An Analysis of Distance Traveled for Healthcare Services Utilizing a GIS

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Abstract

It is hypothesized that patients will seek care at a tertiary care center for an elective procedure requiring highly specialized care. Furthermore, patients with an emergent condition not requiring highly specialized care will seek care at the nearest hospital. This analysis suggests that there is a correlation between urgency and severity of condition and distance traveled for hospital inpatient services. A geographic information system was utilized to obtain a distance analysis based on zip code point files and straight-line distance. The sample group was 3326 patients. This sample included 2043 Mayo Clinic patients and 1283 Mercy Medical Center patients.

Introduction

A patient's hospital selection is based on many common variables including health insurance access, recommendation of friends and family, familiarity with the hospital, and the geographic distance to the hospital (Marketing Health Services, 1999). The correlation between distance traveled and the urgency and severity of condition will be evaluated in this analysis.

The anticipated findings are that patients with emergent conditions that do not require highly specialized care will seek care at the nearest hospital. In contrast, patients with non-emergent conditions requiring highly specialized care will likely opt for a tertiary care center that may not be located in their community.

A healthcare geographic analysis is benefited by the use of a geographic information system (GIS). "A GIS provides an excellent means of visualizing and analyzing epidemiological data, thus revealing trends, dependencies and interrelationships that would be more difficult to discover in other formats" (WHO, 1999).

The geographic perspective of travel can be evaluated as straight-line distance or actual travel time. A travel time analysis is most practical and beneficial for small geographic areas (Phibbs and Luft, 1995). Travel time is based on the roads traveled to arrive at the destination. It is difficult to adequately apply travel time to a large geographic region due to the immense amount of node to node computer analysis required, within a GIS, for each segment of each road. Nodes are the beginning and ending locations of a line or, in this case, a road (ESRI, 1995). A

node would occur at each intersection of a road. A rural area, such as Iowa, includes many roads and intersections of roads.

Williams *et al* (1983) found that actual travel distance or travel time is 20 to 25 percent more than straight-line distance. Their analysis of rural patients' proximity to medical specialists proved to not hold a strong bias for travel time over straight-line distance (Williams *et al*, 1983).

Phibbs and Luft (1995) found straight-line distance to be a valid substitute for travel time in hospital choice models with large numbers of patients. Their analysis concluded the correlation between straight-line distance and travel time was 0.987 for their sample group (Phibbs and Luft, 1995). Their findings confirm straight-line distance serving as a reasonable analysis tool for the purposes of this study. The addition of travel time would not significantly influence a distance analysis over a large geographic region as in this analysis.

The hypothesis established for this analysis is that a patient with a high relative weight and an elective admission will travel further for healthcare than a patient with a low relative weight and an emergent admission. This hypothesis contains healthcare specific terminology that will be defined within this introductory section. The healthcare industry identifies a tertiary care center as a referral center utilizing medical specialists.

In 1983, the United States Congress mandated a national hospital prospective payment system (PPS). PPS utilizes diagnostic related groups (DRGs) in the payment process.

A DRG is a series of numeric values that are assigned for classifications of diagnoses. The DRG is based upon similarities in resource consumption and length of stay patterns in patients. In 1998, there were 503 DRGs, and in 1999, there were 511 DRGs (St. Anthony's 1998 and 1999).

Relative weights (RW) are assigned to each DRG by the Healthcare Financing Administration (HCFA). The relative weight reflects the resource consumption associated with each DRG (St. Anthony's, 1998). Essentially, the higher the relative weight the greater the healthcare resources utilized in the patient's care and consequently, the greater the payment to a hospital.

Although DRGs are assigned to all patients regardless of payer type, they were established for government payer patients. However, commercial payers utilize DRGs for statistical tracking and payment processes.

Another item to consider is the patient's method of admission, in other words, the urgency of the patient's condition. There are three healthcare industry standards for patient admission. These are elective, urgent, and emergent. An elective procedure indicates there is time available to schedule the procedure for the patient. Urgent procedures require immediate attention, which results in the patient receiving the first available admission. Finally, emergent admissions are brought into the hospital through the emergency room, and are the result of life threatening situations or potentially disabling conditions.

The sample groups studied in this analysis are patients from Mayo Clinic in Rochester, Minnesota and Mercy Medical Center in Des Moines, Iowa. These medical centers are considered tertiary care centers with a strong

regional draw for patients. The data is patient volumes from January 1998 through December 1999. The sample group consists of a total of 3326 patients. This total includes 2043 Mayo Clinic patients and 1283 Mercy Medical Center patients.

Additionally, the geographic references available in the patient data are zip codes. By using a zip code as the geographic reference a patient's privacy is assured.

A regional perspective of nine-states was chosen to best represent a reasonable distance analysis and prevent any outliers from distorting the geographic analysis. The states are North Dakota, Minnesota, Wisconsin, Illinois, Missouri, Kansas, Nebraska, South Dakota, and Iowa. These states include and surround Mayo Clinic and Mercy Medical Center. Although a nationwide or worldwide analysis of patient volumes could have been conducted, the choice was made to limit the analysis to the nine-state region. The argument could be made that Mayo Clinic patient draw is national and international. Consequently, a limited regional analysis is an effort to equalize the field and prevent the national and international draw of Mayo Clinic from heavily weighting the distance findings. Furthermore, the argument can be made that Mercy Medical Center does not have the national or international patient draw of Mayo Clinic. Therefore equal comparison can be made within a regional perspective.

This analysis will focus on DRGs selected based upon relative weight and admission type (Table 1). Initially, the DRGs were selected based on volume and the criteria of relative weight and admission type found in Table 1. After the DRGs were chosen, all three admission types of elective, urgent, and emergent were added to the sample for each DRG to create a balanced sample group.

Table 1. Selected DRGs.

DRG	1998 RW	1999 RW	Admit
105, Cardiac Valve Procedures without Cardiac Catheterization	5.7109	5.7099	Elective
337, Transurethral Prostatectomy with CC	0.6129	0.6176	Elective
475, Respiratory System Diagnosis with Ventilator Support	3.7291	3.7429	Emergent
143, Chest Pain	0.5200	0.5263	Emergent

The hypothesis suggests that patients with elective DRG 105 will travel the furthest to tertiary care centers. Patients with the emergent DRG 143 will then travel to the closest facility (Figure 1).

In the sample group, DRG 105 ranks as the highest relative weight of 5.7109 and an average national payment of $23,414.69 (St. Anthony's 1998). The DRG header is cardiac valve procedure without cardiac catheterization. An example of this would be heart valve replacement.

DRG 105 was chosen to represent patients who will potentially travel further for care. Their care would require a higher degree of expertise that is available at a tertiary care center. Although DRG 105 is not the highest relative weight, it represents the highest relative weight in these sample groups.

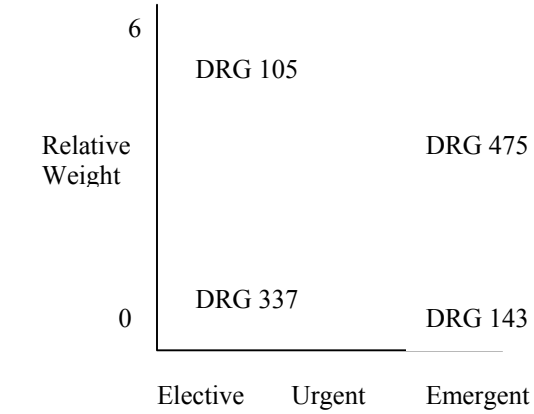

Figure 1. Hypothesis of Travel.

In 1998, DRG 103 heart transplant ranked as the highest relative weight of 16.5746 and an average national payment of $67,955.86. However, due to the limited number of heart transplants the sample size would not be adequate for this study.

The contrast to DRG 105 is DRG 143 chest pain with a relative weight of 0.52. Patients with DRG 105 will typically choose the closest facility.

Methods

Data Collection

The Mercy Medical Center patient data are from the Iowa Discharge Database compiled by the Iowa Hospital Association (Mercy 1998). It is a collection of acute patient discharge data from January 1998 through December 1999.

The Mayo Clinic patient data are a compiling of January 1998 through December 1999 patient data (Mayo 1998). Mayo Clinic provided this data.

Creation of Coverages

The software utilized for this analysis was ESRI ArcView 3.2, Microsoft Access, and Microsoft Excel. The United States state boundary coverages and zip code point coverages were all purchased from ESRI (Environmental Systems Research Institute). In ArcView, the states of North Dakota, Minnesota, Wisconsin, Illinois, Missouri, Kansas, Nebraska, South Dakota, and Iowa were selected. These states were then converted into shapefiles. Through the geoprocessing wizard the zip code coverages were clipped using the queried states as the clipcover.

Next, the hospital data was queried in Access to the four selected DRGs and their corresponding admission type (Table 1). The queries were exported as a database files and imported into ArcView where they were geocoded against the zip point files. To narrow the patients to the nine state regional area, the geoprocessing wizard was utilized to clip the shapefiles.

The last step was to utilize an Avenue script located on the ESRI website titled ProxSpid.ave. This script produced the service area spider lines displayed on the maps, and it additionally returned a straight-line distance based on the map units.

Due to the geographic reference of the data, the map was projected in view properties. The projection is UTM 1983, Zone 14, Transverse Mercator. Zone 14 was chosen as seven of the nine states selected in the analysis are within Zone 14.

Data Discrepancies

Patients living near Mayo Clinic and receiving care at Mayo Clinic will not reside within the same zip code as Mayo Clinic. Mayo Clinic has a dedicated zip

code. This may alter the straight-line distance by 0.17 miles.

Patients who seek care due to an unplanned illness, as they are traveling near Mayo Clinic or Mercy Medical Center are represented in the analysis if their home zip code is within the nine-state region. These patients could not be identified to separate them from the sample group. It can be assumed that these patients would not have sought care at Mayo Clinic or Mercy Medical Center, had they not been travelling near the medical centers.

Results

Spatial Analysis

Returning to the hypothesis. A patient with a high relative weight and an elective admission will travel further for healthcare than a patient with a low relative weight and an emergent admission.

Patients with DRG 105, which had a 1998 relative weight of 5.7109 and a 1999 relative weight of 5.7099, will travel further to tertiary care center. Patients with DRG 143-chest pain, which had a 1998 relative weight of 0.5200 and a 1999 relative weight of 0.5263, will travel to the closest hospital. As anticipated, the greatest distance traveled for healthcare was for DRG 105. These patients on average traveled 154 miles for care at Mayo Clinic and 33 miles for care at Mercy Medical Center (Figure 2). Additionally, as expected, the second highest travel distance was DRG 337 with patients travelling an average of 135 miles for Mayo Clinic and 21 miles for Mercy Medical Center (Figure 2).

Finally, the hypothesis confirmed the shortest travel distance was for DRG 143 with an average of 55 miles for care at Mayo Clinic and 21 miles for care at Mercy Medical Center (Figure 2). Additionally, DRG 475 held to the anticipated second field for shortest travel distance of an average 69 miles for Mayo Clinic and 23 miles for Mercy Medical Center (Figure 2).

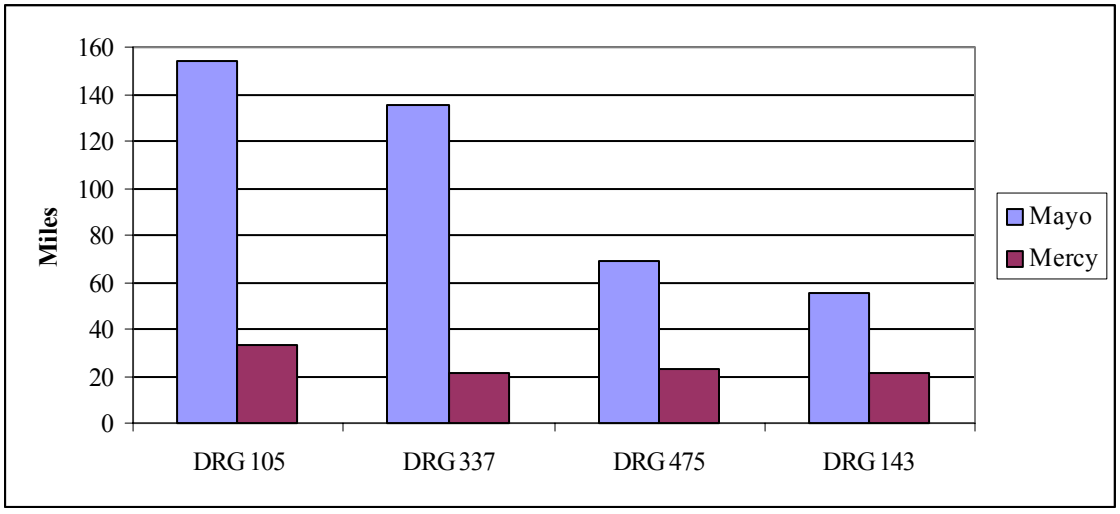

Figure 2. Average Miles Traveled. January 1998 through December 1999 Acute Patient Discharge Data.

The patients were totaled based on 25-mile increments up to 100 miles, and then totaled based on 100-mile increments to the top distance of 700 miles. A combined analysis of both hospitals shows DRG 105 to have a 45% patient concentration at the 100 mile to 700-mile increment. Additionally, a combined analysis of DRG 143 provides a 92% concentration at the zero to 100-mile increment. The concentration of patients from this perspective further supports the hypothesis (Table 2. Figure 3.)

Table 2. Patient Volume for Incremental Miles Traveled by DRG and Hospital.

	DRG 105		DRG 337		DRG 475		DRG 143	
Miles	**Mayo**	**Mercy**	**Mayo**	**Mercy**	**Mayo**	**Mercy**	**Mayo**	**Mercy**
0 - 25	83	79	50	74	117	216	327	493
25.01 - 50	72	61	26	12	104	35	140	107
50.01 - 75	110	40	30	15	48	31	48	72
75.01 - 100	82	9	20	2	24	3	24	15
100.01 - 200	193	2	34	0	49	3	48	8
200.01 - 300	158	0	58	0	25	2	31	2
300.01 - 400	49	0	13	0	8	2	9	0
400.01 - 500	22	0	4	0	1	0	8	0
500.01 - 600	16	0	4	0	1	0	2	0
600.01 - 700	4	0	0	0	0	0	1	0
Total Patients	789	191	239	103	377	292	638	697

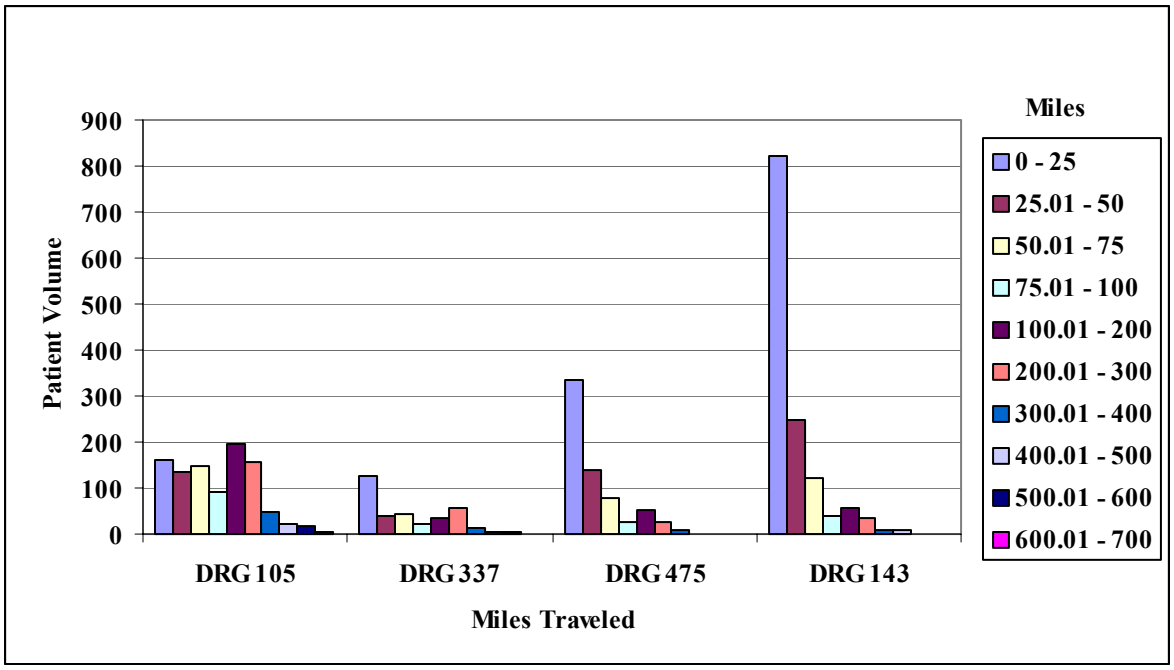

Figure 3. Mayo and Mercy Patients Combined. January 1998 through December 1999 Acute Patient Discharge Data.

Figure 3 displays the total of Mayo Clinic and Mercy Medical Center patients' mileage traveled. The shortest travel distance was for DRG 143 and the greatest travel distance was for DRG 105. The greatest travel distance was concentrated at DRG 105. The shortest travel distance was concentrated at DRG 143 as hypothesized.

Statistical Analysis

A statistical analysis was conducted of various patient volume patterns. The DRG patient volumes for Mayo Clinic and Mercy Medical Center were pooled for the statistical analysis. An F-test for two sample variances was conducted for each comparison. This was followed by a T-test for two samples assuming unequal variances. The statistical tests were conducted in Microsoft Excel.

Figure 1 identifies the hypothesis for travel based on relative weight and admission type. Table 3 is a comparison of DRGs with similar relative weights. In this table, DRG 105 and DRG 475, representing the highest relative weight DRGs and the potential to travel the furthest, are statistically compared to DRG 337 and DRG 143, representing the lowest relative weight and the potential to travel to the closest facility. The findings demonstrate there is a significant difference between these sample groups ($P < 0.001$).

Table 3. Highest Relative Weight versus Lowest Relative Weight.

	DRG 105 DRG 475	DRG 337 DRG 143
Mean Mileage	97.30	50.22
Variance	12661.59788	6925.453
Observations	1649	1677
F-Test one-tail	$P < 0.001$	
T-Test two-tail	$P < 0.001$	

Table 4 is a comparison of admission types. DRG 105 and DRG 337, representing the elective admissions and the potential to travel to the furthest facility, are compared to DRG 475 and DRG 143, representing emergent admissions and the potential to travel to the closest facility. The findings demonstrate there is a significant difference between these sample groups ($P < 0.001$).

Table 4. Elective Admissions versus Emergent Admissions.

	DRG 105 DRG 337	DRG 475 DRG 143
Mean Mileage	122.84	41.06
Variance	14950.48088	4612.97626
Observations	1322	2004
F-Test one-tail	$P < 0.001$	
T-Test two-tail	$P < 0.001$	

Finally, Table 5 is a comparison of DRG 475 and DRG 337. These two DRGs were anticipated to fall second in travel distance. Again, the findings demonstrate there is a significant difference between the two sample groups ($P < 0.001$).

Table 5. Influence on Travel Distance.

	DRG 475	DRG 337
Mean Mileage	48.48	100.49
Variance	4975.933	13667.58
Observations	669	342
F-Test one-tail	$P < 0.001$	
T-Test two-tail	$P < 0.001$	

The findings of the statistical analysis further confirms the hypothesis that patients with a high relative weight will travel further for healthcare than patients with a low relative weight and patients with an elective admission will travel further for healthcare than patients with an emergent admission. There is some evidence that emergency is a

bigger influence than relative weight, although only one DRG contrast was examined.

Potential for Future Use

The geographic representation of epidemiological data by a GIS provides an analysis of patient concentrations, patient willingness to travel, and geographic regions in need of access to hospitals and tertiary care centers. Tertiary care centers may choose to locate hospitals in a rural area currently lacking local care or provide transportation to the tertiary care center via helicopter, plane, or surface transportation.

Discussion

As the healthcare industry continues to grow and become increasingly competitive, the evaluation of patient needs is essential for success. A GIS is one tool that can provide a unique analysis from a geographic perspective.

The distance analysis of Mayo Clinic and Mercy Medical Center patients was not intended to be a comparison of hospitals. Rather, Mercy Medical Center, Des Moines is centrally located in Iowa, on major interstates and highway networks, providing a strong sample group. Additionally, Mercy Medical Center provides a tertiary care perspective in the Des Moines area. Further, the data for Mercy Medical Center was easily obtained. Mayo Clinic provided the data for Mayo Clinic patients.

One of the most popular aspects of a GIS analysis is the visual impact of the maps. The maps for each DRG are included in this section. The spider proximity script utilized for the mileage evaluation provides an interesting visual perspective. On each of these maps, the center of the spider diagram represents Mayo Clinic and Mercy Medical Center, Des Moines, respectively. The straight-line distance extends out to the patient's residential zip code. Multiple patients within the same zip code will overlap on the spider lines, thus they will only be represented by one line.

DRG 105 (Figure 4) has an overshadowing visual draw for Mayo Clinic over Mercy Medical Center. The Mercy Medical Center spider diagram is compacted and virtually hidden beneath the Mayo Clinic spider diagram. This is likely a result of Mayo Clinic's role as a regional referral center utilizing medical specialists and the capacity for Mayo Clinic to handle large patient volumes. DRG 337 (Figure 5), DRG 475 (Figure 6), and DRG 143 (Figure 7) each demonstrate a similar larger geographic draw for Mayo Clinic patients over Mercy Medical Center patients. However, this analysis is not intended to be a comparison of the two hospitals.

This analysis may serve as a template for further distance analysis of other hospitals within the nine-state region. One potential hindrance to an analysis of other hospitals is access to patient release information.

It should be noted the findings confirm that Mayo Clinic patients travel further for care. This was anticipated based on the national and international tertiary care reputation of Mayo Clinic. A future study might involve an analysis of reputation, distance traveled, and available care for Mayo Clinic specifically. A GIS would provide the distance analysis of patient travel to be used in an evaluation of the impact of reputation on distance traveled.

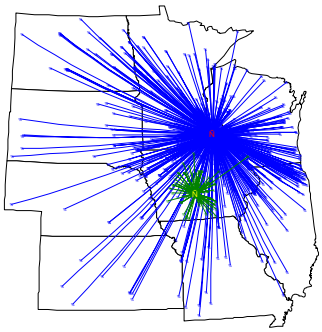

Figure 4. DRG 105 Cardiac Valve Procedures without cardiac catheterization.

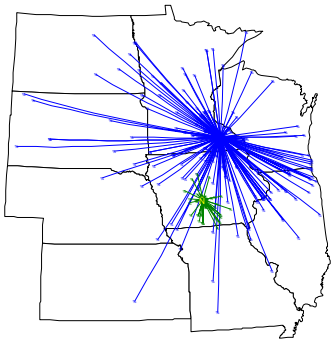

Figure 5. DRG 337 Transurethral Prostatectomy with complication or comorbid condition.

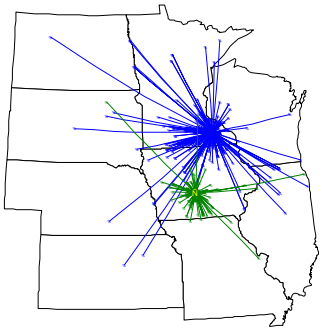

Figure 6. DRG 475 Respiratory System Diagnosis with ventilator.

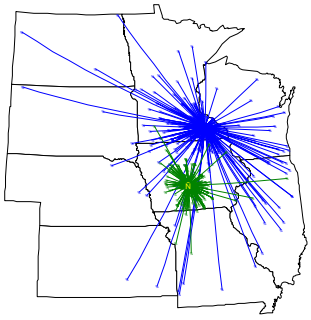

Figure 7. DRG 143 Chest Pain.

Conclusion

The hypothesis confirmed that a correlation exists between the distance a patient will travel for healthcare and the urgency and severity of the condition. A regional perspective of nine-states prevented the national and international draw of Mayo Clinic from overly influencing the geographic analysis

The findings support that patients with emergent conditions, not requiring highly specialized care, will seek care at the nearest hospital. Further, patients with non-emergent conditions in need of highly specialized care will be more likely to seek care at a territory care center that may not be located in their local community.

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