A Study of EMS Preparedness for Cardiac Arrest Victims: Comparing At-Risk Populations in Washington and West Virginia USA

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Keywords: Geographic Information Systems (GIS), ArcGIS, Analysis, Network Analyst, Cardiac Arrest, Emergency Response, Emergency Medical Services (EMS) Preparedness, Service Areas, Proportional Allocation

Abstract

This study investigates and compares the current networks of Emergency Medical Services (EMS) ambulance transport stations within the states of Washington and West Virginia USA. Findings highlight different populations within Washington and West Virginia who are at-risk of cardiac arrest and live outside the reach of timely ambulance response. Service areas around EMS stations were created using ArcGIS 10.3 and these areas were compared with data from the 2010 US Census. Demographic and socio-economic data were utilized to identify at-risk populations and suggestions are made for mitigating problems. Findings show West Virginia has a much larger percentage of its population at risk of poor EMS response than Washington. In West Virginia, the greatest risk is for rural populations while Washington has a noticeable problem in response to urban populations.

Introduction

After cardiac arrest occurs, the chances of survival decrease by 7–10% for every minute that passes without CPR and defibrillation (Larsen, Eisenberg, Cummins, and Halstrom, 1993). This statistic is backed by the American Heart Association (AHA) (American Heart Association. 2013). It is therefore vital first responders reach cardiac arrest victims quickly, because after only 5 minutes the victim's chances of survival can diminish by as much as 50%. After 10 minutes, chances of survival are 0-30%. Table 1 shows the correlation between time and chance of survival for 1 to 10 minutes.

This need for urgent response to cardiac arrest victims necessitate a study to determine populations who may be at risk. The primary risk is purely geographical. If people live and work in areas far from Emergency Medical Services (EMS) stations where ambulances are most often dispatched from, it will take longer for those ambulances to reach them in case of an emergency.

A more detailed analysis can then be investigated by looking at the populations of these areas, using census data, to find out exactly how many people there are at risk of not getting the required timely medical attention in case of a cardiac arrest.

This study explores state-level data for Washington and West Virginia USA. These two states are of interest due to their differences and it is interesting to see the

Harding, Matthew I. 2016. A Study of EMS Preparedness for Cardiac Arrest Victims: Comparing At-Risk Populations in Washington and West Virginia. Volume 19, Papers in Resource Analysis. 12 pp. Saint Mary's University of Minnesota University Central Services Press. Winona, MN. Retrieved (date) from http://www.gis.smumn.edu

status of each state's EMS network. West Virginia has a much smaller population than Washington but a larger percentage of its population lives away from major urban areas.

Table 1. A summary of the correlation between minutes passed since cardiac arrest and the chances of survival (Larsen *et al.*, 1993).

Minutes after Cardiac Arrest	Average Chance of Survival
1	90-100%
2	80-100%
3	70-100%
4	60-90%
5	50-80%
6	40-70%
7	30-60%
8	20-50%
9	10-40%
10	0-30%

When viewing EMS locations in each state, West Virginia appears to have a more even distribution of EMS stations than Washington (Figures 1 and 2).

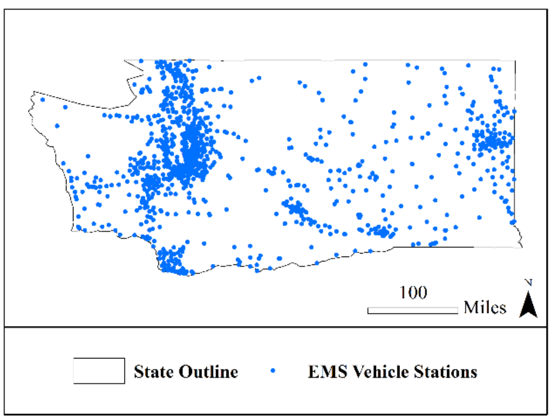

Figure 1. Emergency Medical Service (EMS) ambulance stations in Washington, US.

Research suggests (Centers for Disease Control and Prevention, 2010) that heart disease is the leading cause of death in males and females aged 65+ with 27.3% and 25.9% of all deaths relating to this respectively. In males, the first age group where heart disease becomes the major cause of death is 45-54 with 23.3% of all deaths attributed to heart disease. For females, 17.0% of deaths are caused by heart disease in the 55-64 age range.

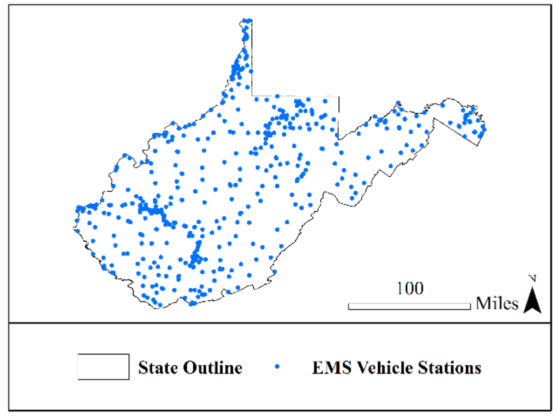

Figure 2. Emergency Medical Service (EMS) ambulance stations in West Virginia, US.

In America, much more emphasis is starting to be placed on preventive health care as a means of reducing health care costs and saving lives. Maciosek, Coffield, Flottemesch, Edwards and Solberg (2010) found that with a panel of 20 different preventive screenings, 1563.9 life-years could be saved, per 10,000 people, per year of intervention. The average cost of these services was $1,001.00 per person, per year. Maciosek *et al.* (2010) found that as a result of these health screenings, subjects needed less reactive health care, saving each person an average of $1,049.20 per year.

From this study we can conclude that not only does preventive health care prolong life and avoid health issues, but it can also cost less than if people contract those health issues and have to pay for treatment. Preventive care can include many different medical screenings and preventive treatments but the ones which appeared to contribute to the biggest cost savings were; childhood immunizations ($267 savings per year); pneumococcal immunization ($67 savings per year); discussion of daily aspirin use ($66 savings per year); smoking cessation advice and assistance ($40 savings per year); and alcohol screening and brief counseling ($11 savings per year). These 5 treatments combined contributed to a savings of 1407 life years per 10,000 people per year. The study also showed other treatments that contributed to saving life-years, but they cost more than the reactive health care solution (Appendix A).

Affordable preventive care is usually more attainable for people who have health insurance. Therefore, finding populations who do not have health insurance and live more than 10 minutes from an EMS station would help at-risk populations.

Another statistic which pairs well with this is the populations who are living below the poverty line. Table 2 shows the US Department of Health and Human Services (HHS) poverty guidelines for 2010 from The Office of the Federal Register (OFR) of the National Archives and Records Administration (NARA) (2010).

Table 2. The U.S. Department of Health and Human Services poverty guidelines for 2010 for the 48 Contiguous States and the District of Columbia (The Office of the Federal Register [OFR] of the National Archives and Records Administration [NARA], 2010).

Persons in Family	Poverty Guideline
1	$10,830
2	$14,570
3	$18,310
4	$22,050
5	$25,790
6	$29,530
7	$33,270
8	$37,010

For families with more than 8 persons, add $3,740 for each additional person.

Methods

Survival windows were created to outline benchmarks in response times. According to research (Wellens, Gorgels, and De Munter, 2003), a good response to cardiac arrest would be within 4 minutes. There is approximately a 50% chance of survival within 6 minutes and only a 10-40% chance of survival within 10 minutes. Response times over 10 minutes result in a 0-30% chance of survival. Therefore, windows of 0-4 minutes, 4-6 minutes, 6-10 minutes, and 10 or more minutes were used to create service areas around EMS stations.

The North America Detailed Streets layer package was used as the transportation network source for both states. This dataset was created by ESRI and TomTom and includes major roads, freeways and detailed streets. The Washington features (Figure 3) and West Virginia features (Figure 4) were extracted from the data and saved as separate geodatabases.

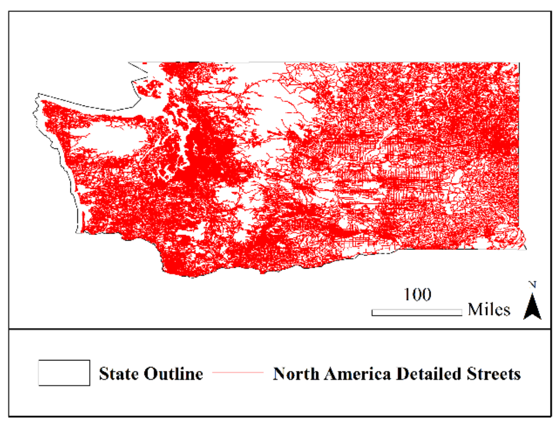

Figure 3. Transportation network of Washington derived from the North America Detailed Streets dataset (ESRI, 2014).

ArcGIS Desktop 10.3 was used to ensure that all roads had speed limit attributes which were required to create timed service areas. Any roads without speed limits were populated with the same speed limit as similar surrounding road types. Topological errors were corrected to

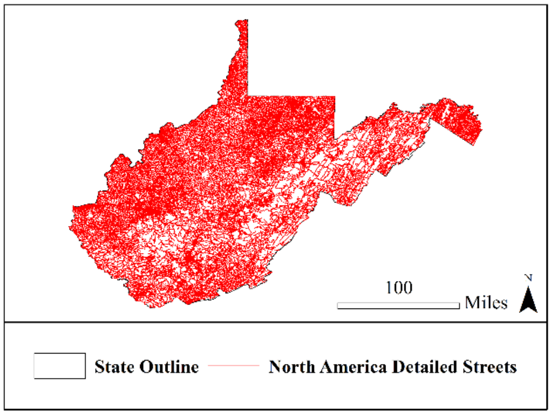

Figure 4. Transportation network of West Virginia derived from the North America Detailed Streets dataset (ESRI, 2014).

remove any small gaps in the network where roads should connect. ArcGIS Network Analyst (ESRI, 2005) was used to create a network dataset from the transportation lines and service areas. Research suggests that, on average, ambulances travel very close to posted speed limits when responding to a call so the speed limit attributes in the transportation lines were not altered. Service areas were created for the cardiac survival windows of 0-4 minutes, 4-6 minutes and 6-10 minutes. Any areas of the state not within these service areas constitute an EMS response greater than 10 minutes. Figure 5 shows an example in Washington of the resulting service areas near the city of Centralia, Washington. Figure 6 shows an example of service areas near the city of Fairmont, West Virginia.

The ArcMap Intersect geoprocessing tool was used to divide the service areas along census tract boundaries. Then a proportional allocation calculation was made to estimate populations (Int_Pop) within each intersection between census tracts and service areas. Figure 7 is an example of the intersections between service areas and census tracts near the city of Orting, Washington. Figure 8 is a similar example near the city of Buckhannon, West Virginia.

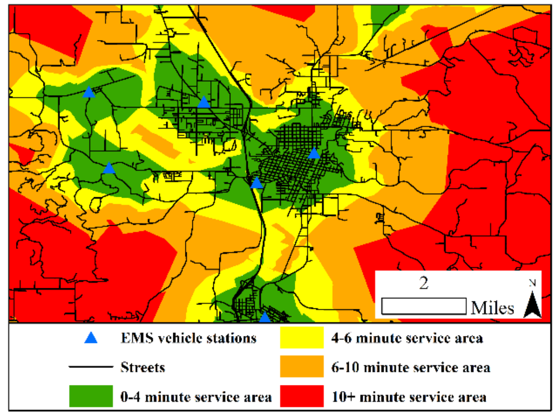

Figure 5. Example of service areas around EMS stations in Centralia, WA, approximately 70 miles south and southwest of Seattle, WA.

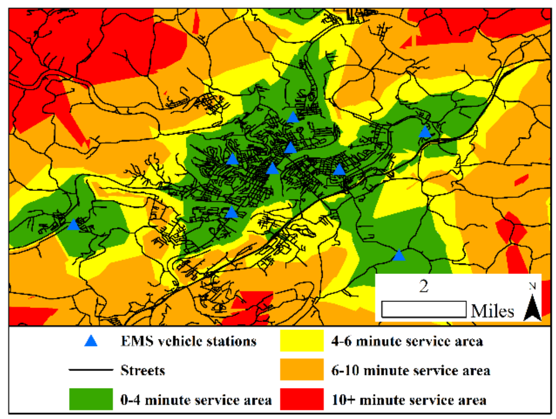

Figure 6. Example of service areas around EMS stations in Fairmont, WV, approximately 112 miles northeast of Charleston, WV.

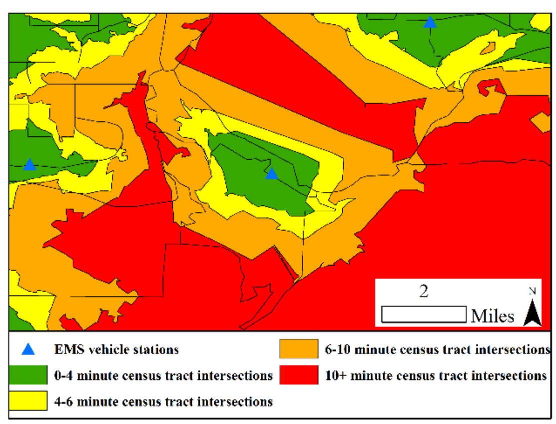

Figure 7. Example of intersected service areas and census tracts near Orting, WA, approximately 36 miles south of Seattle, WA.

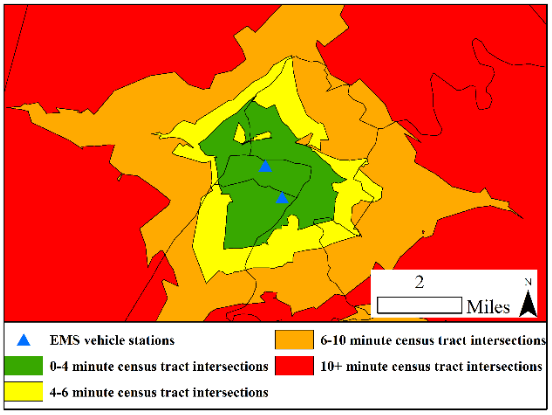

Figure 8. Example of intersected service areas and census tracts near Buckhannon, WV, approximately 88 miles east and northeast of Charleston, WV.

The formula used for proportional allocation was:

Int_Pop = intersecting population
Int_Area = intersecting area between census tract and service area
Census_Area = census tract area
Pop = total census tract population for given US Census category

$$\text{Int\_Pop} = \text{Pop} \times \frac{\text{Int\_Area}}{\text{Census\_Area}}$$

Once the intersections were created and the areas of each intersection calculated using Calculate Geometry, these attribution tables were exported to Excel where the remaining calculations on census data were completed. Microsoft Excel Power Query was used to merge different census data columns to the exported intersected service areas based on census tract IDs. The census data was obtained from the 2010 US Census.

US Census Population Data

The first statistic calculated was the total populations that fell within each of the service area bands. The greater the percentage of population that falls within the 0-4 minute's response area, the greater the likelihood of more people surviving cardiac arrest and therefore showing a better state's EMS preparedness. This was repeated for the other service bands of 4-6 minutes, 6-10 minutes and finally areas where response took 10 or more minutes.

At-risk Populations

With research suggesting an increased occurrence of cardiac arrest in people aged 65 years or older (Centers for Disease Control and Prevention, 2010), census tract data for this age group was isolated and linked with the intersected census tracts found in the 10 or more minute service areas using Power Query in Microsoft Excel. The estimated population was then calculated using proportional allocation. The same steps were used to calculate the number of males aged 45 years and older in these areas and females aged 55 years and older.

Outside of populations determined by age and gender, it was determined that other factors could also be isolated in census data and undergo a proportional allocation to determine other at-risk populations.

Therefore, populations living below the poverty line and those who did not have health insurance and lived in the 10 minute or greater service areas were calculated using the same process as the age and gender calculations. The health insurance and poverty level data came from the 2010 American Community Survey and the gender and age figures from 2010 US Census data.

Finally, a study of areas that are classified as urban but are in the 10 minute or greater service areas was undertaken. The 2010 urban area shapefile was downloaded from the US Census bureau (US Census Bureau, 2010) and the intersect geoprocessing tool run between the urban areas and 10 minute or greater service area. Figures 9 and 10 show the distribution of urban areas in Washington and West Virginia respectively at the time of the 2010 Census (US Census Bureau, 2010).

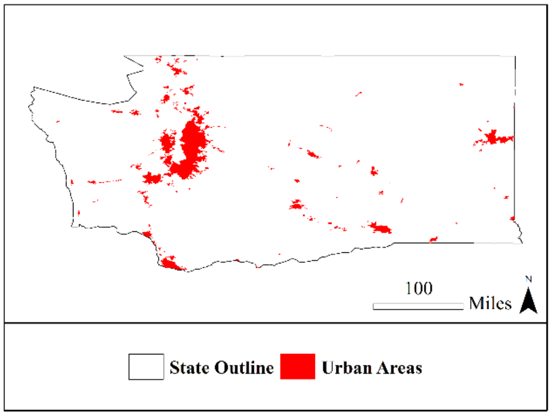

Figure 9. Distribution of areas designated as urban in Washington at the time of the 2010 US Census (US Census Bureau, 2010).

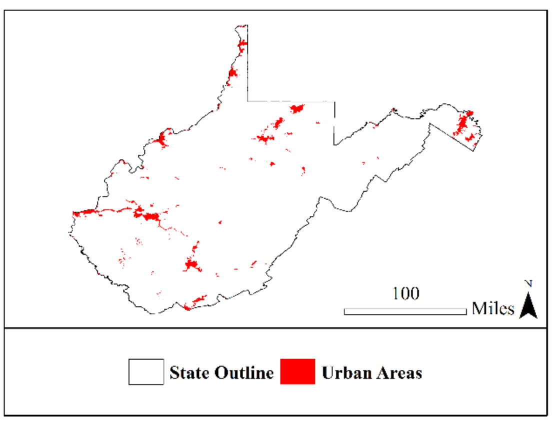

Figure 10. Distribution of areas designated as urban in West Virginia at the time of the 2010 US Census (US Census Bureau, 2010).

The result was then intersected with the census tracts and proportional allocation used to find the population in each census tract within urban areas who were in the 10 minute or greater service areas.

The results of these calculations were then totaled to find the total urban population in the 10 minute or greater service areas.

Results

A different prediction of populations by census criteria was calculated within the 10+ minute service areas using the proportional allocation calculation:

Int_Pop = intersecting population
Int_Area = intersecting area between census tract and service area
Census_Area = census tract area
Pop = total census tract population for given US Census category

$$\text{Int\_Pop} = \text{Pop} \times \frac{\text{Int\_Area}}{\text{Census\_Area}}$$

These results were compared to the total state population to see what percentage of residents was predicted by each model. Figure 11 shows the calculated population in each service area for Washington and West Virginia.

Proportional allocation of census tract populations intersecting the service areas show that Washington had a much higher percentage of people within the 0-4 minute service area (60-100% chance of survival from cardiac arrest) than any other area and could respond quickly to over 40% of its population. Within this same model, West Virginia could respond to only 22.8% of its population.

Washington's response in the 4-6 minutes service area (40-60% chance of survival from cardiac arrest) covered 23.5% of the state's population, whereas West Virginia could respond to only 12% of its population.

In the 6-10 minutes service areas (0-40% chance of survival from cardiac arrest), Washington EMS could reach

17.5% of its population while West Virginia reached 20.7% of its population.

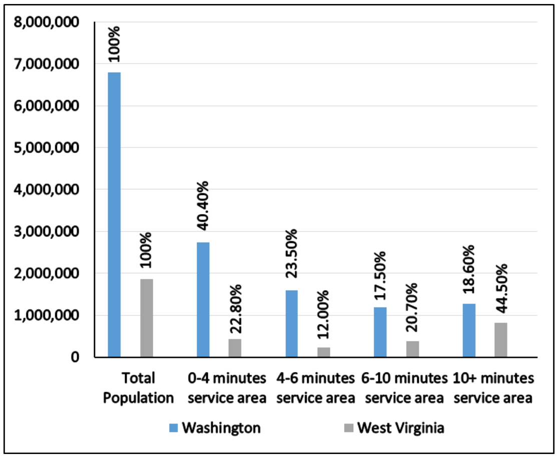

Figure 11. Total state populations and populations within each service area for Washington and West Virginia.

The striking statistic of this study is the percentage of each state's population that lived in the 10 minutes or greater service areas and therefore have a much lower chance of survival if they suffer a cardiac arrest and are reliant on EMS responders to provide initial resuscitation. Washington had 1,267,555 residents in these areas which constituted 18.6% of its total population. West Virginia had 823,925 residents in areas where EMS cannot reach victims within 10 minutes. This amounts to 44.5%, or nearly half, of the state's total population.

The 10 minutes or greater service areas were analyzed against census tract data for age and gender groups who are statistically at-risk of cardiac arrest and for people who are reported to live below the poverty line or have no health insurance.

Figure 12 shows Washington had a lower percentage of its 65 years or older population in 10 minutes or greater service areas (2.75%, 187,304 people) than West Virginia (7.49%, 138,767 people). For males aged 45 years and older in the 10 minutes or greater service areas, Washington had 286,369 people in this group, just over 4% of the total population. West Virginia had 191,281 people in this group, over 10% of its population.

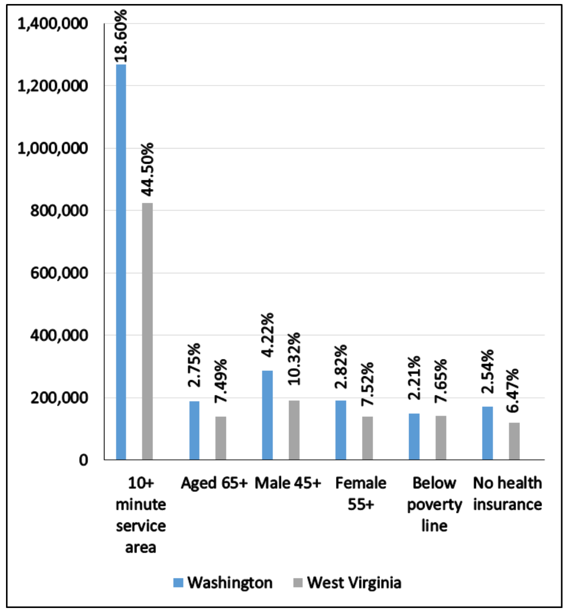

Figure 12. Population in the 10 minute and greater service area and populations of each studied demographic in the 10 minute and greater service area for Washington and West Virginia.

For females aged 55 years or older. There were 191,664 women in the 10 minutes or greater service area for Washington (2.82% total population) and in West Virginia there were 139,339 (7.52%) people.

The number of people within each state who were in the 10 minutes or greater service area and lived below the poverty line was similar with 149,752 (2.21%) in Washington and 141,701 (7.65%) in West Virginia.

Finally, there were 172,281 (2.54%) people in Washington who lived more than 10 minutes from an EMS station and did not have health insurance. West Virginia had 119,816 (6.47%) of its population living more than 10 minutes from EMS services and without health insurance.

3.5% of Washington consisted of urban areas at the time of the 2010 census and 2.7% for West Virginia. Table 3 shows the result of intersecting these urban areas with the 10 minutes or greater service areas to find the urban populations who are at risk from poor EMS response times. In Washington there were 290,822 people (4.3% of the population) living in these areas. In West Virginia there were 30,756 people (1.7% of the population) in a similar circumstance.

Table 3. Total state population and population of urban and rural inhabitants within the 10 minutes or greater service areas.

	Washington	West Virginia
Total Population	6,789,673	1,852,994
Urban	290,822	30,756
Rural	976,733	793,169

Discussion

In 2010, 44.5% of West Virginia's population lived in areas where EMS response was greater than 10 minutes. This shows that even though West Virginia had a small population compared to Washington, it would struggle to reach almost half its population within 10 minutes which would more than likely prove insufficient for cardiac arrest victims, as survival chances decrease by 7-10% every minute after cardiac arrest (Larsen *et al*., 1993). This can be attributed to West Virginia having a large rural population (51%) (US Census Bureau, 2010) and highlights the need for either more EMS stations in rural areas or increased use of air ambulances.

From Table 3 we can see that Washington had a larger percentage of its population in urban areas than West Virginia (US Census Bureau, 2010). This helps to explain Washington's ability to respond to 81.4% of its population within 10 minutes.

In the 65 years and older age range, each state had a similar number of people living in the 10 minutes or greater service area. However, the proportion of the population varied with Washington at 2.75% and West Virginia at 7.49%. This represents populations who have an acute risk of cardiac arrest due to their age and have a low chance of receiving timely medical assistance and therefore a low chance of survival. These populations should be more closely identified and targeted to receive extra care and consideration.

Males chances of a cardiac arrest increase dramatically after the age of 45 (Centers for Disease Control and Prevention, 2010) and in the 10 minutes or greater service areas, Washington had 286,369 people in this group which accounts for just over 4% of the total population. West Virginia had 191,281 people in this group, which was over 10% of its population. While these groups are at less risk than the over 65 years age group they represent a large number of people who should receive targeted preventive health education.

Females chances of cardiac arrest increase after the age of 55. There were 191,664 women in this age group in the 10 minutes or greater service area for Washington (2.82% of the population) and West Virginia has 139,339 (7.52%) in this category. These populations would benefit greatly from preventive medical screening.

Both Washington and West Virginia had a similar number of people living in poverty in the 10 minutes or greater service areas, with 149,752 and 141,701 people respectively. These populations are in particular need of preventive health care to increase life expectancy and as this has proven to be cheaper than treating medical conditions which may arise from not having preventive health care (Maciosek *et al*., 2010).

People without health insurance living in the 10 minutes or greater service areas were similar in number to those living below the poverty line in the 10 minutes or greater service areas. Washington had 172,281 people in this category and West Virginia had 119,816. It is more than likely that this represents most of the same people who are living below the poverty line.

The test to find urban populations who were in the 10 minutes or greater service areas shows that Washington has a greater problem with providing enough EMS resources in urban environments than does West Virginia, necessitating a need for an urban solution, mostly likely in the form of more EMS stations. In West Virginia the problem is significantly more rural, highlighting a need for more rural solutions to problems with EMS response. A rural population is sparse in nature, making more EMS stations less effective in a cost-benefit analysis. These populations are better served by alternative de-centralized solutions such as health education and different types of EMS response such as air ambulances.

Conclusions

When responding to cardiac arrest victims, the chances of survival greatly diminish as response time increases. If response is outside of the 10 minute window, a cardiac arrest victim's chances of survival are less than 30%. There are very different levels of EMS preparedness between states, particularly when you think of potential cardiac arrest victims. At the time of the 2010 US Census, 55.5% of West Virginia's residents lived within 10 minutes of ambulatory response. At the same time, 81.4% of Washington's residents lived within 10 minutes of ambulatory response. This is striking given that Washington has more than three times the population of West Virginia.

In the urban areas of each state, particularly Washington, there appears to be a need for more EMS stations, the exact locations of which could be determined by closer analysis of these areas using real-world EMS response data.

After identifying areas outside of the 10 minute window, it is possible to find populations who are particularly at risk due to gender, age, health or economic factors and provide resources to those people to mitigate the risk of not only cardiac arrest but any other emergency medical situation. The most obvious, but costly, solution is to build more EMS stations and employ more paramedics in rural areas. However, there are less costly alternatives such as: community education in basic first aid and CPR (Cardio-Pulmonary Resuscitation), provision of AEDs (automated external defibrillators), promoting healthy lifestyles, and the encouragement of community support and networks to support those who are at risk.

Increasing community CPR education programs for family, neighbors or coworkers could provide initial first response care while the EMS crews are on their way. The prevalence of AEDs in public areas and workplaces has done a lot to speed up first response and increase survival rates to cardiac arrest victims in urban areas (American Heart Association, 2013) and with the price of AEDs reducing dramatically over recent years these could be incorporated more in rural communities to help with initial response. Many states, including West Virginia, have laws providing liability exemption for trained users of AEDs, therefore limiting liability toward unanticipated users who render aid (AED Brands, 2015)**.**

The risk to these populations could be reduced by placing AEDs at rural town halls, at prominent highway intersections accessible by local, trained volunteers and in the rural homes or workplaces where there is a known risk of cardiac arrest and a family member or coworker could provide CPR/AED response. It is in the best interests of health and life insurance companies to provide these machines and training at discounted cost or even free, to potentially reduce medical expenses and life insurance payouts on term-life insurance policies.

West Virginia state police are all trained in CPR first response and having all state and local police vehicles equipped with AEDs would help provide a more successful response as the police are out on patrols in the community.

The US government has taken steps to reduce the number of uninsured people in recent years. Since 2014, the Patient Protection and Affordable Care Act (PPACA), often referred to as Obamacare, requires everyone to have health insurance either privately, through employment or through the health insurance marketplace. Failure to do so results in financial penalties. This is intended to give everyone access to affordable health care (Obamacare Facts, 2015). New results from the Commonwealth Fund Biennial Health Insurance Survey, 2014, indicate that the Affordable Care Act's subsidized insurance options and consumer protections reduced the number of uninsured working-age adults from an estimated 37 million people, or 20 percent of the population, in 2010 to 29 million, or 16 percent, by the second half of 2014 (Collins, Rasmussen, Doty, and Beutel, 2015).

Through further study and identification of at-risk populations, increased health education, preventive health care, and investment in life saving facilities and equipment, the chances of survival for cardiac arrest victims of all ages and economic standing can be improved.

Acknowledgements

I would like to thank Dr. David McConville, John Ebert and Greta Poser of Saint Mary's University for their support and encouragement throughout graduate school and this project. I would also like to thank my loving wife Jessica for her unending support and patience throughout graduate school and especially during this research and writing.

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Appendix A. Breakdown of preventive health care services showing average life-years saved per 10,000 people per year of intervention and associated costs and savings (Maciosek *et al.*, 2010).

Clinical preventive service	Life-years saved per 10,000 people per year of intervention	Medical cost of service per person per year	Medical savings of service per person per year	Annual net medical cost savings per person per year
Childhood immunizations	1,233.10	$306.00	$573.00	$267.00
Influenza immunization	23.8	$28.00	$20.00	-$8.00
Pneumococcal immunization	6.4	$46.00	$113.00	$67.00
Tetanus-diphtheria booster	0.1	$4.00	$0.20	-$4.00
Discuss daily aspirin use	63	$21.00	$87.00	$66.00
Discuss folic acid use	2	$9.00	$2.00	-$7.00
Smoking cessation advice and assistance	97.5	$10.00	$50.00	$40.00
Alcohol screening and brief counseling	7	$9.00	$20.00	$11.00
Breast cancer screening	45	$64.00	$3.00	-$61.00
Cervical cancer screening	2.1	$49.00	$8.00	-$41.00
Chlamydia screening	0	$18.00	$12.00	-$6.00
Cholesterol screening	27.8	$128.00	$24.00	-$104.00
Colorectal cancer screening	40.8	$46.00	$31.00	-$15.00
Depression screening	0	$42.00	$0.00	-$42.00
Hearing screening	0	$23.00	$0.00	-$23.00
Hypertension screening	10.7	$79.00	$50.00	-$29.00
Obesity screening	1	$10.00	$15.00	$5.00
Osteoporosis screening	1.5	$90.00	$19.00	-$71.00
Vision screening (adults)	2.1	$5.00	$22.00	$17.00
Vision screening (children)	0	$14.00	$0.00	-$14.00
Totals	**1563.9**	**$1,001.00**	**$1,049.20**	**$48.00**