsuperscript{207,208,209}. Wyoming’s unique combination of population and size makes achieving low standard reperfusion times for all of its rural and frontier inhabitants a significant task for public health experts and government officials. This memorandum has attempted a complete and unbiased evaluation of the translation of established rural STEMI systems of care to the context of northwest Wyoming. The information provided throughout this analysis is limited in its use and application due to data constraints and translational assumptions; however, it can still provide valuable insight into the current debate of heart attack care in very rural settings.

Cost-benefit analysis of the current healthcare profile and two proposed STEMI system models was provided for Big Horn, Hot Springs, and Washakie counties. The analysis was limited to estimated cost and benefit impacts of reductions in 30-day STEMI mortality on county citizens and healthcare providers and should not be extrapolated beyond this context. By quantifying the costs of healthcare service provision and the benefits of mortality reduction, the cost-benefit analysis suggests that a low-cost implementation of an air EMS wheel-and-spoke model would yield the highest net present value for patients and healthcare providers in northwest Wyoming. This is the only alternative that yields a net present value greater than the status quo quantification which would involve no changes to the current healthcare infrastructure within the study area.

Despite the greater net present value determined for the low-cost wheel-and-spoke model, this memorandum recommends the continuation of the status quo measures of STEMI care within Big Horn, Hot Springs, and Washakie counties for the near future. Although the regionalization of STEMI care

\textsuperscript{207} Reimer \textit{et al}, 1977.  
\textsuperscript{208} De Luca \textit{et al}, 2004.  
\textsuperscript{209} Burke and Virmani, 2007.
utilized in North Carolina and the wheel-and-spoke model implemented in Illinois were both designed to overcome the challenges of rural heart attack treatment, Wyoming still presents unique geographic challenges that are not addressed in these models. Wyoming is nearly twice the size of both states with a total land-area of 97,093 square miles and is significantly less dense with 5.8 persons per square mile\textsuperscript{210}. These data are presented quantitatively in Table 5. While differences in geography do not preclude the implementation of a regionalization or wheel-and-spoke model of STEMI care in northwest Wyoming, the impact of these physical disparities on the estimated results of similar systems cannot be ignored.

Table 5: State Population Distributions

<table>
<thead>
<tr>
<th>State</th>
<th>Land Area (square miles)</th>
<th>Population Density (per square mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Carolina</td>
<td>48,617</td>
<td>196.1</td>
</tr>
<tr>
<td>Illinois</td>
<td>55,518</td>
<td>231.1</td>
</tr>
<tr>
<td>Wyoming</td>
<td>87,093</td>
<td>5.8</td>
</tr>
</tbody>
</table>

This conclusion is supported by the sensitivity analysis presented in Table 4. The low-cost wheel-and-spoke model initially presents a higher net present value than the status quo even after controlling for geographic reductions in model success as compared to the original Prairie Stat Heart program. However, if one additional STEMI patient were to die due to consequences of resource reduction or other factors, the low-cost alternative would produce a net present value below the status quo projection. Although the wheel-and-spoke model could also produce a significantly higher net present value based on its best-case scenario, the small margin for error before the model would lose its net present value advantage makes the overall program less desirable for implementation in northwest Wyoming.

Ultimately, the public health climate in Wyoming is restricted by limited healthcare resources that produce high costs of system implementation and the small number of projected patients within its rural regions that limit the potential number of lives saved. These two factors make large-scale STEMI system intervention difficult to justify. A universal system would require numerous additional emergency physicians in a state that already has low per-capita medical specialists\textsuperscript{211}. The significant healthcare

\textsuperscript{210} State and County QuickFacts.
\textsuperscript{211} Hirshon et al, 2014.
resource investment required for an integrated STEMI system would also pose considerable costs that would be passed on to Wyoming consumers. But most importantly, a complex and efficient STEMI system would only have the potential to save a projected eight lives each year.

Beyond the physical and financial aspects of STEMI care, healthcare system implementation in rural Wyoming presents important philosophical considerations. Living in rural America inherently produces considerable lifestyle tradeoffs compared to urban living. In this case, increased autonomy is balanced with decreased healthcare access. The emergency medicine climate in the state of Wyoming is the worst in the United States and the Wyoming state government has not made the investment necessary to improve the situation\textsuperscript{212}. Although a minimum level of healthcare access is slowly becoming and individual right in many parts of the United States, access to timely coronary reperfusion through specialized heart surgery cannot be guaranteed in all places. In fact, the minimum accepted level of healthcare access in the state of Wyoming is likely lower than other states as evidenced by the state’s low total expenditures and minimal health and public assistance spending\textsuperscript{213}. This autonomous, minimal spending ideology makes the implementation of an extensive and universal STEMI system of care unlikely in the state of Wyoming.

Although a comprehensive STEMI system might not be feasible in Wyoming in the near future, the state could still benefit from small and localized health interventions that would improve STEMI treatment on a per-hospital basis. Hospitals could invest in primary care resources that aim to reduce STEMI risk factors within the population over an extended period of time at low cost. The state or individual counties could focus on patient education to improve patient response times during heart attack and promote healthier lifestyles that mitigate STEMI incidence. Additionally, technological changes might make a larger STEMI system of care viable in the future as procedures become less invasive and therapy moves beyond the medical setting. In the mean time, however, this memorandum recommends

\textsuperscript{212} Ibid.
the continuation of status quo measures for the treatment of ST-Elevation Myocardial Infarction in Big Horn, Hot Springs, and Washakie counties in northwest Wyoming.

**Weaknesses and Limitations**

This memorandum possesses numerous weakness and limitations that must be understood before drawing conclusions based on this analysis. The most significant assumption in this evaluation is the relative importance of time in the treatment of STEMI in rural Wyoming. This memorandum is based on the premise that time before treatment is the main driver of STEMI mortality in a rural context and consequently assumes that reductions in treatment times through the implementation of STMEI systems of care would ultimately result in decreased STEMI mortality. While the proposed STEMI system of care interventions are designed to reduce treatment times from patient contact with EMS, this analysis intentionally does not address the importance of patient education in STEMI care.

STEMI systems of care can only be effective if patients are cognizant of the signs and symptoms of STEMI and are willing to utilize emergency medical services at the time of symptom onset. However there is limited data that suggests a significant number of heart attack patients fail to call 911 during a cardiac emergency and an even larger number of individuals wait an extended period of time before summoning EMS. It is likely that lack of education or general unwillingness to rely on healthcare services may impact STEMI mortality in rural Wyoming and patient education interventions are encouraged. However, strategies for patient education are beyond the scope of this memorandum.

This analysis also assumes that previously established STEMI system of care models from across the country could be successfully implemented in northwest Wyoming. However, the realities of healthcare service provision in the United States suggest that there may be barriers to implementation including resource limitations, insurance company biases, and interhospital physician group competition. The evaluations in this paper are provided on the supposition that all STEMI models could be
successfully implemented in Wyoming; however, potential barriers to implementation should be considered before recommending any changes to the status quo STEMI system in the region.

Finally, this memorandum is limited by available data. All heart attack mortality rates are listed as crude, non-age-adjusted rates due to lack of information. Quantified STEMI incidence and mortality in the study region is limited to national projections and context-based estimates. Although all estimations in this analysis are intentionally kept conservative to limit the impact of as many uncontrollable variables as possible, the scope of this memorandum remains limited.
Appendices

Appendix A: STEMI Treatment in the Emergency Department

Figure I: STEMI Diagnosis and Treatment Flow Chart

In reality, the diagnosis and treatment of STEMI in an emergency department can involve numerous tests and therapies. This example illustrates three initial paths for STEMI patients upon presentation to the emergency department. In some cases, patients are immediately transferred to a cardiac catheterization laboratory for primary PCI. In other cases, a patient may receive fibrinolytic therapy or remain untreated before receiving PCI following a series of tests. A patient’s specific path through this flow chart is dictated by patient symptoms, hospital resources, and the severity of the occlusion.
This figure illustrates two separate emergency department protocols before and after the implementation of an interdepartmental STEMI system. The adoption of the code STEMI system allowed the emergency department physician to evaluate potential STEMI patients and activate the CCL without ordering timely consults. The protocol also expedited the transfer of the STEMI patient to the CCL by initiating transfer prior to CCL team arrival. The implementation of this protocol increased the number of patients receiving PCI within 90 minutes by 87 percent and did not increase the rate of false-positive CCL activations.\textsuperscript{214}

Appendix B: National Emergency Care Report Card Excerpts

Executive Summary

| NATIONAL GRADE BY CATEGORY |
|---------------------------|--------|
| ACCESS TO EMERGENCY CARE   | D-     |
| QUALITY & PATIENT SAFETY ENVIRONMENT | C      |
| MEDICAL LIABILITY ENVIRONMENT | C-    |
| PUBLIC HEALTH & INJURY PREVENTION | C     |
| DISASTER PREPAREDNESS     | C-     |
| OVERALL                   | D+     |

For millions of Americans who experience sudden, serious illness or injury every year—and in the increasing scores of communities that must respond to disasters and mass casualty events—immediate access to quality emergency care is essential to saving life and limb. But the availability of that care is threatened by a wide range of factors, including shrinking capacity and an ever-increasing demand for services. Even as more and more Americans come to rely on emergency departments for their acute care needs, particularly aging and sick Boomers and people newly enrolled in Medicaid, such care will increasingly become harder to access.

This national Report Card rates the overall environment in which the emergency care system operates with a near-failing grade of D+. This is a poorer grade than the one earned in 2009, a C-. Overall state rankings have changed since the 2009 Report Card, with the District of Columbia now ranking first and Wyoming ranking last in the nation.

These findings are the result of a comprehensive and focused study of the emergency care environment nationwide and state-by-state. The American College of Emergency Physicians (ACEP) convened a blue-ribbon task force of experts to produce this third edition of a national report card. It builds on previous work to provide a comprehensive look at the nation’s emergency medical system in five categories. Despite hoped-for changes and improvements, the environment has not improved; it has, in fact, gotten worse.

The five categories are based on 136 objective measures that reflect the most current data available from reliable public sources, including the U.S. Centers for Disease Control and Prevention, the National Highway Traffic Safety Administration, and the Centers for Medicare and Medicaid Services, as well as other sources, such as the American Medical Association. The 136 measures were selected because they represent factors vital to life-saving emergency care and meet the key criteria of relevance, reliability, validity, reproducibility, and consistency across all states.

Access to Emergency Care

This important category represents 30% of the total grade and includes four subcategories: access to providers, access to treatment centers, financial barriers, and hospital capacity. It also includes access to specialists, such as neurosurgeons, orthopedists, and plastic surgeons.

Access to emergency care is fundamental and complex—and essential. Several factors affect people’s access, such as the availability of emergency departments, the capacity of those departments, and the workforce available to staff those departments. In addition, the environment is affected by an unfunded government mandate, the Emergency Medical Treatment and Labor Act (EMTALA), that requires emergency departments to screen and stabilize anyone who presents with an emergency medical condition, which means that all patients are seen, regardless of ability to pay.

This failing grade reflects trouble for a nation that has too few emergency departments to meet the needs of a growing, aging population, and of the increasing number of people now insured as a result of the Affordable Care Act. For more than 20 years, emergency visit rates have increased at twice the rate of the growth of the U.S. population, totaling 130 million in 2010. And that growth in demand is poised to continue.

Quality & Patient Safety Environment

This category represents 20% of the total grade and includes subcategories reflecting state systems and institutions that can support the emergency care environment. Measuring this environment is essential, as is examining how better-quality systems and technologies can help improve care and prevent injuries. Federal agencies, state governments, and private institutions have made advancements in developing and implementing indicators of health care quality. ACEP continues to monitor direct state investments in improving quality and safety, such as funding for emergency medical services (EMS) medical directors and development and implementation of destination and triage policies that allow EMS to bypass local hospitals to take patients to appropriate hospital specialty centers. Institutional improvements include advances, such as the use of computerized practitioner order entry and attention to addressing racial and ethnic disparities in care.

Medical Liability Environment

This category represents 20% of the total grade and includes subcategories that describe the legal atmosphere, insurance availability, and tort reform across the states.

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\(^{215}\) Hirshon et al, 2014.
The U.S. Department of Health and Human Services characterizes the medical liability environment as a broken system, one that features wide variations in policies and practices across states. In some cases, high liability insurance rates have forced physicians to curtail their practices, stop performing high-risk but critically necessary procedures, such as delivering babies, or move to states with more favorable liability environments. And the country pays for it: studies estimate that liability costs, including those associated with the practice of defensive medicine, add as much as $108 billion to the annual total cost of health care, resulting in patients experiencing higher costs, longer waits, and more challenges in accessing care.

This category includes data on numerous types of liability reforms, such as medical liability caps on non-economic damages, pretrial screening panels, periodic payments of malpractice awards, the presence of state-funded patient compensation funds, and additional liability protections for care mandated by EMTALA.

Public Health & Injury Prevention

This category represents 15% of the total grade and includes measures of traffic safety and drunk driving, immunization, fatal injury, state health and injury prevention efforts, and health risk factors.

Injuries account for nearly one-third of emergency visits. And preventable and behavior-related factors, such as smoking, poor diet, alcohol consumption, and drug abuse, contribute to many more. States can positively impact all of these factors through life-saving policies, such as those requiring seat belt use in vehicles and helmet use while riding motorcycles, as well as education and outreach to increase healthy choices among the general population, including vaccination. Failure to adopt effective measures at the state-level can negatively impact public health and have a considerable effect on the need for emergency services.

Disaster Preparedness

This category represents 15% of the total grade and includes financial resources, state coordination, hospital capacity, and personnel data related to the capacity to respond to disasters.

The ever-present threat and reality of natural disasters and man-made catastrophes require an effective response capability. Disaster preparedness efforts rely on ongoing collaboration of many entities at all levels of government and in all economic sectors. In this process, emergency physicians, who have training and experience in managing mass casualty events and delivering lifesaving care, are integral to this process. Despite real and present threats, states continue to experience great variability in planning and response capacities. In many communities, capacity is already stretched to the limit, and hospital bed surge capacity, staffing, and resources are inadequate to respond to the extraordinary demands precipitated by any disaster.

Recommendations

In response to these findings, the American College of Emergency Physicians makes the following recommendations, each aimed at improving care in terms of access, safety and quality, medical liability, public health and injury prevention, and disaster preparedness.

1. Protect access to emergency care as health care reforms are implemented.

2. Support programs that recognize the pivotal role emergency medicine plays in care coordination and transitions of care.

3. Reduce the incidence of hospital overcrowding and boarding of admitted patients in the emergency department.

4. Enact federal and state medical liability reforms that enhance timely access to quality care, particularly those that provide appropriate liability protections for EMTALA-mandated care.

5. Increase coordination and regionalization of specialized emergency services and support funding of federally authorized regional pilot programs.

6. Devote consistent federal and state funding to ensure adequate and sustainable local and regional disaster preparedness.

7. Continue to increase the use of systems, standards, and information technologies to track and enhance the quality and patient safety environment.

8. Continue pursuit of state laws that help reduce the number of preventable deaths and injuries, particularly those that address traffic-related injuries and fatalities.

9. Expand access to standardized and user-friendly state and federal prescription drug monitoring programs to decrease unintentional deaths by drug overdose.

10. Fund graduate medical education programs that support emergency care, especially those related to addressing physician shortages in disadvantaged areas and in rural areas.

11. Support emergency medicine research, including basic, clinical, and translational research into improving the delivery of emergency care services.

Emergency physicians today mobilize resources to diagnose and treat every kind of medical emergency. They also play a pivotal role in setting the health care course for their patients by coordinating care with on-call specialists and other clinicians in the hospital and in communities. Care that once was provided in inpatient settings is now being done in emergency departments. Yet emergency physicians work in a stressed system that operates in a near-crisis situation. This Report Card points to shortcomings and challenges in the emergency care environment, but it does not attempt to grade the care provided by dedicated emergency physicians and staff, nor does it underestimate the day-to-day commitment and concern that emergency physicians demonstrate in caring for millions of patients each year.
Wyoming has robust hospital capacity and some liability protections for health care providers. However, financial barriers to care, health care work force shortages, and a lack of statewide policies and practices for its Quality and Patient Safety Environment and Disaster Preparedness lands the state at the bottom of this year’s rankings.

**Strengths.** Wyoming has some strong elements facilitating Access to Emergency Care with robust access to important medical facilities. The state is fourth in the nation for access to emergency departments (ED) and fifth for its high per capita rate of Level I or II trauma centers; however, because of its geography, only 33% of the population is within 60 minutes of a trauma center. Wyoming has the second lowest hospital occupancy rate in the nation and ranks among the top 10 for per capita rates of psychiatric care beds and staffed inpatient beds. The state's median time from ED arrival to departure for admitted patients is only 216 minutes, well below the national average.

Wyoming has instituted some protections for practitioners in its Medical Liability Environment. Mandatory pretrial screening panels help discourage lawsuits that lack merit, and physician apologies are not admissible as evidence in court. Wyoming has abolished joint and several liability, reducing unfair liability payments. While its average malpractice award payments are among the highest in the nation ($45,729), the state does have one of the lowest rates of malpractice payments.

Finally, Wyoming has very low obesity rates, with a low proportion of children who are obese (10.7%) and a below-average proportion of adults who are obese (25.0%).

**Challenges.** Wyoming has the lowest ranked Quality and Patient Safety Environment in the country, largely due to a lack of state-level investment in this area. Wyoming provides no funding for quality improvement within the emergency medical services (EMS) system or a state EMS medical director. Wyoming also lacks a uniform system for providing pre-arrival instructions and triage and destination policies for stroke, SH-elevation myocardial infarction (STEMI), and trauma patients.

Although Wyoming fares well in overall hospital capacity, lack of health insurance and a health care workforce shortage are troubling barriers to care. The state has high proportions of adults and children with no health insurance (20.3% and 10.0%, respectively) and the second highest proportion of children who are underinsured (22.5%). The state also has low per capita rates of emergency physicians, neurosurgeons, plastic surgeons, and ear, nose, and throat specialists which can affect the availability of on-call specialty care in the ED.

These numbers are troubling in light of Wyoming’s challenges in Public Health and Injury Prevention. Wyoming has the highest rate of traffic fatalities in the country (26.9 per 100,000 people) and the second highest rate of fatal occupational injuries (99.0 per 1 million workers). The state also has high rates of homicide and suicide; firearm-related deaths; and poisoning-related deaths, which include drug overdoses. Wyoming also has extremely low rates of vaccination among children and older adults.

Wyoming needs to invest in patient safety and quality improvement in the emergency care system.

Wyoming has the second highest per capita federal investment in Disaster Preparedness at $18.84 but lags behind most other states, largely due to a lack of important statewide policies and plans. The state has no redundant medical communication system in place, which would be an asset in a large and rural state, and no statewide patient-tracking system. Wyoming’s medical response plan does not include patients dependent on medications or dialysis to ensure these patients receive needed care.

**Recommendations.** Wyoming needs to invest in quality improvement in the emergency care system and in patient safety. In addition to developing state-level protocols for stroke, STEMI, and trauma patients, Wyoming should encourage more of its hospitals to adopt technological advances, such as computerized practitioner order entry and electronic medical records, which help reduce errors and improve the ability of doctors and hospitals to provide timely and appropriate care.

While many of Wyoming’s challenges in Access to Emergency Care are due to being a large, rural state, Wyoming can and must take action to improve vaccination rates and reduce traffic fatalities. The state should invest in outreach and education aimed at increasing seatbelt use and pass legislation to require helmets for all motorcycle riders. The state could also explore innovative approaches to increasing immunization rates among children and the elderly.

Wyoming can strengthen its Medical Liability Environment to help lower the average malpractice award payment and to aid in recruiting a skilled workforce. The state should explore a medical liability cap on non-economic damages and require periodic payments of malpractice awards. Wyoming should consider providing special liability protections for care mandated by the Emergency Medical Treatment and Labor Act to further alleviate the burden on physicians who are willing to provide emergent, life-saving care to patients.
Appendix C: The World Burden of CVDs Background

216 Types of Cardiovascular Disease. (n.d.).
Appendix D: Life Course Variables of Disease and Public Action Plan

Figure III: Example of life course variables affecting disease

Schematic representation of biological and psychosocial exposures acting across the life course that may influence lung function and/or respiratory disease.

Figure I is a schematic representation of the life course exposures that influence the development of respiratory disease as adapted from Ben-Shlomo and Kuh, 2002. This figure captures the complicated nature of NCD prevention at the population level.
Figure IV: CDC 2008 Public Action Plan to Prevent Heart Disease and Stroke

Figure II captures the complicated interventional model put forth by the United States Centers for Disease Control and Prevention in the 2008 Action Plan to Prevent Heart Disease and Stroke. Reducing the prevalence of heart disease in the US population is a daunting task that requires public health planning and action at multiple levels of society.
Appendix E: Electrocardiography Background

EKG Background:

The electrocardiogram or EKG is an instrument that records the electrical activity of the heart. By placing current measuring leads on the chest and extremities, the EKG is able to measure the beating pattern of the heart muscle and determine if there is muscle damage or abnormality\(^\text{217}\). Although an EKG is relatively easy to perform and presents no medical risk to the patient, clear and accurate data are sometimes hard to obtain because slightly altered lead placement, obstructions to lead contact sites, or patient movement during the test can significantly impact the quality of the results. A schematic of EKG lead placement is shown below:

![EKG Lead Placement Schematic](http://kiferwater.com/ecg-electrode-placement-on-women.html)

Once completed, the EKG instrument produces a progression of waveforms that illustrate the patient’s current cardiac rhythm cycle. The wave progression of a normal sinus rhythm with no abnormalities is shown below. Each unique point and feature within the waveform corresponds to a specific function of the heart and is universally labeled with the letters P-U.

![Idealized Cardiac Cycle](http://www.nlm.nih.gov/medlineplus/ency/article/003868.htm)

As the name suggests, patients experiencing ST Segment Elevation Myocardial Infarction show a classic bump in their waveform between the S and T segments as depicted below.

The classic ST presentation of STEMI on an EKG causes roughly 94 percent of STEMI patients to produce diagnostic waveforms on a 12-lead electrocardiogram\textsuperscript{218}. However, it still takes a trained eye to decipher some cases of STEMI. Examples of normal and STEMI EKG results are provided below.

Normal EKG Results:

STEMI EKG Results:

\textsuperscript{218} Pope \textit{et al}, 2000.
Appendix F: Complete Wyoming AMI Mortality Data

Complete Wyoming Acute Myocardial Infarction Data by County between as Recorded by the United States Centers for Disease Control and Prevention Online Wonder Mortality Database

Table I: Wyoming Myocardial Infarction Mortality Rates
Compressed Mortality, 1999-2013 Results

<table>
<thead>
<tr>
<th>County</th>
<th>Deaths</th>
<th>Population</th>
<th>Crude Rate Per 100,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albany County, WY (56001)</td>
<td>155</td>
<td>106,841</td>
<td>145.1</td>
</tr>
<tr>
<td>Big Horn County, WY (56003)</td>
<td>51</td>
<td>52,457</td>
<td>97.2</td>
</tr>
<tr>
<td>Campbell County, WY (56005)</td>
<td>86</td>
<td>159,930</td>
<td>53.8</td>
</tr>
<tr>
<td>Carbon County, WY (56007)</td>
<td>72</td>
<td>68,927</td>
<td>104.5</td>
</tr>
<tr>
<td>Converse County, WY (56009)</td>
<td>52</td>
<td>59,124</td>
<td>87.9</td>
</tr>
<tr>
<td>Crook County, WY (56011)</td>
<td>36</td>
<td>32,238</td>
<td>111.7</td>
</tr>
<tr>
<td>Fremont County, WY (56013)</td>
<td>181</td>
<td>109,236</td>
<td>107.0</td>
</tr>
<tr>
<td>Goshen County, WY (56015)</td>
<td>120</td>
<td>61,448</td>
<td>195.3</td>
</tr>
<tr>
<td>Hot Springs County, WY (56017)</td>
<td>29</td>
<td>29,402</td>
<td>118.8</td>
</tr>
<tr>
<td>Johnson County, WY (56019)</td>
<td>36</td>
<td>40,451</td>
<td>89.0</td>
</tr>
<tr>
<td>Laramie County, WY (56021)</td>
<td>489</td>
<td>370,334</td>
<td>129.9</td>
</tr>
<tr>
<td>Lincoln County, WY (56023)</td>
<td>65</td>
<td>74,264</td>
<td>87.5</td>
</tr>
<tr>
<td>Natrona County, WY (56025)</td>
<td>234</td>
<td>308,520</td>
<td>75.8</td>
</tr>
<tr>
<td>Niobrara County, WY (56027)</td>
<td>16</td>
<td>12,427</td>
<td>128.8 (Unreliable)</td>
</tr>
<tr>
<td>Park County, WY (56029)</td>
<td>82</td>
<td>130,836</td>
<td>62.7</td>
</tr>
<tr>
<td>Platte County, WY (56031)</td>
<td>48</td>
<td>44,094</td>
<td>108.9</td>
</tr>
<tr>
<td>Sheridan County, WY (56033)</td>
<td>157</td>
<td>133,082</td>
<td>118.0</td>
</tr>
<tr>
<td>Sublette County, WY (56035)</td>
<td>32</td>
<td>41,285</td>
<td>77.5</td>
</tr>
<tr>
<td>Sweetwater County, WY (56037)</td>
<td>136</td>
<td>161,432</td>
<td>84.2</td>
</tr>
<tr>
<td>Teton County, WY (56039)</td>
<td>23</td>
<td>88,362</td>
<td>26.0</td>
</tr>
<tr>
<td>Uinta County, WY (56041)</td>
<td>41</td>
<td>79,616</td>
<td>51.5</td>
</tr>
<tr>
<td>Washakie County, WY (56043)</td>
<td>61</td>
<td>38,289</td>
<td>159.4</td>
</tr>
<tr>
<td>Weston County, WY (56045)</td>
<td>37</td>
<td>32,909</td>
<td>112.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,139</strong></td>
<td><strong>2,296,526</strong></td>
<td><strong>97.5</strong></td>
</tr>
</tbody>
</table>

Notes:

Caveats: About sub-national population figures for regions, divisions, states and counties: population figures for 1999 are from the 1990-1999 series of bridged-race intercensal estimates of the July 1 resident population; population figures for 2000 and 2010 are bridged-race April 1 census counts; population figures for 2001-2009 are from the revised 2000-2009 series of bridged race intercensal estimates of the July 1 resident population; and population figures for 2011-2013 are bridged-race postcensal estimates of the July 1 resident population, from the Vintage 2013 series released by the NCHS on June 26, 2014.
Death rates are flagged as Unreliable when the rate is calculated with a numerator of 20 or less.

Death of persons with Age “Not Stated” are included in “All” counts and rates, but are not distributed among groups, so are not included in age-specific counts, age-specific rates or in age-adjusted rates.

Changes to cause of death classification affect reporting trends.

**Help:** See Compressed Morality, 1999-2013 Documentation for more information.

**Query Date:** Jan 16, 2015 7:13:52 PM

**Suggested Citation:**


**Query Criteria:**

- **Title:**
  - 2013 Urbanization: All
  - Age Group: 35-44 years, 45-54 years, 55-64 years, 65-74 years, 75-84 years, 85+ years
  - Gender: All
  - Hispanic Origin: All
  - ICD-10 Codes: I21.0 (Acute transmural myocardial infarction of anterior wall), I21.1 (Acute transmural myocardial infarction of inferior wall), I21.2 (Acute transmural myocardial infarction of other sites), I21.3 (Acute transmural myocardial infarction of unspecified site), I21.4 (Acute subendocardial myocardial infarction), I21.9 (Acute myocardial infarction unspecified), I22.0 (Subsequent myocardial infarction of anterior wall), I22.1 (Subsequent myocardial infarction of inferior wall), I22.8 (Subsequent myocardial infarction of other sites), I22.9 (Subsequent myocardial infarction of unspecified site)
  - Race: All
  - States: Wyoming (56)
  - Group By: County
  - Show Totals: True
  - Show Zero Values: False
  - Show Suppressed: False
  - Calculate Rates Per: 100,000
Appendix G: Consumer Cost Sharing

Medical Insurance and Moral Hazard$^{219,220,221}$

Health economics has traditionally viewed the demand for healthcare insurance as a demand for certainty against the risk of illness. Individuals are unable to predict the occurrence or extent of most illnesses and thus experience an unpredictable risk of personal health costs over a specified time period that could range from near-zero cost to significant health expenditures. If individuals are characterized as rational and risk adverse actors, then the pooling of the risk of illness through health insurance with a guaranteed cost of an actuarially fair monthly insurance premium would be desirable because it reduces the variance associated with individual health expenditures. Insurance companies are additionally better equipped to handle the uncertainty of individual illness due to the law of large numbers which makes the risk of illness among a large group of individuals relatively predictable.

A neoclassical approach to healthcare economics can characterize healthcare as a normal good that is consumed in a competitive market at a market price based on an individual’s personal tastes and preferences for healthcare utilization. Put simply, an individual’s willingness to pay for healthcare services determines how many physician visits, medical treatments, or other healthcare resources they would consume at a given market value. While the sum of these individual demand schedules helps to form the market demand for healthcare services, neoclassical theory also suggests that the presence of total health insurance coverage ultimately leads to inefficiency in the market due to the concept of moral hazard.

![Figure V: Moral Hazard Visualization](image)

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The concept of moral hazard suggests that individuals alter their consumption behavior when provided with health insurance. These individuals are said to consume healthcare resources beyond the point where their marginal utility from additional resource consumption is less than the market cost of the resource. Such individuals are assumed to take fewer precautions to prevent illness, shop around less for cheapest medical prices, and ultimately over consume medical care because they do not pay the market price for healthcare services. It is argued that this consumption is caused by a form of “prisoners’ dilemma” where individuals realize that excess use of medical services under health insurance will cause premiums to rise but the individual gain from incremental increased use is less than the collective cost of increased premiums spread among the entire pool of insurance buyers. While insurance consumers as a collective would be best off not over consuming medical care, the individual gain from over consuming is greater than the individual gain from restraining. The inefficiency produced by individual moral hazard was thought to be the cause of ballooning healthcare costs in the United States in the late 20th century.

In order to combat this purported market inefficiency, health insurance companies devised methods of consumer cost sharing that increase the individual cost of each additional unit of healthcare services purchased. These measures, which include co-payments, co-insurance, and deductibles, were designed to dissuade individuals from consuming unneeded healthcare services by increasing the marginal cost of healthcare utilization. An example of consumer cost sharing in a modern insurance plan is provided in the figure below.

Image borrowed from: Quincy, 2011.
Appendix H: Cost-Benefit Analysis Descriptions and Calculations

County Data
Population of Region of Interest:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Horn</td>
<td>12,142</td>
<td>6,665</td>
<td>0.80</td>
<td>6,936</td>
</tr>
<tr>
<td>Hot Springs</td>
<td>4,960</td>
<td>3,087</td>
<td>0.46</td>
<td>3,159</td>
</tr>
<tr>
<td>Washakie</td>
<td>8,720</td>
<td>4,871</td>
<td>0.60</td>
<td>5,019</td>
</tr>
<tr>
<td>Total</td>
<td>25,822</td>
<td>14,623</td>
<td>-</td>
<td>15,113</td>
</tr>
</tbody>
</table>

- Total and Age 35+ populations were retrieved from the US Census Bureau and then projected to 2015 levels based on the University of Wyoming’s Department of Agricultural and Applied Economics average population changes between 2004 and 2013222,223.

Status Quo

Total number of expected Myocardial Infarction and STEMI in the region:

<table>
<thead>
<tr>
<th>Expected MI in 2015:</th>
<th>54</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected STEMI 2015:</td>
<td>20</td>
</tr>
</tbody>
</table>

- Expected Myocardial Infarctions were determined using national incidence data from a large 2010 study in the New England Journal of Medicine224. The rate of 208 MI per 100,000 population was applied to the projected total population in the study area. Results were rounded to the nearest whole number for ease of understanding and application.
  - \( \left( \frac{25,882}{100,000} \right) \times 208 = 52 \) projected MI

- Expected STEMI were determined using national incidence data as reported by the American Medical Journal225. The rate of 77 STEMI per 100,000 persons was applied to the projected total population in the study area. Results were rounded to the nearest whole number.
  - \( \left( \frac{25,882}{100,000} \right) \times 77 = 20 \) projected STEMI

- Limitation: These calculations assume that MI and STEMI rates in Wyoming are similar to national averages due to limitations to Wyoming-specific data. Although Wyoming’s MI mortality is shown to be above the national average by the CDC, this memorandum uses national averages for incidence because Wyoming is near average in population health as the 17th healthiest state226. This memorandum thus contends that MI mortality is due to additional factors beyond population health.

222 State and County Quick Facts, 2014.
225 McManus et al, 2011.
226 Outcomes, 2014.
Total number of expected MI and STEMI deaths:

<table>
<thead>
<tr>
<th>MI MR per 100K Age 35+ (2005-12)</th>
<th>2015 Expected MI</th>
</tr>
</thead>
<tbody>
<tr>
<td>97.2</td>
<td>7</td>
</tr>
<tr>
<td>118.8</td>
<td>4</td>
</tr>
<tr>
<td>159.4</td>
<td>8</td>
</tr>
<tr>
<td>Total Deaths</td>
<td>19</td>
</tr>
<tr>
<td>Est. STEMI Deaths</td>
<td>8</td>
</tr>
</tbody>
</table>

- The expected number of MI deaths was calculated using mortality rates from the United States’ Centers for Disease Control and Prevention online Wonder Database\(^{227}\). Data was limited to individuals aged 35+ in the counties of interest in order to capture the most likely candidates for heart attack\(^{228}\). Estimates from the CDC Wonder Database were derived from 2005 to 2012 in order to produce enough results for the system to provide crude mortality rates. Expected deaths were calculated using the projected 2015 age 35+ population presented previously.

- Specific STEMI mortality data are not available for the state of Wyoming. STEMI deaths were estimated at double the national STEMI mortality rate of 20 percent\(^{229,230,231}\). This assumption was rationalized on the premise that Wyoming’s overall MI mortality is near fifty percent based on a statewide mortality rate of 97.5 per 100,000 and an incidence of 208 per 100,000.

Projected Hospitalizations for MI and STEMI:

<table>
<thead>
<tr>
<th>Projected Hospitalizations for MI: **</th>
<th>Projected Hospitalizations for STEMI:**</th>
<th>Estimated STEMI Deaths:</th>
<th>Estimated STEMI Survivals:</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>19</td>
<td>8</td>
<td>11</td>
</tr>
</tbody>
</table>

** includes 5% MI death rate from cardiac rupture

- Nationally, it is estimated that 5 percent of heart attack patients experience cardiac rupture\(^{232}\). This severe pathology would cause near-sudden death and preclude an individual from any form of intervention. Wyoming also has a 1.48 percent dead-on-arrival rate for heart attack patients statewide which was included in this calculation\(^{233}\). Both MI and STEMI hospitalizations were projected using these estimates.

- \(54 \ast (1 - (0.05 + 0.0148)) = 50\) Projected Hospitalizations for MI

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\(^{227}\) Centers for Disease Control and Prevention, National Center for Health Statistics. Compressed Mortality File 1999-2012 on CDC WONDER Online Database, released October 2014.

\(^{228}\) Mozaffarian et al, 2015.

\(^{229}\) Wilson et al, n.d.

\(^{230}\) Fang et al, 2002.

\(^{231}\) Rosamond et al, 1998.

\(^{232}\) Burke and Virmani, 2007.

\(^{233}\) Centers for Disease Control and Prevention, National Center for Health Statistics. Compressed Mortality File 1999-2012 on CDC WONDER Online Database, released October 2014.
20 \times (1 - (0.05 + 0.0148)) = 19 \text{ Projected Hospitalizations or STEMI}

### Value of a fatal heart attack prevented:
- The United States Food and Drug Administration places a value of $1.76 million on a fatal heart attack averted. This value is derived from an average of 13 years of life lost from a fatal heart attack, a value of a statistical life year of $220,000, a discount rate of 7 percent, and a quality adjusted life year following the heart attack of -0.18234.

### Hospitalization costs of STEMI mortality or survival:
- The average cost of hospitalization for a STEMI patient who dies is $30,373 and the average cost of hospitalization for a STEMI survivor is $20,642 based on the National Inpatient Sample; the largest all-payer inpatient care database in the United States235.
- The costs of STEMI mortality and survival were then increased by 17.6 percent because are estimated to be 17.6 percent higher in rural areas within the United States236.
- The difference in price between STEMI mortality and survival was used to calculate the benefit that healthcare providers receive for each STEMI survival.

### Average medical costs to patient following STEMI survival:
- According to the United States Food and Drug Administration, fatal heart attack survivors incur an average of $38,122 in additional medical costs over the remainder of their lifetimes237. This value was also increased by 17.6 percent to account for higher average medical costs in rural areas.

### Cost of land ambulance use:
- According to the United States Government Accountability Office, the average cost of an ambulance ride in a “super rural” setting is $554.76238. This cost is listed as a consumer cost because the price of ambulance utilization is commonly passed directly to healthcare consumers.

### Recommendation 1: Regionalization of STEMI Care

### Total number of ambulances and emergency medical personnel in the study area:

<table>
<thead>
<tr>
<th>County</th>
<th>Number of Ambulances</th>
<th>Ambulance Staff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Horn</td>
<td>6</td>
<td>44</td>
</tr>
<tr>
<td>Hot Springs</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Washakie</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>14</strong></td>
<td><strong>78</strong></td>
</tr>
</tbody>
</table>

234 Bruns, 2013.
236 ibid.
237 Bruns, 2013.
Estimates of the total number of ambulances and ambulance staff operating in the study area were obtained from the 2002 Ambulance Survey by the Wyoming Economic Analysis Division.

**Limitation:** This survey has not been repeated so therefore this memorandum must assume minimal changes to EMS resources.

### Projected additional land ambulance utilization:

<table>
<thead>
<tr>
<th>Expected STEMI 2015 (Total)</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Horn STEMI</td>
<td>9</td>
</tr>
<tr>
<td>Hot Springs STEMI</td>
<td>4</td>
</tr>
<tr>
<td>Washakie STEMI</td>
<td>7</td>
</tr>
</tbody>
</table>

The projected number of STEMI within the study region was broken down by county based on individual age 35+ population totals. Patients living in Big Horn and Hot Springs counties were allocated an additional land ambulance use for transfer from their respective county hospitals to PCI receiving centers for cardiac catheterization.

Individuals in Washakie County were not allocated an additional land ambulance use because they would present directly to a PCI-capable hospital.

### Number of lives saved with regionalization program:

- Studies suggest that STEMI mortality increased by 7.5 percent for every additional 30 minutes of cardiac ischemia\(^{239}\). Based on this rate, the reduction in average ischemic time from 165 to 128 minutes in North Carolina reduced STEMI mortality rates by 22.43 percent for patients who would otherwise not have received PCI\(^{240}\).

\[
1 - \left(\frac{\frac{128}{30} + \frac{7.5}{30}}{\frac{165}{30} + \frac{7.5}{30}}\right) \times 100 = 22.43\% \text{ Reduction}
\]

- This mortality reduction was applied to the total number of deaths projected in the status quo calculations

\[
8 \times (1 - 0.2243) = 6 \text{ Projected STEMI deaths post intervention}
\]

### Cost of equipping a PCI center:

- The average cost of PCI equipment was determined from a Trinity University study that utilized equipment costs from University Hospital in San Antonio, Texas\(^{241}\). Costs total $2,613,033 and include bi-plane x-ray generator and catheterization instruments.

### Average cost of PCI per patient:

- The average cost of a PCI procedure was taken from a Mayo Clinic study involving 771 procedures at two separate hospitals. After applying the rural cost adjustment of 17.6 percent, the cost was determined to be $22,945. This price includes staffing costs.

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\(^{239}\) Fredi, 2011.

\(^{240}\) Jollis *et al.*, 2006.

Cost of EKG equipment for Wyoming ambulances
- A study of EMS agencies surrounding the 200 largest cities in the United States estimated that 90 percent of ambulances carried EKG equipment. This analysis assumes that twice as many ambulances in rural Wyoming might be without equipment.
- The number of ambulances was estimated using the 2002 Ambulance Survey by the Wyoming Economic Analysis Division mentioned previously.
- The cost of a 12-lead EKG instrument was estimated using the average cost of seven EKG models provided by a medical supplier.
  - 0.2 * 14 ambulances * $2,288 = $6,408

Cost of additional EKG training for Wyoming EMTs
- Although the majority of ambulances in the United States are equipped with EKG, it is estimated that less than ten percent of patients have a pre-hospital EKG performed by EMS. In order to assure that emergency medical personnel are sufficiently trained to provide quality EKG testing on a regular basis, this memorandum recommended utilizing online training modules for all EMTs.
- The cost of online EKG training was determined to be $150.

Recommendation 2: Wheel-and-Spoke Model

<table>
<thead>
<tr>
<th>Patient Categories</th>
<th>Prairie Mortality Est.</th>
<th>Wyoming Mortality Est.</th>
<th>Projected Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients Less than 90 Min</td>
<td>Mortality Less than 90 Min</td>
<td>4%</td>
<td>8%</td>
</tr>
<tr>
<td>Patients Less than 120 Min</td>
<td>Mortality Greater than 90 Min</td>
<td>6.4%</td>
<td>13%</td>
</tr>
<tr>
<td>Patients Greater than 120 Min</td>
<td>Mortality with No Intervention</td>
<td>14.1%</td>
<td>40%</td>
</tr>
</tbody>
</table>

Recommended: Assumes that long distances will make 50% of longest transfer times ineligible for PCI

- The prairie stat heart program was shown to achieve door-to-balloon time, or time between hospital arrival and surgery, of <90 minutes for 12.2 percent of patients, <120 minutes for 58 percent of patients, and >120 minutes for 42 percent of patients.
- Additional studies on door-to-balloon times show that STEMI mortality is reduced to 1 percent with times <60 minutes, 3.7 percent with times <75 minutes, 4 percent with times <90 minutes, 6.4 percent with times >91 minutes, and 14.1 percent with no PCI intervention.

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244 Curtis et al, 2006.
- Assumption: Because both the Prairie Stat Heart program and the door-to-balloon time study both recorded patient values after presentation to the hospital, this analysis assumes that mortality rates will be at least two times higher in Wyoming with a similar program due to the long transportation time necessary for a patient to reach a hospital.

- Assumption: Additionally, it was assumed that 50 percent of patients with the longest transport times (>120 minutes) would be ineligible for PCI when compounding upon their long transport time to the hospital. These patients were projected to receive no treatment and defaulted to the standard Wyoming STEMI mortality rate of 40 percent with no intervention.

- STEMI patients were divided into <90 minute, 90-120 minute, and >120 minute categories based on the percentages achieved in the Prairie Stat Heart study. Estimated mortality rates were applied to each category based on door-to-balloon time study and estimated Wyoming adjustment. This resulted in 4 projected STEMI deaths following intervention.

Average cost of airlift per patient:
- In 2006, Maryland Senate Bill 770 required the Maryland Health Care Commission to produce a comprehensive air ambulance study248. This study estimated that rotary wing air ambulances incur an average of $4,950 in base patient costs per transport with an additional $32.60 per mile cost.
- Another study has shown that rotary wing ambulances can achieve an effective radius of 200 miles249.
- The average cost of airlift per patient was determined using the base cost with an average transport distance of 200 miles. While 200 miles is an over-estimate for some of the study hospitals, this radius covers all three transferring hospitals in the study region. The total cost was then adjusted for additional rural costs by the 17.6 percent multiplier.
  - \( (4950 + (32.60 \times 200)) \times 1.176 = 13,489 \) average per patient transport

Average cost to purchase rotary wing air ambulance:
- The average cost of a rotary wing air ambulance was found to be between $4.59 million and $7.27 million250. The average lifespan of a rotary wing air ambulance is 10-20 years so this analysis utilized a projected 15 year lifespan251. The yearly cost of purchasing a new air ambulance was determined using a straight-line depreciation over a 15 year lifespan with a salvage value of $100,000.
- For the high-cost estimate for a wheel-and-spoke model, the high-end helicopter cost was utilized and estimated for all four transferring hospitals. For the low-cost estimate, the low-end helicopter cost was utilized and estimated for two hospitals due to the low annual STEMI call volume in the study area. This resulted in yearly costs of $1,912,341 and $598,985 respectively.

Average cost to operate air ambulance services:
- The average annual cost to operate a rotary wing air ambulance was estimated to be $1,270,146 per helicopter252. This estimate was multiplied by 1.176 to adjust for rural costs.
  - \( (1,270,146 \times 1.176 \times 4) = 5,974,770 \) for high-cost model
  - \( (1,270,146 \times 1.176 \times 2) = 2,987,385 \) for low-cost model

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249 Gunes and Szechtmian, 2005.
251 Salamon and Cowdry, 2006.
Cost of extra PCI resources:
- Assumption: The original Prairie Stat Heart program benefitted from access to large teaching hospitals with high PCI capacity. This analysis assumes that Wyoming Medical Center in Casper will need to purchase additional resources before it can increase its PCI capabilities. While it is unlikely that Wyoming Medical Center would need to establish an entirely new CCL due to the low STEMI incidence in the study area, this analysis projects an increase in resource investment equal to 25 percent of a new CCL to provide additional materials and surgical space.
  - 0.25 * $2,613,033 = $653,258

General Notes

Inflation:
- All prices recorded in this cost-benefit analysis were inflated to 2015 values using the United States Department of Labor Bureau of Labor Statistic’s CPI inflation calculator.

Assumptions and Limitations:
- All assumptions and limitations are intended to provide conservative estimates for program success.
- While this analysis attempted a comprehensive evaluation of its recommendations, there are likely other variables that would impact the costs and benefits of these proposed interventions. The scope of this memorandum is therefore limited and these data should be utilized accordingly.
Appendix I: Recommendation 2 Sensitivity Analysis Description

Background Data

Population of region of interest:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Horn</td>
<td>12142</td>
<td>6665</td>
<td>0.8</td>
<td>6936</td>
<td>97.2</td>
<td>7</td>
</tr>
<tr>
<td>Hot Springs</td>
<td>4960</td>
<td>3087</td>
<td>0.46</td>
<td>3159</td>
<td>118.8</td>
<td>4</td>
</tr>
<tr>
<td>Washakie</td>
<td>8720</td>
<td>4871</td>
<td>0.6</td>
<td>5019</td>
<td>159.4</td>
<td>8</td>
</tr>
</tbody>
</table>

- The population data utilized in this sensitivity analysis is listed above. Further information regarding this data is available in the Cost-Benefit Analysis Descriptions provided in Appendix x.

Projected MI and STEMI hospitalizations and deaths:

<table>
<thead>
<tr>
<th>Projects</th>
<th>Projected Hospitalizations for MI: **</th>
<th>Projected Hospitalizations for STEMI:**</th>
<th>Estimated STEMI Deaths Post Intervention:**</th>
<th>Estimated STEMI Survivals:</th>
<th>Projected Helicopter Transports:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
<td>19</td>
<td>4</td>
<td>15</td>
<td>17</td>
</tr>
</tbody>
</table>

** includes 5% MI death rate from cardiac rupture

- The projected hospitalizations for MI and STEMI, projected STEMI deaths and survivals, and the projected number of helicopter transports at baseline for Recommendation 2 are listed above. Further information regarding this data is available in the Cost-Benefit Analysis Descriptions provided in Appendix x.

Sensitivity Analysis of Low-Cost Recommendation 2

Projected STEMI mortality in low, projected, and high mortality situations

<table>
<thead>
<tr>
<th>Mortality</th>
<th>4%</th>
<th>8%</th>
<th>16%</th>
<th>Patients Less than 90 Min</th>
<th>Total Patients</th>
<th>Projected Deaths Avg</th>
<th>Proj. Deaths Low</th>
<th>Proj. Deaths High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 90 Min</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greater than 90 Min</td>
<td>9</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with No Intervention</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bold: Assumes that long distances will make 50% of longest transfer times ineligible for PCI

High Mortality assumes additional patients will be ineligible for PCI due to longer transport times

Totals: 4 3 5
Average projected mortality rates and deaths are determined using the projected mortality rates outlined in recommendation 2 of the Cost-Benefit Analysis Descriptions provided in Appendix x. Patient categories are help constant throughout the sensitivity analysis.

Low estimate mortality rate estimates were based on the mortality rates observed in the original Prairie Stat Heart program implemented in Illinois. This represents a low-mortality estimate for rural Wyoming because Illinois implemented this program with a base STEMI mortality rate of 14.1 percent whereas Wyoming’s base STEMI mortality rate is roughly 40 percent.253

The high-estimate mortality rates were determined by doubling the initial projected mortality rates utilized in the cost-benefit analysis. Additionally, the high-mortality estimation predicts that 75 percent of the longest transfer times will be ineligible for PCI as compared to 50 percent projected in the cost-benefit analysis. These individuals would not achieve PCI and experience the status quo STEMI mortality of 40 percent.

Projected Cost and Benefit Outcomes

<table>
<thead>
<tr>
<th>Original</th>
<th>4 Deaths</th>
<th>Best Case Scenario</th>
<th>3 Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Hospital Death:</td>
<td>$ 142,876</td>
<td>Cost of Hospital Death:</td>
<td>$ 107,157</td>
</tr>
<tr>
<td>Cost of Hospital Discharge:</td>
<td>$ 364,128</td>
<td>Cost of Hospital Discharge:</td>
<td>$ 388,403</td>
</tr>
<tr>
<td>Cost Saved by STEMI Survival:</td>
<td>$ 171,659</td>
<td>Cost Saved by STEMI Survival:</td>
<td>$ 183,102</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Worst Case Scenario</th>
<th>5 Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value of Lives Saved:</td>
<td>$ 24,719,328</td>
</tr>
<tr>
<td>Cost of Hospital Death:</td>
<td>$ 178,596</td>
</tr>
<tr>
<td>Cost of Hospital Discharge:</td>
<td>$ 339,853</td>
</tr>
<tr>
<td>Cost Saved by STEMI Survival:</td>
<td>$ 160,215</td>
</tr>
</tbody>
</table>

Projected changes in major costs and benefits based on mortality rate projections are listed above. Total quantification of all changes to costs and benefits are provided in the table below.

<table>
<thead>
<tr>
<th>Sensitivity Analysis:</th>
<th>Alternative 2 Low Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>Best-Case</td>
<td>$22,378,053</td>
</tr>
<tr>
<td>Predicted</td>
<td>$20,589,499</td>
</tr>
<tr>
<td>Worst-Case</td>
<td>$18,800,945</td>
</tr>
<tr>
<td>Status Quo</td>
<td>$19,192,062</td>
</tr>
</tbody>
</table>

Appendix J: Field Fibrinolytics Cost-Benefit Analysis

Cost-Benefit Analysis Matrix[^1],[^2],[^3],[^4]  

<table>
<thead>
<tr>
<th>Stakeholders</th>
<th>Alternative 3: Field Fibrinolytics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frontier STEMI Patients</strong></td>
<td></td>
</tr>
<tr>
<td>Value of statistical life for fatal</td>
<td>$ 22,953,662</td>
</tr>
<tr>
<td>heart attacks prevented</td>
<td></td>
</tr>
<tr>
<td><strong>Healthcare Providers</strong></td>
<td></td>
</tr>
<tr>
<td>Costs saved by STEMI survival vs</td>
<td>$ 148,771</td>
</tr>
<tr>
<td>mortality</td>
<td></td>
</tr>
<tr>
<td><strong>Total Benefits</strong></td>
<td>$ 23,102,432</td>
</tr>
<tr>
<td><strong>Frontier STEMI Patients</strong></td>
<td></td>
</tr>
<tr>
<td>Average cost of frontier land</td>
<td>$ 12,912</td>
</tr>
<tr>
<td>ambulance use</td>
<td></td>
</tr>
<tr>
<td>Average cost of frontier air</td>
<td></td>
</tr>
<tr>
<td>ambulance use</td>
<td></td>
</tr>
<tr>
<td>Medical cost of STEMI survival</td>
<td>$ 582,814</td>
</tr>
<tr>
<td>Cost of PCI</td>
<td>$ 98,092</td>
</tr>
<tr>
<td><strong>Healthcare Providers</strong></td>
<td></td>
</tr>
<tr>
<td>Average cost of STEMI mortality</td>
<td>$ 214,315</td>
</tr>
<tr>
<td>Average cost of STEMI survival</td>
<td>$ 315,578</td>
</tr>
<tr>
<td>Outfitting air EMS</td>
<td></td>
</tr>
<tr>
<td>Operating air EMS</td>
<td></td>
</tr>
<tr>
<td>PCI equipment</td>
<td></td>
</tr>
<tr>
<td>EMS EKG equipment</td>
<td>$ 6,408</td>
</tr>
<tr>
<td>EMS EKG training</td>
<td>$ 11,700</td>
</tr>
<tr>
<td>Ambulance Physician Salary</td>
<td>$ 3,847,716</td>
</tr>
<tr>
<td><strong>Total Costs</strong></td>
<td>$ 5,089,534</td>
</tr>
<tr>
<td><strong>Net Present Value</strong></td>
<td>$ 18,012,898</td>
</tr>
</tbody>
</table>

Appendix K: Comprehensive Works Cited


Danchin, N., & Crea, F. (2012, August). FAST-MI Programme: Decrease in early mortality in STEMI is related to changing patient profile and behavior, as well as improved organization of care: Data from 4 French nationwide surveys over 15 years. Presentation presented at the Acute Coronary Syndromes, European Society of Cardiology.


Ischemia | deficient supply of blood to a body part (as the heart or brain) that is due to obstruction of the inflow of arterial blood. (n.d.). Retrieved January 4, 2015, from http://www.merriam-webster.com/dictionary/ischemia


