Call Analysis of Cardiac Related Events

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Abstract

Resource management is a crucial part of being able to adequately serve clients. Geographic Information Systems (GIS) have become an important tool for managing those resources and assessing client needs. Specific to emergency medical services (EMS), this includes analysis of everything from geographic locations of calls to response times to the equipment used on calls. Resource management is critical when serving a large area and specific tools can make managing resources easier. GIS is such a tool that has the ability to make data more relevant and decision-making more efficient. The intent of this study is to perform a retroactive call analysis of calls from 2010 for five possible cardiac related call types (cardiac/ respiratory arrest, chest pain, heart problem, unconscious/fainting, and unknown/man down) for an ambulance service in the upper Midwest. Data were analyzed with visual representation of geocoded calls de-identified for confidentiality, symbolized by graduated colors by zip code and response time, as well as numerical statistical analysis. Through GIS data processing and statistical analysis, results show geographic location, frequency, distribution of and response to possible cardiac related events in 2010.

Introduction

Significance of Research

The exact number of cardiac arrests experienced in the United States per year is unknown. Hess and White (2010) cite 154,800 out of hospital cardiac arrests (OHCAs) annually from extrapolation of U.S. Census data 2000, while Nichol, Thomas, Callaway, Hedges, Powell, Aufderheide, Rea, Lowe, Brown, Dreyer, Davis, Idris, and Stiell (2008) cite a range of 166,000 to 310,000 from the American Heart Association 2008 update on heart disease and stroke statistics. Myerburg, Fenster, Velez, Rosenberg, Lai, Kurlansky, Newton, Knox, and Castellanos (2002) cite OHCAs "account for 50% of cardiovascular deaths." According to Roger, Go, Lloyd-Jones, Adams, Berry, Brown, Carnethon, Dai, de Simone, Ford, Fox, Fullerton, Gillespie, Greenlund, Hailpern, Heit, Ho, Howard, Kissela, Kittner, Lackland, Lichtman, Lisabeth, Makuc, Marcus, Marelli, Matchar, McDermott, Meigs, Moy, Mozaffarian, Mussolino, Nichol, Paynter, Rosamond, Sorlie, Stafford, Turan, Turner, Wong, and Wylie-Rosett (2010), 33.6% of all 2007 deaths showed an underlying cause of death to be cardiovascular disease related, with 295,000 OHCAs annually (quasi confidence 236,000 to 325,000). Despite the variation of the statistics, it is known that cardiovascular disease related deaths

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are the number one cause of death in the United States (Roger *et al*., 2010).

In the event of cardiac arrest, it is imperative the heart restores an effective rhythm and function as soon as possible. Cummins, Ornato, Thies, and Pepe (1991) describe a chain of survival with four links necessary to increase survival from cardiac arrest. These links are: early access to an emergency medical system, early cardiopulmonary resuscitation (CPR), early defibrillation, and early advanced care.

Shockable Rhythm and Response Time

An automated external defibrillator (AED) is a portable electronic device that recognizes whether a patient in cardiac arrest has a shockable rhythm and can deliver a defibrillating dose of electricity. Shockable rhythms include ventricular fibrillation (VF) and ventricular tachycardia (VT). Defibrillation has been shown to be most effective if delivered within the first 4 minutes of cardiac arrest and efficacy decreases as time passes, especially after 10 minutes (Weisfeldt and Becker, 2002). According to Stiell, Wells, Field, Spaite *et al*. (2004), survival was best with witnessed arrest, bystander CPR, and defibrillation within 8 minutes.

In a study completed by Nichol *et al*. (2008), 7.9% of the total cardiac arrest patients survived to discharge, compared to 21% of those same patients who had original rhythms of VF. The median response time was 7:24 minutes.

Geographic Patterns

Research studies show calls have geographic patterns so it is imperative to analyze and assess call locations, high frequency areas, response times, and call types to best position EMS resources to reach patients (Lerner, Fairbanks, and Shah, 2005; Ong, Tan, Yan, Anushia, Lim, Leong, Ong, Tiah, Yap, Overton, and Anantharaman, 2008). Analysis can be used to identify possible relationships with population movement throughout time periods either during the day, day of the week, month of the year, etc. Examining factors surrounding cardiac related events may not offer a direct cause and effect relationship however when studied over time may reveal patterns of occurrence.

Study Area

The study focuses on a multisite ambulance service serving multiple cities with a population of 120,000 and less across a two State region. In one specific area they cover portions of five counties: County A, County B, County C, County D, and County E. Response in this area covers over 60 townships, including 35 towns, with a total population of approximately 150,000.

Study Purpose

When a cardiac related event occurs, every minute counts. The sooner appropriate resources reach the patient, the better the chance of survival (Cummins *et al*., 1991). The purpose of this study was to analyze one year of cardiac related call types, focusing on call frequency per zip code, call distribution, and response times. An eight minute benchmark was used for the response time analysis (Stiell *et al*., 2004, Weisfeldt and Becker, 2002).

Methods

Data Acquisition and Software

Data was obtained from the ambulance service for the primary service area (PSA) boundaries, zip codes, and Priority 1 (emergent) 2010 calls. The 2010 U.S. Census Bureau TIGER/Line shapefiles were also utilized for zip code boundaries. The 2010 call spreadsheet included: Identification Number, Address, City, Zip, County, Comments, and Call Type. It also included time metrics of: Started, Assigned, Enroute, At Scene, and Transport. Lastly, ArcGIS 10.1 software was used for the analysis.

Data Organization and Manipulation

The 2010 call spreadsheet contained call types with and without codes (example '10-C-1' versus 'chest pain'). All codes were removed and replaced with worded call types. The call type column was standardized for ease of sorting later (ex: 'cardiac arrest' changed to match 'cardiac/respiratory arrest'). Data were then sorted to select the desired five call types: cardiac/respiratory arrest, chest pain, heart problem, unconscious/fainting, and unknown/man down. The next step involved removing duplicate calls (example: where a second ambulance was sent to assist), mutual aide requests, and intercept requests. A response time column was then added and computed for each call using time columns of Enroute and At Scene.

With the table formatted, the next step was to add layers and geocode addresses. PSA boundaries and zip codes were added; source projections were noted and transformed as needed. The two PSA layers were combined. The street layer was already one complete PSA. All layers were then clipped to match the new combined PSA. Call addresses were then geocoded using the 10.0 North American Geocode Service (ArcGis Online) address locator in ArcMap 10.1.

Analysis and comparisons were completed by zip code, city, county, or PSA and symbolized to represent values and locations without making individual information identifiable.

Statistics

Percentages, descriptive statistics, and measures of variability were computed for zip code, city, county, and full spreadsheet comparison and visualization from methods found in Zar (2010). Data were represented with tables, box-and-whisker plots, scatter plots, pie graphs, as well as maps with graduated colors and symbols.

Sample variance was calculated for these data with the following equation:

$$s^2 = \sum ((x_i-\overline{x})^2/n-1)$$

The sample standard deviation (SD) was calculated as the square root of variance.

The Chi Square Goodness of Fit test was used to assess how much the three main city (City 11) zip code sample observations differed from the hypothesized distribution of cardiac/respiratory arrests. Where f_i equals the frequency observed, $\hat{f}_i$ equals the expected frequency.

H_0 = The sample from the population has a 1:1:1 ratio of calls in each zip code.
H_a = The sample from the population does not have a 1:1:1 ratio of calls in each zip code.

Zip code 00001, $f_i = 21$
Zip code 00003, $f_i = 25$
Zip code 00004, $f_i = 17$
$\hat{f}_i = 21$ (expected)

$$X^2 = \sum ((f_i - \hat{f}_i)/ \hat{f}_i)$$

Results and Discussion

Call Frequency

The dot density map (Figure 1) showed all calls within the PSA. The highest quantities of dots are seen surrounding City 11 in the southern portion of the PSA.

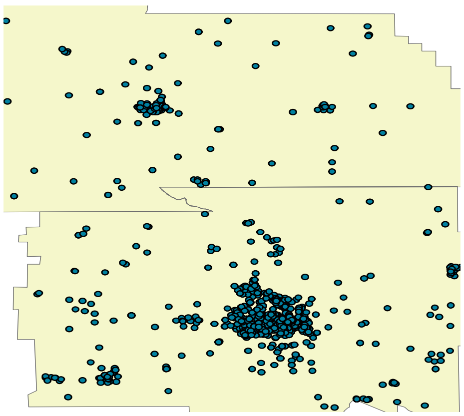

Figure 1. Dot density map of all 2010 calls. Beige shading is the PSA, approximately 30 square miles. Each dot represents a call.

The following table shows percentages of total population and total calls in cities where 15 or more calls occurred (Table 1). City 11 accounted for 45.9% of the calls. Its population is 47.5% of the PSA, thus a near proportionality between call volume and percent of the total PSA population.

City 2 did not show the same level of proportionality. The city accounted for 1.5% of total calls with only 0.4% of the total PSA population thus nearly four times the amount of calls compared to population.

Similarly, in the northern portion of the PSA, the largest city, City 6, accounted for 7.9% of the total calls with its population being 5.6% of the PSA population, a somewhat higher call rate than percent of population. City 7 accounted for 1.8% of total calls with its population being only 0.9% of the PSA population thus a call volume twice that of the population.

Table 1. Cities that had 15 or more calls in 2010. Individual percentages of total population and total calls.

City	% Total Population	% Total Calls
City 1	0.9	1.4
City 2	0.4	1.5
City 3	1.2	1.4
City 4	2.7	3.9
City 5	1.7	2.8
City 6	5.6	7.9
City 7	0.9	1.8
City 8	0.9	1.7
City 9	8.6	8.9
City 10	10.6	6.5
City 11	47.5	45.9
City 12	4.4	2.7
City 13	4.5	5.7

Age distribution could explain some of the difference in call frequency compared to percent of the total population. City 11 has a median age of 29 years with only 10% of the residents 65 years or older. City 6 has a median age of 41 years with 21% of its population 65 years or older. City 7 has a median age of 43 years with 27% of its residents 65 years or older. This is the highest city percent of residents 65 years and older in the PSA.

County B, which contains both City 6 and City 7, has a median age of 41 and 16% of the population 65 years and older (Table 2). The other counties in the PSA have a 65 years and older population of 12% or less.

Calls were also displayed by zip code (Figure 2). Four zip codes contained over 100 calls. Three of these were City 11 zip codes, all with larger concentrations of people. The fourth was City 9, which is the town adjacent to the northeast of City 11. Combined, these two cities made up

54.8% of the calls with 56% of the total service area population.

Table 2. County breakdown of median age and percent of total population of 65 years and older.

County	Median Age	Percent of Population 65+
A	34	12
B	41	16
C	34	8
D	33	12
E	35	10

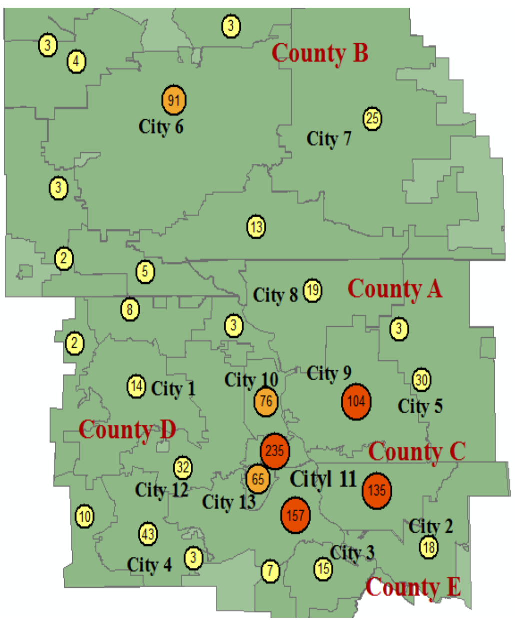

Figure 2. All 2010 calls by zip code. Represented by graduated color and graduated symbol (Yellow = 1-50, Orange = 51-100, Red = 101-235). PSA is about 30 square miles.

City 6, City 10, and City 13 zip codes had between 50 and 100 calls. The remaining zip codes ranged from 1-50 calls. Overall distribution by city showed a mean of 34 calls with a SD of 16 calls. However, there was a median of 5 calls, range of 498 calls, and a variance of 227 calls. There was a large variation of call frequency per city.

Examining call frequency by county showed County B ranged from 1-91 per zip code (Figure 3). This equated to 13.4% of all calls with 9.5% of the total service area population. County A ranged from 2-97 calls per zip code while County D was 3-235. County C and County E each had one zip code in the PSA, with call frequencies of 16 and 15 respectively (Figure 4).

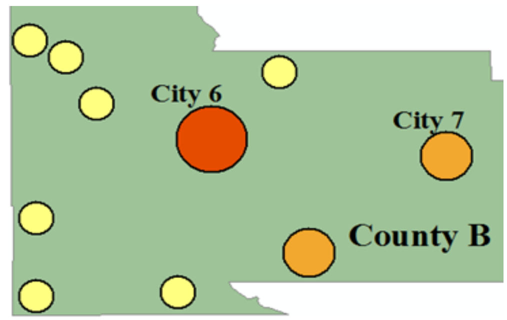

Figure 3. Primary cities in County B represented by graduated color and symbol for frequency of calls by zip code (Yellow = 1-5, Orange = 6-25, Red = 26-91). Area is about 30 miles x 15 miles.

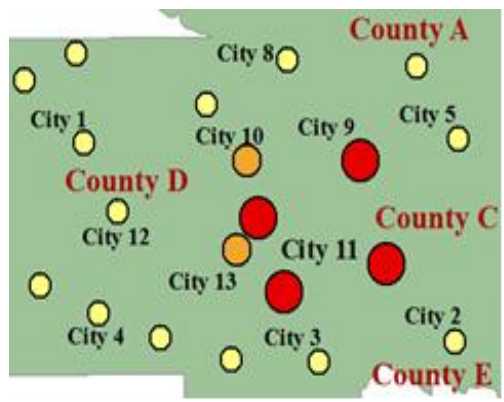

Figure 4. Primary cities by graduated color and symbol for frequency of calls by zip code (Yellow = 1-50, Orange = 51-100, Red = 101-235). Area is about 30 miles x 20 miles.

Quantity of calls by county showed: County A with 241, County B with 146, County C with 59, County D with 630, and County E with 12 of the total 1,088 calls (Figure 5). The distribution showed the average was 218 calls with a median of 146 calls, range 618 calls, variance of 224 calls, and SD of 15 calls.

Overall, the call frequency rate largely mimicked population density with the largest call rates occurring in the more densely populated areas. Given that the population for the southern section of the PSA had nearly 10 times the population of the northern section, it is logical that 87% of calls came from that area.

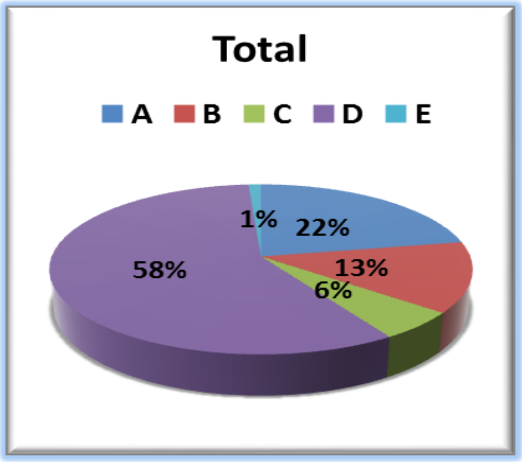

Figure 5. All 2010 calls represented with percentages by county with n = 1088.

Call Type

The majority of cardiac related events responded to were chest pain. This call type accounted for 559 out of the total 1,088 calls or 51% (Figure 6). County distribution showed a mean of 112 calls, a median 69 calls, and SD 11 calls (Table 3). Chest pain also had the highest range and variation of frequency. Heart problems and unconscious/fainting both accounted for 14% of the calls. Their means and medians were similar to each other and each had standard deviations of 5 calls showing a relatively homogeneity of distribution of these call types per county.

The Chi Square Goodness of Fit test was used to examine incident equality specifically for cardiac/respiratory arrest calls in the three City 11 zip codes. It showed $x^2 = 1.52$. The null hypothesis (H_0) of incident equality was not rejected ($0.50 > p > 0.25$).

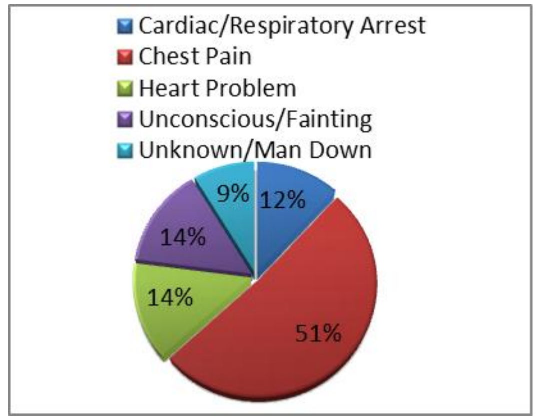

Figure 6. All 2010 calls represented with percentages by call type.

Response Times

Of the 1,037 calls an ambulance arrived on scene, there was an average response time of 8 minutes. The median was 6 minutes and the mode was 5 minutes. All three of these descriptive statistics were less or equal to the benchmark of eight minute response time. The range of response was zero to 47 minutes, the variance 30 minutes, and SD 5.5 minutes.

Overall response to all calls was 44% in five minutes or less and 69% in eight minutes or less. Figure 7 represents all calls and clearly shows the skewness of the data, as well as two outliers beyond 40 minutes.

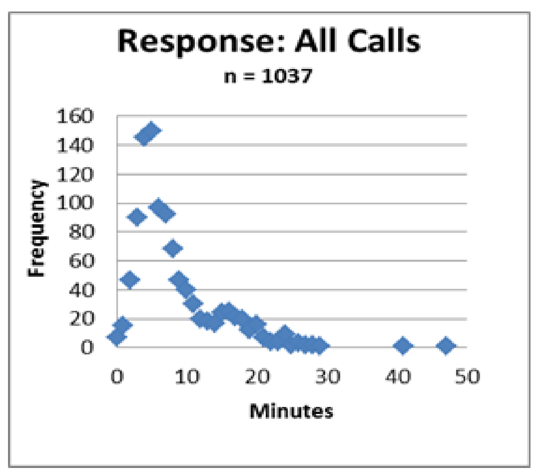

Figure 7. All 2010 calls represented in response time and frequency for response times.

Table 3. Call type distribution statistics with n = 1088.

Call Type	Mean	Median	Range	Variance	SD
Cardiac/Respiratory Arrest	26	21	74	26	5
Chest Pain	112	69	310	111	11
Heart Problem	30	28	82	29	5
Unconscious	31	21	82	27	5
Unknown	19	7	70	36	6

Figure 8 shows a box-and-whiskers plot of call response times and frequency with 50% of the calls falling between the lower (Q1) and upper (Q3) quartiles. Five percent of the calls were outliers beyond the Upper whisker which is 1.5 times the interquartile range above the median. Three of the calls were considered extreme outliers being 3 times the interquartile range from the box.

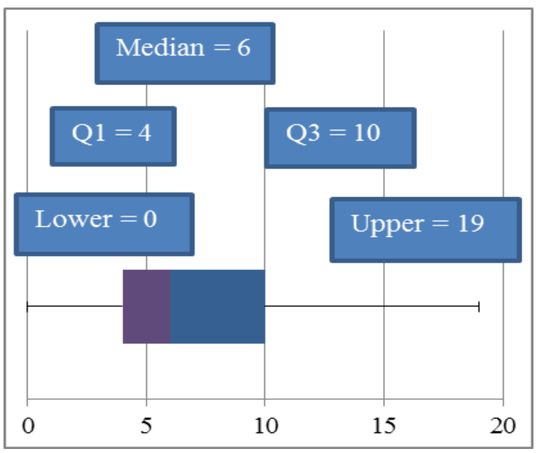

Figure 8. Box-and-whiskers plot of all call response times with n = 1037 calls.

The chest pain call type accounted for over 50% of the total calls and had an ambulance on scene in 8 minutes or less 66% of the time (Figure 9). This demonstrated a skewed picture nearly identical to the overall response times of all 5 call types. Figure 10 shows a box-and-whiskers plot of the chest pain call type response times. It showed a median of 7 minutes with 50% of calls responded to between 5 and 10 minutes. Ten percent of these calls were outliers, lying beyond the upper whisker of 17 minutes.

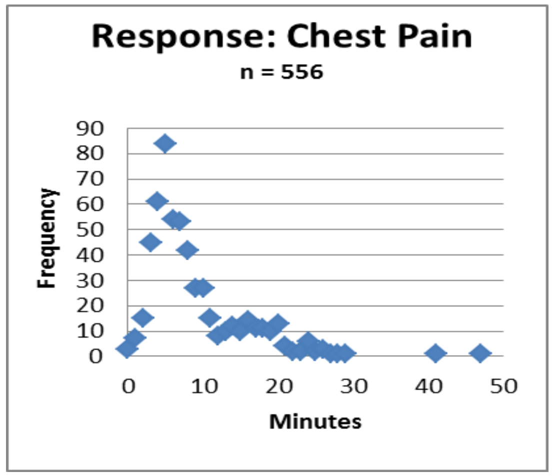

Figure 9. Response times for 2010 chest pain call type.

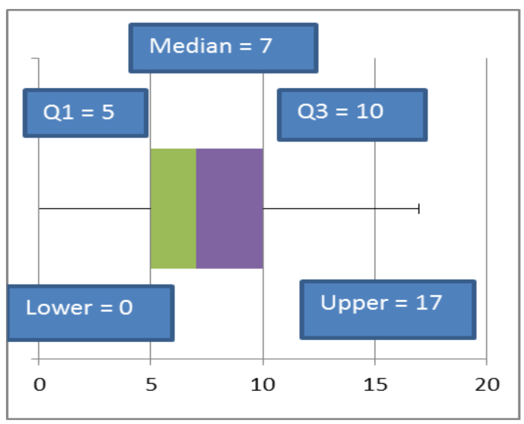

Figure 10. Box-and-whiskers plot of Chest Pain response times with n = 556.

Overall, response times showed 69% of calls had an ambulance on scene in 8 minutes or less. Focusing on the seven to eight minute window recommended for use of an AED and the best cardiac arrest survivability rates more work could be done to decrease response times (Nichol *et al*. (2008); Peleg and Pliskin, 2004; Stiell *et al*. (2004); White, Bunch, and Hankins (2005). With a mean response time of 8 minutes, a median of 6 and a mode of 5 it would seem that response time percentages could improve.

Further Opportunities

Call response time would be a great area for a future analysis because the ambulance service has since implemented a new system status management (SSM). SSM uses the previous 5 years' call data to determine crew posting locations to match where calls are predicted to be during specific times of day and day of the week.

Further research also could be conducted using first responder response data to analyze how quickly any responder (volunteer, law enforcement, fire, EMS) arrives on scene. If data could be obtained from local AED programs, analysis could also be done on their locations throughout the community, as well as trained personnel in area.

Similar data to this study could also be used in conjunction with more U.S. Census Bureau demographics to see if patterns emerge about other factors such as income, education levels, etc. Known nursing home, assisted living facility, and residential home locations could also be compared to the call data.

Additionally, this study could be replicated with additional call types (ex: breathing problems, traumatic injuries, traffic accidents) and service areas.

Conclusion

This study analyzed five types of possible cardiac related events for an upper Midwest ambulance service PSA in 2010. It specifically examined the geographic location, frequency, distribution characteristics of, and response to calls. With the quantity of data and other call types that could be analyzed, much more analysis could be done. This study provides a solid baseline for future works.

Acknowledgments

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