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Metrics of the Social Contact Networks of Patients and Staff in the Emergency Department

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Master of Science in Public Health

Biostatistics

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Abstract

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Patients who go to the emergency department are often waiting in overcrowded waiting rooms with other patients. This presents a major opportunity for the spread of respiratory disease. Emergency departments have not done an adequate job in isolating infectious patients for several reasons, including lack of awareness of the need to isolate, lack of recognition of communicable diseases, an inadequate staffing or supplies.

Understanding how a disease propagates though an emergency department is a very important step in managing disease outbreaks. Mathematical models have become important tools in this regard, but with their focus on differential-equation models and equal mixing of populations, we miss the true picture on how populations interact with each other and how disease transmits in a varied population. In an emergency department, patients would have different interactions with other patients than with hospital staff. In addition, differential equations assume a large population, which does not apply to an emergency department – even a large one. Social network models may be more useful in predicting disease transmission in an emergency department.

An important step in the development of network models is accurately measuring interactions between and within groups of patients and healthcare workers. Such measurements will give us a better understanding of the ED network.

The goal of this thesis was to report metrics of networks of patient and emergency department staff during 82 12-hour shifts at the emergency department at Midtown Hospital, in Atlanta, GA. A radio frequency tracking system was used to accurately track patients and staff in the emergency department. We looked at several social network factors: degree, diameter, shortest path, clustering coefficient, and density.

In addition, another goal of this thesis was to assess any differences that might exist in our metric by time of year, AM or PM shift, whether it was H1N1 influenza season, weekend or weekday shift, and day of the week.

We used generalized estimating equations (GEE) to assess differences in our data. GEEs take into account the correlations we expect to find among patient to patents interaction groups, staff to patients interaction groups, and staff to staff interaction groups.

We found that the mean shortest path increased significantly over time, which implies that the number of individuals between any two people in the ED increased over time, decrease the probability that an individual would contact an infectious person in the ED. No other differences were observed.

Public health implications and future directions of research are also discussed.

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1. Introduction

1.1. Respiratory Illness in the Emergency Department (ED)

On May 8, 2003, the Taiwan local health department indentified three severe acute respiratory syndrome (SARS) cases in patients whose only contact history involved treatment at the National Taiwan University Hospital Emergency Department (ED). Source and contact tracing failed to identify an index patient. On May 12, 2003, operation of the ER was suspended. On the same day, the infection control team was informed that three healthcare workers who worked in the ER had fever. They were immediately isolated, but initial interviews with the healthcare workers failed to identify a common source of infection (Chen, Huang et al. 2004).

In the end, thirty-one cases of SARS were identified in this ED. Three clusters were identified over a 3-week period. The first cluster (5 individuals) and the second cluster (14 individuals) occurred among patients, family members, and nursing aids. The third cluster (12 individuals) occurred exclusively among healthcare workers. Six healthcare workers had close contact with SARS patients. Six others, with different working patterns, indicated that they did not have contact with a SARS patient. Environmental surveys found 9 of 119 samples of inanimate objects to be positive for SARS corona virus RNA. These observations indicate that although transmission by direct contact with known SARS patients was responsible for most cases, environmental contamination with the SARS corona virus may have lead to infection among healthcare workers without documented contact with known hospitalized SARS patients (Chen, Huang et al. 2004). This is just one example of the risk of disease transmission within an emergency department.

Patients who go to an ED for care are treated in dedicated treatment areas, but often waiting in waiting rooms, treated in hallways, evaluated in diagnostic departments, or moving back and forth between these areas. As EDs become more crowded, patients spend more time waiting for treatment, often among other patients (McCarthy, Zeger et al. 2009).

This situation presents a major opportunity for the spread of infectious disease because EDs have not done an adequate job isolating patients with potentially infectious diseases. EDs make this mistake for many reasons: lack of awareness of the need to isolate, lack of recognition of communicable diseases, inadequate staffing or supplies, or lack of adequate isolation-grade treatment areas (Berk and Todd 1994; Meengs, Giles et al. 1994; Moran, Fuchs et al. 1995; Kim, Roghmann et al. 2003; Loh, Chelliah et al. 2004; Chen, Wu et al. 2005). EDs generally do not have an adequate number of isolation units to service those with symptoms of infectious disease, especially in a widespread outbreak or pandemic.

Given that most ED patients do not walk in the door with infectious disease, the risk posed by an infected individual to these patients, many who may have compromised immune systems, is substantial.

1.2. Problem Statement

Understanding how a disease propagates through an ED is a very important step in managing disease outbreaks. Mathematical models have become important tools in analyzing the spread and control of infectious diseases. Traditional epidemiological research has focused on differential-equation models on completely mixing populations, but a major shortcoming to these models is their assumption that populations are homogeneous with regard to disease susceptibility and that populations mix uniformly. In actual disease outbreaks, this is rarely the case. For example, individuals with a compromised immune system – often the case with patients in the ED – may be more susceptible to influenza. In addition, these models assume that an individual has contact with each individual at an equal rate, so there is uniform mixing. In a real ED, interactions between patients and healthcare workers would violate this assumption based on position. Physicians would have different interactions with patients than cleaning staff in an ED (Andersson and Britton 2000). In addition, these models also assume the population is very large, which limits the usefulness of the model when applied to finite networks, such as an ED (Lewis 2008).

A critical stage in the development of network models is accurately measuring interactions between and within groups of patients and healthcare workers. Such measurements will give us a better understanding of the ED network and also the interaction patterns between healthcare workers and patients that will enable us to prevent the spread of infections and protect healthcare workers and patients.

It addition, it is also important to examine these measurements by time of year. Research has shown that time of year plays a part in the transmissibility of disease like influenza, in particular H1N1 (Lofgren, Fefferman et al. 2007; Balcan, Hu et al. 2009). Finding significant differences in our measurements based on seasonality could be crucial when planning adequate public health interventions to mitigate the spread of influenza and other seasonal diseases.

1.3. Purpose Statement

Recently, there has been a resurgence of research in complex networks: the renewed interest is driven by a number of empirical and theoretical studies showing that network structure plays a crucial role in understanding the overall behavior of complex systems (Barabasi and Albert 1999; Albert, Jeong et al. 2000; Broder, Kumar et al. 2000; Albert and Barabasi 2002; Ancel Meyers, Newman et al. 2003; Newman and Park 2003). However, properties of social contact networks that are crucial for understanding epidemics have been explored only recently (Newman and Park 2003, Newman 2003, Newman et-al 2002, Meyers et-al 2003). New insights on disease dynamics can be obtained by understanding the contact structure carefully(Ancel Meyers, Newman et al. 2003).

Modeling up until now has focused on the transmission of influenza in communities, not a healthcare setting. Social networks in healthcare are unique in that they are restricted (patients and healthcare workers), and the probability of transmission is higher because of close interactions between patients and healthcare workers. A better understanding of these networks and interactions is needed to prevent the spread of infections and protect patients and healthcare workers (Gundlapalli, Ma et al. 2009).

The ultimate goal of this research, but not this thesis, is to develop modeling epidemiological tools to enable the prediction of possible outcomes and propagations paths of a particular disease from the point source exposure to an ill patient presenting in the ED. This model will contain healthcare worker-patient, patient-patient, and healthcare worker-healthcare worker interactions. Using this model, we hope to predict possible outcomes of particular diseases and test hypothetical preventative measures.

1.4. Objectives

1.4.1. Objective 1

The goal for this thesis is to report metrics of networks of patient and emergency department staff contacts during 82 12-hour shifts at a large urban emergency department. The belief is that an enhanced comprehension of social networks of patient-healthcare worker interactions will improve researchers’ understanding of the potential transmission of infectious disease in the ED.

1.4.2. Objective 2

The secondary goal for this thesis is to test the hypothesis that time of year has an effect on the metrics we collected. This will enable us to determine if the seasonality of diseases like influenza is reflected in the metric we collected. We will analyze how our metrics change over the quarters of a year. In addition, we will examine if any difference exists in our metrics between the AM and PM shifts, the days of the week, the weekend and weekday shifts, and shifts that occurs in the H1N1 season and those that did not.

2. Literature Review

2.1. Background

Epidemic models have long been valuable tools for studying the dynamics of infectious diseases in human populations. Assuming an unstructured population and the standard incidence, disease transmission occurs by means of homogeneous mixing, where each contagious individual is free to contact and infect any susceptible individual; but if the population is structured according to cultural, socio-economic, demographic or geographic factors, there is a mixing matrix that limits opportunities for disease causing contacts (Bombardt 2006). That is where network theory comes in.

There is a close relationship between epidemiology and network theory that goes back to the mid-1980s. The connections between individuals that allow an infectious disease to spread are defined by a network (Klovdahl 1985; Anderson and May 1991).

The network approach to disease transmission is inherently individual-based rather than population based. A network, or graph, is made up of individuals represented by nodes, and interactions between them as edges. The interaction is defined based on the disease of interest: for influenza, casual contact is enough for transmission to occur; but for an STD, sexual contact would be the interaction of interest. Research has shown, in general, each individual only interacts with a small subsection of the population; in addition, pairs of individuals that interact do so repeatedly. Therefore, we see that while a social network is dynamic, changing as new interactions form and disappear, a large number of links remain in place over time (Eames and Read 2008).A network can be represented by a matrix called the adjacency matrix A, which in the simplest case is an n x n symmetric matrix, where n is the number of nodes in the network. The adjacency matrix has elements

$$A_{ij} = \begin{cases} 1 & \text{if there is an edge between nodes i and j,} \\ 0 & \text{otherwise.} \end{cases}$$

The matrix is symmetric since if there is an edge between i and j, then there is an edge between j and i, thus $A_{ij} = A_{ji}$. This is called an undirected graph and is applicable to our study. There also exist directed graphs, in which edges point in a particular direction between two nodes (Newman 2008). We would use this method if we were studying transmission of disease in which i can pass disease to j, but j does not have to pass disease to i.

There have been many studies on how disease spreads in complex social networks (Meyers, Newman et al. 2003; Christley, Pinchbeck et al. 2005; Keeling and Eames 2005; Meyers, Pourbohloul et al. 2005; Pourbohloul, Meyers et al. 2005; Watts, Muhamad et al. 2005; Colizza, Barrat et al. 2006; Riley 2007; Volz and Meyers 2007), while transmissions in healthcare setting have not received as much attention. Disease propagation may occur in a healthcare facility in a manner different from that in an urban community setting due to different network architecture (Gundlapalli, Ma et al. 2009). First, social networks of EDs may be structured differently from networks of other communities. A hospital is typically a constrained environment compared to other communities studied. Second, a healthcare facility is composed of individuals of distinct roles, such as patients, visitors, and healthcare workers. Healthcare workers can be subdivided into different classes, such as nurses and medical doctors. Susceptibility, mortality, infectiousness, and many other factors that affect how diseases spread depend on the type of individuals. For example, junior doctors may visit more wards than nurses do, possibly carrying pathogens from ward to ward. Patients may be less active but likely have larger case fatality than healthcare workers (Leung, Hedley et al. 2004; Forrester and Pettitt 2005). In urban community social networks, the role of different types of individuals in disease propagation may not be so clear-cut. In spite of seminal modeling work of nosocomial infection based on network analysis (Meyers, Newman et al. 2003; Liljeros, Giesecke et al. 2007), how diseases spread in potentially hierarchical networks of healthcare facilities composed of individuals of different classes is not sufficiently understood (Ueno and Masuda 2008).

2.2. Weighted Networks

Often, diseases do not spread at the same rate along all edges or interactions. One factor that influences transmission rates of disease like influenza, common colds, whooping cough, and SARS is how long individuals are in contact with each other. The longer two people interact, the greater the probability the transmission of disease will occur (Eames and Read 2008).

This contact time between individuals can be summarized by the use of weighted networks. Nodes are not expressed as simply linked or unlinked, but their interaction is weighted according to their contact time (Eames and Read 2008).

Going back to our definition of the adjacency matrix, where it has elements

$$A_{ij} = \left\{ \begin{array}{ll} 1 & \text{if there is an edge between nodes i and j,} \\ 0 & \text{otherwise.} \end{array} \right\}.$$

In our weighted network, we have elements

$$A_{ij} = \left\{ \begin{array}{ll} c_{ij} & \text{if there is an edge between nodes i and j,} \\ 0 & \text{otherwise.} \end{array} \right\},$$

where c_{ij} depends on the duration of contact between i and j.

2.3. Network Components

All parts of a network are not necessarily reachable from all others. A node belongs to a component within a network if it can be reached by edges running from other nodes in the component. We will be analyzing our networks to determine if they contain giant components; that is, components which contain a majority of the nodes in the network (Danon, Ford et al. 2010).

The concept of components is very important in disease transmission. An epidemic is limited by the component it begins in. If a network component is small, a disease spreading through it cannot spread beyond it. If it is a strongly connected component (SCC), meaning everyone in the network is connected, all are vulnerable (Danon, Ford et al. 2010).

2.4. Network Centrality

One way to measure social network centrality is to determine the number of contacts a person has within the network. It implies greater access to others in the network. Several studies have demonstrated the validity of using such measures to identify the most connected individuals for surveillance in the transmission of infectious diseases (Christley, Pinchbeck et al. 2005; Colizza, Barrat et al. 2006). We will not be examining all of the following metrics, but this list gives a good summary on what metrics have been defined and how they can be used to study social networks.

2.4.1. Degree

One measure of centrality is degree. It is defined as the number of neighbors a node has. In our case, it is the number of people a person has had direct contact with. The degree k_i of node i is

$$k_i = \sum_{j=i}^{n} A_{ij},$$

$$\text{where} A_{ij} = \left\{ \begin{array}{ll} 1 & \text{if there is an edge between nodes i and j,} \\ 0 & \text{otherwise.} \end{array} \right\}$$

The distribution of degrees of nodes is one of the most important ways of describing the heterogeneity in patients and staff's potential to become infected, as well as cause infection. The higher the number of contacts a person has, the higher the probability one of them is infected. Also, the more connections an infected person has, the more people he can infect (Danon, Ford et al. 2010).

2.4.2. Distance

The shortest path between a pair of nodes i and j is the path requiring the smallest number of steps to reach j from i. The distance, d, is the number of steps to reach j from i along the shortest path, and the average distance, $\bar{d}$, is the mean of the distances between all pairs of nodes:

$$\bar{d} = \frac{1}{N(N+1)} \sum_{i \neq j} d_{i,j}$$

where N is the number of nodes in the network.

For our ED model, quantifying the number of steps needed to reach a person in the ED from any other person is important because if only a few steps are require to reach everyone in the ED, diseases will be able spread more rapidly (Danon, Ford et al. 2010).

2.4.3. Betweenness

Another measure of centrality is betweenness. In a network, it is a measure of the proportion of shortest paths that pass through a given node. For a graph G: = (V,E), made up of V - which is the set of nodes - and E - which is a set of edges - with v nodes, the betweenness $C_B(v)$ for node v is computed as follows:

$$C_B(v) = \sum_{s \neq v \neq t \in V} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

where σ_{st} is the number of shortest paths from s to t, and $\sigma_{st}(v)$ is the number of shortest paths from s to t that pass through a node v.

Nodes with high betweenness are more central in a network, and in terms of disease spread, these nodes are typically infected early in an epidemic and are important intervention targets (Bell, Atkinson et al. 1999).

2.4.4. Closeness

Closeness, $C_C(v)$, for a node v ∈V is the reciprocal of the sum of distances between a node and all other nodes of V:

$$C_C(v) = \frac{1}{\sum_{t \in V, t \neq v} d(v,t)}$$

Closeness provides an index of the extent to which an individual is in the middle of a given network. The more central the individual, the greater potential role he has in facilitating disease transmission (Perkins, Cagnacci et al. 2009).

2.4.5. Eigenvector Centrality

Another important centrality measure is the eigenvector centrality. Eigenvector centrality weights a node’s degree centrality, proportional to its neighbors; therefore, nodes that are strongly tied to other central nodes are proportionally more central than those that are tied to less central nodes. In other words, the key idea of this centrality measure is to express that an important node is connected to other important neighbors (Gundlapalli, Ma et al. 2009). If we denote the centrality of vertex i by x_i, then we can allow for this effect by making x_i proportional to the average of the centralities of i's network neighbors:

$$X_i = \frac{1}{\lambda}\sum_{j=1}^{n} A_{ij}x_j$$

where λ is a constant. Defining the vector of centralities x = (x1, x2,…), we can rewrite this equation in matrix form as

$$\lambda \boldsymbol{x} = \boldsymbol{A}\boldsymbol{x}$$

and we see x is an eigenvector of the adjacency matrix with eigenvalue λ. Assuming that we wish the centralities to be non-negative, it can be shown (using the Perron–Frobenius theorem (Lu and Chung 2006)) that λ must be the largest eigenvalue of the adjacency matrix and x the corresponding eigenvector. The eigenvector centrality defined in this way accords each vertex a centrality that depends both on the number and the quality of its connections: having a large number of connections still counts for something, but a vertex with a smaller number of high-quality contacts may outrank one with a larger number of mediocre contacts (Newman 2008).

2.4.6. Reach

Reach measures the number of nodes each node can reach in k or less steps. For k=1, this is equivalent to degree centrality (Hanneman and Riddle 2005).

2.4.7. Density

The number of observed edges, expressed as percentage of the number of unordered pairs for an undirected graph (Hanneman and Riddle 2005).

2.4.8. Centralization

Centralization is the degree to which a network revolves around a single node (Hanneman and Riddle 2005).

2.4.9. Structural Cohesion

Structural cohesion is defined as the minimum number of nodes which, if removed from a network, would disconnect the network. Research on large networks such as the World-Wide Web finds that an extremely small number of nodes are connected to an extremely large number of partners. These networks require nodes with relatively large degrees to remain connected, and targeted interventions - such as virus attacks in computer networks, and education and treatment effects in sexually transmitted disease networks - will disconnect the network and disrupt the flow (Barabasi and Albert 1999; Pastor-Satorras and Vespignani 2001).

2.4.10. Structural Equivalence

When discussing structural equivalence, we first need to define some terms. The color of a node v, written $C_s(v)$ is the equivalence class it belongs to, such as a class of doctors or a class of patients. Nodes are assigned to exhaustive and mutually exclusive classes. The neighborhood of v, written $N_s(v)$ is the set of nodes adjacent to v. The size of a node's neighborhood is equivalent to its degree.

A coloration C_s is strongly structural if $C_s(u)=C_s(v)$ iff $N_s(u)=N_s(v)$, where $u,v\in V$. Structural equivalence implies the same degree, centrality, belong to same number of cliques, etc (Borgatti 2004).

2.4.11. Homophily

Given a partition of a network in a number of exhaustive and mutually exclusive groups, then homophily is defined as the number of ties external to the groups minus the number of ties that are internal to the group divided by the total number of ties. That is, it is a measure of the extent a group chooses themselves (Hanneman and Riddle 2005). A network with a high degree of homophily makes a disease hard to transmit between groups.

2.5. Clustering

It is found that most networks have a high degree of transitivity or clustering, i.e., that there is a high probability that "the friend of my friend is also my friend". In topological terms, this means that there is a heightened density of loops of length three in the network, and more generally it is found that networks have a heightened density of short loops of various lengths (Newman 2003).

Many social networks are expected to have high levels of clustering. Households, schools, and workplaces are expected to contain groups of people who all interact with each other (Eubank, Guclu et al. 2004; Palla, Derenyi et al. 2005; Cooper 2006; Ferguson, Cummings et al. 2006). It would not be surprising for a household to have a clustering coefficient of 1.

In a highly clustered network, connected individuals most likely share other contacts, so there is a probability that contacts of a secondary case have already been infected by the index case. This reduces the number of cases that the secondary case can generate, thereby slowing the spread of the disease (Keeling 1999)

2.5.1. Clustering Coefficient

The clustering coefficient measures the extent to which neighbors of a node are connected by edges. It is defined as the mean probability that two vertices in a network are connected, given that they share a common network neighbor. Clustering has important implications for the rate and probability of disease spread. As the clustering coefficient becomes large, the epidemic will reach most of the people who are reachable even for transmissibilities that are only slightly above the epidemic threshold (Newman 2003). The local clustering coefficient for an undirected graph, G: = (V,E),is defined by

$$C_i = \frac{2\left|\{e_{ij}\}\right|}{k_i(k_i - 1)}$$

where$e_{ij} \in E$, $\left|\{e_{ij}\}\right| =$ number of edges of i, e_{ij}, and $k_i =$ degree of node i.

Another definition of, but equivalent to, the clustering coefficient is:

Let $\lambda_G(v)$ be the number of triangles on $v \in V(G)$for undirected graph G. That is, $\lambda_G(v)$ is the number of subgraphs of G with 3 edges and 3 nodes, one of which is v. Let $\tau_G(v)$ be the number of triples on $v \in V(G)$. That is, $\tau_G(v)$ is the number of subgraphs with 2 edges and 3 nodes, one of which is v and such that v is incident to both edges. Then we can also define the clustering coefficient as,

$$C_i = \frac{\lambda_G(v)}{\tau_G(v)}$$

2.5.2. Clique

Given a subgraph S∈G, S is a clique if for all nodes u,v∈S, u and v are linked. That is, a node in a clique is linked to every other node in the clique. If a disease strikes a clique, all in the clique are susceptible to the disease (Borgatti and Everett 2006).

2.6. Power-law distribution

It has been observed that a wide range of phenomena such as airports arrivals and landings, money distribution in the United States, the number of hits on a website, etc. follow a power law distribution and are called scale-free (Watts 2003; Newman 2005). This means that a majority of the nodes have very few connections to other nodes, but a few nodes have many connections.

For example, let's look at the airport arrivals and landings example. Relatively speaking, a majority of airports have very few flights on a daily basis. Then we have airport such as O'Hare in Chicago, JFK in New York, and Hartsfield-Jackson in Atlanta, which have many flights arriving and leaving.

The power law distribution is plotted on a log-log scale using the formula

$$\ln p(x) = -a \ln(x) + c$$

where x is the random variable, the exponent a is the slope of the line, and c is a constant and the intercept of this line.

2.7. Small World Phenomenon

In a small world network, nodes are highly clustered in the neighborhood (clustering coefficients are high); in addition, the path length between any two nodes is short compared to the size of the network (Gundlapalli, Ma et al. 2009).

This has big implications for disease transmission. In a highly connected network, this season's influenza virus can spread far faster than in a network where the path between individuals is relatively long.

2.8. Seasonality of Disease

Research has shown that time of year plays a part in the potential transmissabilty of H1N1. In temperate climates, like the United States, flu infections are characterized by a flu season. The disease is thought to exist at a low level throughout the year but exhibit a marked seasonal increase, typically during the winter months. The reason behind the seasonality of influenza is not well understood but has been attributed to crowding, dehydration of mucus membranes, the ability of the virus to last longer in colder temperatures, etc (Lofgren, Fefferman et al. 2007; Balcan, Hu et al. 2009). This could be crucial when planning for adequate public health interventions to mitigate the spread and impact of influenza. For this reason, we compare contact interactions over four quarters in order to assess statically significant differences in our measures that would account for increased transmission risk.

2.9. RFID Network

In creating models that account for heterogeneous populations, data are seldom accessible to quantitatively define population mixing for a large and highly structured population (Gundlapalli, Ma et al. 2009); but we have collected the necessary data to map population movements within the Emergency Department of a large urban hospital. This will enable the creation of better epidemic surveillance models and vaccination plans.

We collected contact information through the use of a radiofrequency identification device (RFID) network already in use in the emergency department. Studies have shown that RFID networks are an increasingly effective way to collect contact data (Cattuto, Van den Broeck et al. 2010; Salathe, Kazandjieva et al. 2010).

3. Methods

3.1. Study Funding

This study was funded as a pilot project within the Influenza Pathogenesis and Immunology Research Center (IPIRC), a Center of Excellence in Influenza Research and Surveillance funded by the National Institute of Allergy and Infectious Diseases of the National Institutes of Health.

3.2. Study Setting

This study was carried out in the emergency department of Emory University Midtown Hospital in Atlanta, Georgia. The ED averages 140 ED visits per day, and 150,000 per year. A detailed map of the emergency department with locations of sensor area marked is included in Appendix C.

3.3. Data Source

3.3.1. The FirstNet Emergency Department Triage and Tracking

This patient flow management system tracks the time of registration, triage, entry into the examination room, evaluation by healthcare workers, and discharge for the ED. It was modified for this study to allow the tracking of patients with RFIDs. Data from the system are archived and accessible for patient care and research.

3.3.2. The Radiense Radiofrequency Identification (RFID) System

Radiense, Inc (Andover, MA) was the vendor for the RFID system used for this project. This has been in operation at the Emory University Midtown Hospital since 2009. The purpose of the locator system is to account for healthcare workers and equipment locations in order to mitigate risk. For this study, patients were also tracked. The sensors placed on individuals and equipment emit a unique infra-red signal approximately every ten seconds. Infrared receivers placed in various locations within the ED detect the signals allowing the system to identify and timestamp an individual to that location. Data of location and time stamps of patients and healthcare workers are stored and reports can be exported to Microsoft Excel for examination and analysis.

3.3.3. Sampling Period

Sampling Periods were stratified by week, then one day shift (7:00 AM to 7:00 PM) and one night shift (7:00 PM to 7:00 AM) were randomly selected from the 14 eligible shifts. Sampling was constrained so that at least 48 hours occurred between sampling periods. Of the 104 randomly selected periods between July 1, 2009 and June 30, 2010, sampling was carried out in 82. Sampling was not conducted in the remaining 22 periods for staffing issues (volunteers did some of the work), and weather related issues.

3.3.4. Participants

During each sampling period, all staff working and all patients present were eligible for RFID monitoring. Emergency department staff was given permanent RFID badges and were tracked unless they forgot their badges or refused to be tracked. Patients were tagged when they first came into the waiting room or through the emergency bay. Patients who had been there before the shift started were tagged at their beds. Patients were not tagged in cases of overcrowding, oversight, or refusal. Only individual who had contact (within 3 feet) with other individuals during their time in the ED were included in the study.

3.3.5. Data Preparation

Data from the two systems were merged using time-stamps and identification codes. Twelve calendar months of data were analyzed. All ED networks in this study have undirected edges, and they are weighted to reflect contact time between individuals.

3.4. Outcome Variables

3.4.1. Measures of Centrality

- Degree: A measure of the total contacts for an individual during a shift.

- Weighted Degree: A measure of the total contact hours with other individuals within the ED. It is a better representation of actual contacts between individuals in the ED since it takes into account contact time.

3.4.2. Measures of Clustering

- Network Density: The number of observed contacts, expressed as the percentage of the number of all possible contacts within the ED.

- Clustering Coefficient: The clustering coefficient measures the extent to which neighbors of a patient or healthcare worker in ED are in contact with each other. It is essentially a measure of local density, or how connected are individuals connected to a particular person.

3.4.3. Measures of Distance

- Weighted Shortest Path: The distance is the number of shortest steps between two individuals in the ED. The weighted shortest path takes into account actual contact time (in seconds) between individuals. In determining a shortest path for disease transmission, more weight should be given to longer contact times since longer contact time is associated with a higher probability of respiratory disease transmission.

- Weighted Diameter: The diameter in a network is the maximum distance between any pair of individuals. To find the diameter of a graph, first find the shortest path between each pair of individuals. The greatest length of any of these paths is the diameter of the graph. The weighted diameter takes into account contact time (in seconds) within a network.

3.5. Independent Variables

We wanted to examine how our outcome variables changed over time and under different situations. This would help researchers develop models that that into account the circumstances under which the interactions between patients and staff differ.

3.5.1. Quarter

Researchers are interested in how our metrics change over the course of a year, so we examined how they change across quarters. Our quarters are defined as,

- Quarter 1: July 2009 – September 2009
- Quarter 2: October 2009 – December 2009
- Quarter 3: January 2010 – March 2010
- Quarter 4: April 2010 – June 2010

3.5.2. Day of the Week

Researchers are also interested in is there is a statistical difference between our metrics according to what day of the week a person was in the ED.

3.5.3. Weekend/Weekday

Researchers are also interested in is there is a statistical difference between our metrics according to if they occurred over the weekend or weekday.

3.5.4. H1N1 Season

Researchers are also interested in is there is a statistical difference between our metrics according to if they occurred during a shift that occurred in H1N1 influenza season or not. In Atlanta, this season was between August 2009 and November 2009.

3.5.5. Shift (AM/PM)

Researchers are also interested in the statistical differences between our metrics according to the shift they occurred in at the ED.

3.6. Statistical Analysis

The major problem encountered in efforts to make statistical inference from network data is the interdependency between observations. Outcomes may be correlated over time since the ED - relatively speaking - will tend to have the same staff in the ED, and since individuals tend to have contacts with the same individuals (Fowler and Christakis 2008).

We evaluated longitudinal regression models of our outcome measures as a function of the quarter the observation took place, time of week it took place, and either ED status or ED interaction type, depending on the outcome measure. The main coefficient of interest in these regression models is quarter.

We used generalized estimating equations (GEE) procedures to account for multiple correlated observations over time. We cannot assume a normal distribution for our outcome variables, and in fact it is known that degree distribution often follows a power law (Watts and Strogatz 1998; Watts 2003; Newman 2005; Gundlapalli, Ma et al. 2009; Danon, Ford et al. 2010), therefore GEE analysis is more appropriate than linear regression based on independent observations. We only included patient-patient, staff-staff, and staff-patient interactions in our analysis.

We also assumed that staff to staff interactions are correlated; as are staff to patient, patient to patient interactions. We assumed a stationary correlation structure when we analyzed changes in metrics based on time (quarter) since we expect correlation to decrease as time progresses; otherwise, we assumed an exchangeable correlation structure.

We examined weighted networks when possible to take into account contact time, which is associated with disease transmission.

3.7. Software Packages

The dataset containing interactions (frequency and duration) between patients and healthcare workers was created using SAS (version 9.2, SAS Institute Inc.). Social networks were created and analyzed using R (version 2.8.1) and using the igraph software package for complex network research developed by G. Csardi (2006). We graphed our networks using Cytoscape (version 2.8.1, Institute of System Biology, San Diego, CA.) with the weighted Spring Embedded algorithm. This algorithm positions nodes so that the nodes and the edges connecting them are in their proper positions of centrality, weighted for time of contact, thus producing interpretable results.

4. Results

4.1. Introduction

We present several social network metrics that describe interactions between patients and staff within emergency department. Mean measures of individual contact (degree) are presented along with total hours of contact with other individuals (weighted degree) and average hours of contact with other individuals. We looked at interactions between staff and other staff, patients and other patients, staff and patients, and all interactions. In addition, we present results for statistically significant differences that occur between our measures over time (quarter, time of week, weekend versus weekday, H1N1 season or not, and night shift versus day shift). We also present similar data for other measures such as mean shortest path between individuals within the ED, the mean diameter between individuals, the mean density of our ED networks. More detailed tables can be viewed in Appendix A, along with unweighted versions of our tables.

4.2. Study Population

In total, 6,498 individuals participated in this study. We had 4,294 patient observations, and 2,204 observations ED staff observations. These are not unique individuals since on a day-today basis the same staff will be tracked, but our database does not keep individual IDs. In addition, if a patient were tracked on more than one occasion, each visit to the ED would be considered unique. All of our networks contain giant components; that is, networks that contain a majority of the individuals in the ED. In fact, many of our ED networks are strongly connected components (SCC) which means that every patient or staff is reachable by every other patient or staff.

4.3. Outcome Variables

4.3.1. Degree

4.3.1.1. By Quarter

Table 1 shows the mean number of contact hours per shift for each contact group.

Table 1	Weighted Degrees (hours of contact)									
	quarter								Total	
	1		2		3		4			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact										
Patient-Patient	5.50	7.64	7.26	9.01	10.21	10.93	14.03	16.64	9.55	12.34
Staff-Patient	3.57	5.91	5.81	9.75	5.08	9.05	4.85	9.97	4.89	8.91
Staff-Staff	26.54	26.01	29.69	27.45	18.86	19.63	12.59	14.52	22.90	23.99
All Contacts	15.98	21.46	21.50	25.59	18.05	19.96	17.44	21.21	18.40	22.37

Generalized estimation equation (GEE) analysis showed, on average, the mean weighted degree, which better represents contact that would result in the transmission of disease, did not change significantly over time (p-value=0.10), adjusted for the correlations within each group. A stationary correlation structure was assumed within each group.

4.3.1.2. By Day of Week:

Table 2	Weighted Degrees (in hours)															
	Day of Week														Total	
	Sun		Mon		Tues		Wed		Thurs		Fri		Sat			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact																
Patient-Patient	7.56	11.61	12.16	12.97	11.24	12.58	7.09	7.97	5.84	6.91	10.71	17.11	9.34	11.14	9.55	12.34
Staff-Patient	4.74	8.85	5.41	9.79	5.01	10.17	5.36	7.74	3.86	6.43	4.66	8.91	4.56	9.29	4.89	8.91
Staff-Staff	25.68	23.38	18.72	21.04	24.17	22.53	28.43	27.40	29.62	30.27	18.48	20.16	15.04	17.23	22.90	23.99
All Contacts	18.85	22.68	19.04	21.38	19.43	22.06	20.20	24.06	17.55	24.06	17.69	22.76	14.86	19.06	18.40	22.37

The mean weighted degree measure did not change significantly over the course of a week (p-value=0.70), adjusted for the correlations among contact groups (table2). An exchangeable correlation structure was assumed.

4.3.1.3. By Shift (AM/PM):

Table 3	Weighted Degrees (in hours)					
	Shift				Total	
	AM		PM			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	10.26	13.11	8.60	11.15	9.55	12.34
Staff-Patient	5.60	9.55	3.86	7.80	4.89	8.91
Staff-Staff	22.81	22.65	23.00	25.55	22.90	23.99
All Contacts	19.55	22.59	16.88	21.98	18.40	22.37

The mean weighted degree measure did not change significantly between the AM and PM shifts (p-value=0.18), adjusted for the correlations among contact groups. We assumed compound exchangeable correlation structure within each group.

4.3.1.4. By Occurrence on Weekend versus Weekday:

Table 4	Weighted Degrees (in hours)					
	Occurred on Weekend				Total	
	No		Yes			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	9.84	12.60	8.57	11.37	9.55	12.34
Staff-Patient	4.96	8.86	4.65	9.08	4.89	8.91
Staff-Staff	23.37	24.59	21.21	21.65	22.90	23.99
All Contacts	18.87	22.74	16.79	20.98	18.40	22.37

The mean weighted degree measure did not change significantly between the weekend shifts and weekday shifts (p-value=0.75), adjusted for the correlations among contact groups. We assumed an exchangeable correlation structure.

4.3.1.5. By Occurence during H1N1 Season versus non-H1N1 Season:

Table 5	Weighted Degrees (in hours)					
	H1N1 Season				Total	
	No		Yes			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	10.78	13.53	6.56	8.03	9.55	12.34
Staff-Patient	4.71	9.10	5.25	8.51	4.89	8.91
Staff-Staff	21.20	24.25	26.52	23.02	22.90	23.99
All Contacts	18.30	22.46	18.62	22.15	18.40	22.37

The mean weighted degree measure did not change significantly between the shifts that occurred during the H1N1 season and those that did not (p-value=0.94), adjusted for the correlations among contact groups. We assumed an exchangeable correlation structure for our model.

4.3.2. Shortest Path

4.3.2.1. By Quarter

Table 6	Weighted Shortest Path									
	quarter								Total	
	1		2		3		4			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact										
Patient-Patient	153.54	237.68	190.87	406.33	268.53	488.95	914.83	2,966.44	408.55	1,649.91
Staff-Patient	167.89	478.25	193.94	310.23	431.44	709.59	703.45	1,186.57	364.64	759.95
Staff-Staff	172.08	530.55	341.98	803.30	780.45	1,591.55	1,623.55	2,467.06	653.66	1,516.05
All Contacts	57.50	159.86	94.87	412.46	128.77	441.10	680.18	2,684.13	242.11	1,405.39

The mean weighted shortest path increased significantly over time (p-value<0.001). The mean shortest path, adjusted for the correlations among contact groups, was 122 (SE: 100.6) for quarter one, 173.3 (SE: 95.3) for quarter two, 338 (SE: 100) for quarter three, and 831.2 (SE: 101.9) for quarter four.

4.3.2.2. By Day of Week

Table 7	Weighted Shortest Path															
	Day of Week														Total	
	Sun		Mon		Tues		Wed		Thurs		Fri		Sat			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact																
Patient-Patient	345.85	702.14	204.04	426.51	1,100.65	3,896.31	187.26	287.89	167.23	316.87	590.86	1,476.91	293.80	440.53	408.55	1,649.91
Staff-Patient	312.96	748.13	349.23	673.20	333.76	434.35	239.79	312.02	159.77	200.54	316.13	418.56	915.29	1,618.24	364.64	759.95
Staff-Staff	335.00	800.69	776.34	1,385.93	1,078.45	2,271.63	338.29	667.90	338.76	1,119.13	886.18	2,034.96	799.59	1,415.41	653.66	1,516.05
All Contacts	195.99	709.67	126.96	450.43	772.58	3,448.77	74.01	159.18	95.84	414.70	247.41	755.45	217.87	676.71	242.11	1,405.39

GEE analysis shows that, overall, the mean weighted shortest path did not change significantly over the course of an average week, controlling for the correlations between contact groups (p-value=0.14). The adjusted means, controlling for the correlations within each contact group, are listed below in table 8. An exchangeable correlation structure was assumed.

Table 8	Adjusted Estimate of	Standard

Day of Week	Weighted Distance	Error
Sunday	325.2	173.3
Monday	368.4	123.2
Tuesday	751.2	155.3
Wednesday	241.1	142.3
Thursday	194	171.2
Friday	520.2	145.3
Saturday	656.3	167.8

4.3.2.3. By Shift (AM/PM)

Table 9	Weighted Shortest Path					
	Shift				Total	
	AM		PM			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	318.77	829.79	528.71	2,328.17	408.55	1,649.91
Staff-Patient	334.61	611.41	408.13	932.56	364.64	759.95
Staff-Staff	567.95	1,290.75	758.42	1,747.50	653.66	1,516.05
All Contacts	119.53	398.20	402.29	2,074.72	242.11	1,405.39

GEE analysis shows the mean weighted shortest path was not significantly different between the AM and the PM shifts (table 9), controlling for the correlated contact groups, (522.3 (SE: 82.1) for PM versus 375.3.5 (SE: 70.1) for AM; p-value=0.07). An exchangeable correlation structure was assumed within our contact groups.

4.3.2.4. By Occurrence on Weekend versus Weekday

Table 10	Weighted Shortest Path					
	Occurred on Weekend				Total	
	No		Yes			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	436.30	1,854.72	316.21	568.41	408.55	1,649.91
Staff-Patient	289.44	472.75	623.24	1,307.60	364.64	759.95
Staff-Staff	687.96	1,606.64	530.07	1,123.78	653.66	1,516.05
All Contacts	252.40	1,554.55	207.28	692.71	242.11	1,405.39

GEE analysis shows that, overall, the mean weighted shortest path was not significantly different between the weekend and weekday shifts (table 10), controlling for the correlation between groups (468.3 (SE: 64.8) for non-H1N1 versus 142.2 (SE: 96.6) for H1N1; p-value=0.79). An exchangeable correlation structure was assumed.

4.3.2.5. By Occurence during H1N1 Season versus non-H1N1 Season

Table 11	Weighted Shortest Path					
	H1N1 Season				Total	
	No		Yes			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	510.26	1,943.33	160.98	264.98	408.55	1,649.91
Staff-Patient	461.27	870.67	164.80	380.91	364.64	759.95
Staff-Staff	824.62	1,739.10	288.83	745.17	653.66	1,516.05
All Contacts	323.71	1,679.11	58.08	149.73	242.11	1,405.39

GEE analysis shows that, overall, the mean weighted shortest path was not found to be significantly different between the H1N1 season and the non-H1N1 season, controlling for the correlations within each group, (545.6 (SE: 69) for the non-H1N1 season versus 186.9 (SE: 102.4) for the H1N1 season; p-value=0.06). An exchangeable correlation structure was assumed.

4.3.3. Diameter

4.3.3.1. By Quarter

Table 12	Weighted Diameter									
	quarter								Total	
	1		2		3		4			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact										
Patient-Patient	1,498.86	1,650.14	2,147.26	2,568.01	1,913.17	1,650.23	2,601.71	4,170.32	2,100.48	2,803.40
Staff-Patient	3,478.00	4,943.40	2,876.89	2,416.82	3,619.42	2,822.22	5,476.70	5,658.02	3,952.29	4,196.95
Staff-Staff	1,578.57	3,076.40	3,464.37	3,770.71	3,984.18	4,231.70	4,968.00	5,323.88	3,762.59	4,381.86
All Contacts	944.00	1,777.24	2,207.42	3,206.76	1,797.29	3,240.46	3,662.92	4,778.81	2,298.79	3,656.29

GEE analysis shows that, overall, the mean weighted diameter increased over time, controlling for the correlations within each group (p-value=0.07) (Table 12). The adjusted mean for quarter 1 was 2,235.6 (SE: 821.6), for quarter 2 was 2,872 (SE: 704), for quarter 3 was 3,280 (SE: 590), and for quarter 4 was 4,375(SE: 631.9). We examined the effect of time on the weighted diameter because it takes into account contact time between individuals which is important in disease transmission.

4.3.3.2. By Day of Week

Table 13	Weighted Diameter															
	Day of Week														Total	
	Sun		Mon		Tues		Wed		Thurs		Fri		Sat			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact																
Patient-Patient	1,759.11	1,519.82	2,326.31	2,684.21	2,878.77	5,357.94	1,691.92	1,489.88	2,047.63	2,220.36	2,087.46	2,325.97	1,584.10	1,468.11	2,100.48	2,803.4
Staff-Patient	5,670.89	6,111.71	3,855.25	2,956.50	3,052.08	1,465.80	2,422.50	943.35	1,874.13	1,048.08	2,989.69	1,750.88	8,390.70	7,996.99	3,952.29	4,196.9
Staff-Staff	3,009.00	4,100.69	4,296.89	4,531.77	5,471.79	6,189.89	2,726.14	2,883.34	3,680.50	5,125.26	3,577.19	4,550.50	2,978.00	2,258.19	3,762.59	4,381.8
All Contacts	1,001.78	1,538.68	2,684.88	4,035.59	2,626.85	5,241.25	1,265.17	1,174.24	2,526.75	3,693.29	3,262.69	4,704.69	2,226.80	2,495.55	2,298.79	3,656.3

From Table 13, GEE analysis shows that, overall, the mean weighted diameter did not change significantly for day of week (p-value=0.64). The adjusted means, controlling for the correlations with each groups, are listed below in table 14. An exchangeable correlation structure is assumed.

Table 14 Day of Week	Adjusted Estimate of Weighted Distance	Standard Error
Sunday	2,891.7	803
Monday	3,290.8	803
Tuesday	3,507.4	803
Wednesday	2,026.4	803
Thursday	2,532.3	803
Friday	2,979.2	803
Saturday	3,794.9	803

4.3.3.3. By Shift (AM/PM)

Table 15	Weighted Diameter					
	Shift				Total	
	AM		PM			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	2,114.14	2,197.09	2,085.03	3,393.02	2,100.48	2,803.40
Staff-Patient	4,024.42	4,114.29	3,868.46	4,346.45	3,952.29	4,196.95
Staff-Staff	3,209.98	3,586.94	4,366.60	5,087.29	3,762.59	4,381.86
All Contacts	1,838.65	2,996.86	2,819.47	4,264.44	2,298.79	3,656.29

The weighted diameter for the ED during this study was not significantly lower for the AM shift versus the PM shift (p-value=0.24). The adjusted weighted diameter means were 2,796 (SE: 509) for the AM shift versus 3,285 (SE: 509) for the PM shift. The exchangeable correlation structure was assumed (Table15).

4.3.3.4. By Occurrence on Weekend versus Weekday

Table 16	Weighted Diameter					
	Shift				Total	
	AM		PM			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	2,114.14	2,197.09	2,085.03	3,393.02	2,100.48	2,803.40
Staff-Patient	4,024.42	4,114.29	3,868.46	4,346.45	3,952.29	4,196.95
Staff-Staff	3,209.98	3,586.94	4,366.60	5,087.29	3,762.59	4,381.86
All Contacts	1,838.65	2,996.86	2,819.47	4,264.44	2,298.79	3,656.29

The weighted diameter for the ED was not statistically different between the weekend shifts and the weekday shifts (p-value=0.75). The adjusted weighted diameter means were 2,921 (SE: 951) for the weekday shifts and 3,352 (SE: 951) for the weekend shifts. The independent correlation structure was assumed.

4.3.3.5. By Occurence during H1N1 Season versus non-H1N1 Season

Table 17	Weighted Diameter					
	H1N1 Season				Total	
	No		Yes			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	2,232.16	3,085.53	1,698.85	1,673.46	2,100.48	2,803.40
Staff-Patient	4,283.12	4,276.63	2,959.80	3,881.02	3,952.29	4,196.95
Staff-Staff	4,016.41	4,498.35	2,874.20	3,922.55	3,762.59	4,381.86
All Contacts	2,752.43	4,022.81	915.20	1,583.77	2,298.79	3,656.29

The weighted mean diameter for the ED was not significantly different between the H1N1 season and the non-H1N1 season, adjusted for the correlations within the contact groups (p-value=0.27). The adjusted weighted diameter means were 2,525.3 (SE: 849) for the H1N1 season versus 3,532 (SE: 475.9) for the non-H1N1 season. The exchangeable correlation structure was assumed.

4.3.4. Density

4.3.4.1. By Quarter

Table 18	Density									
	quarter								Total	
	1		2		3		4			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact										
Patient-Patient	0.24	0.11	0.29	0.07	0.41	0.19	0.35	0.09	0.33	0.14
Staff-Patient	0.14	0.04	0.16	0.03	0.17	0.06	0.17	0.19	0.16	0.11
Staff-Staff	0.53	0.08	0.47	0.08	0.50	0.14	0.47	0.18	0.49	0.14
All Contacts	0.27	0.08	0.31	0.06	0.34	0.08	0.30	0.08	0.31	0.08

The mean network density did not significantly change over time (p-value=0.24). The staff to staff networks are statistically denser than the patient to patient networks (p-value=0.008) and the staff to patient networks (p-value<0.001). A stationary correlation structure was fit to our model.

4.3.4.2. By Day of Week

Table 19	Density															
	Day of Week														Total	
	Sun		Mon		Tues		Wed		Thurs		Fri		Sat			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact																
Patient-Patient	0.28	0.13	0.33	0.08	0.39	0.17	0.33	0.12	0.28	0.10	0.38	0.22	0.29	0.10	0.33	0.14
Staff-Patient	0.25	0.28	0.14	0.05	0.17	0.05	0.16	0.04	0.14	0.05	0.16	0.06	0.13	0.05	0.16	0.11
Staff-Staff	0.53	0.12	0.42	0.11	0.57	0.20	0.51	0.09	0.51	0.13	0.48	0.12	0.42	0.12	0.49	0.14
All Contacts	0.29	0.06	0.31	0.07	0.33	0.10	0.32	0.04	0.31	0.11	0.32	0.07	0.28	0.08	0.31	0.08

The mean network density, adjusted for the correlations within each contact group, did not vary significantly over an average week (p-value=0.12). An exchangeable correlation structure was assumed.

4.3.4.3. By Shift (AM/PM)

Table 20	Density					
	Shift				Total	
	AM		PM			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	0.32	0.15	0.35	0.13	0.33	0.14

Table 20	Density					
	Shift				Total	
	AM		PM			
	Mean	SD	Mean	SD	Mean	SD
Staff-Patient	0.16	0.05	0.16	0.15	0.16	0.11
Staff-Staff	0.49	0.13	0.49	0.15	0.49	0.14
All Contacts	0.32	0.07	0.29	0.08	0.31	0.08

The mean network density was not statistically different between the AM and PM shifts (p-value=0.43). The mean density, adjusted for the correlations between contact groups, was 0.32 (SE: 0.06) for the PM shifts and 0.32 (SE: 0.06) for AM shifts. An exchangeable correlation structure was assumed.

4.3.4.4. By Occurrence on Weekend versus Weekday

Table 21	Density					
	Occurred on Weekend				Total	
	No		Yes			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	0.35	0.15	0.28	0.11	0.33	0.14
Staff-Patient	0.15	0.05	0.18	0.20	0.16	0.11
Staff-Staff	0.49	0.14	0.47	0.13	0.49	0.14
All Contacts	0.32	0.08	0.28	0.07	0.31	0.08

The mean network density was not found to be statistically different between the weekend and weekday shifts (p-value=0.84). The mean density, adjusted for correlations between contact groups, was 0.34 (SE: 0.07) for the weekend shifts and 0.32 (SE: 0.14) for weekday shifts. An exchangeable correlation structure was assumed.

4.3.4.5. By Occurrence during H1N1 Season versus non-H1N1 Season

Table 22	Density					
	H1N1 Season				Total	
	No		Yes			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	0.35	0.15	0.27	0.10	0.33	0.14
Staff-Patient	0.16	0.12	0.16	0.04	0.16	0.11
Staff-Staff	0.48	0.15	0.50	0.09	0.49	0.14
All Contacts	0.31	0.08	0.31	0.07	0.31	0.08

The mean network density was not found to be statistically different between the H1N1 period and the non-H1N1period (p-value=0.83). The mean density, adjusted for the number of individuals in the ED, was 0.32 (SE: 0.12) for the H1N1 shifts and 0.34 (SE: 0.08) for non-H1N1 shifts. An exchangeable correlation structure was assumed.

4.3.5. Clustering Coefficient

Clustering in the staff and patients contact networks are not applicable because, as Figure 1 shows, a staff member can only be connected to patients and those patients cannot be connect to each other since they have to be connected to other staff. Therefore, staff and patients networks will always have a clustering coefficient of zero. We did not include staff and patient interaction measures in our calculations.

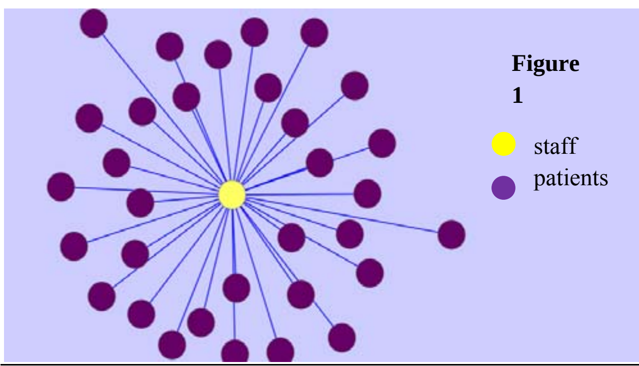

Figure 1

4.3.5.1. By Quarter

Table 23	Clustering Coefficient									
	quarter								Total	
	1		2		3		4			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact										
Patient-Patient	0.59	0.22	0.62	0.20	0.70	0.20	0.76	0.19	0.68	0.21
Staff-Patient	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staff-Staff	0.82	0.14	0.82	0.15	0.82	0.18	0.80	0.21	0.81	0.17
All Contacts	0.65	0.18	0.67	0.17	0.71	0.18	0.74	0.20	0.69	0.18

The mean clustering coefficient did not change significantly over time (p-value=0.33). The mean clustering coefficient, adjusted for correlations between contact groups, was 0.70 (SE: 0.08) for quarter one, 0.72 (SE: 0.08) for quarter two, 0.77 (SE: 0.07) for quarter three, and 0.81 (SE: 0.08) for quarter four. An exchangeable correlation structure was assumed.

4.3.5.2. By Day of Week

Table 24	Clustering Coefficient															
	Day of Week														Total	
	Sun		Mon		Tues		Wed		Thurs		Fri		Sat			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact																
Patient-Patient	0.63	0.26	0.71	0.18	0.72	0.19	0.65	0.20	0.61	0.20	0.68	0.23	0.68	0.25	0.68	0.21
Staff-Patient	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Staff-Staff	0.82	0.16	0.79	0.20	0.84	0.16	0.83	0.14	0.82	0.15	0.82	0.17	0.79	0.20	0.81	0.17
All Contacts	0.67	0.20	0.71	0.17	0.72	0.18	0.69	0.16	0.66	0.17	0.71	0.18	0.68	0.20	0.69	0.18

The mean clustering coefficient was not found to significantly change during an average week (p-value=0.21). An exchangeable correlation structure was assumed.

4.3.5.3. By Shift (AM/PM)

Table 25	Clustering Coefficient					
	Shift				Total	
	AM		PM			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	0.68	0.22	0.67	0.21	0.68	0.21
Staff-Patient	0.00	0.00	0.00	0.00	0.00	0.00
Staff-Staff	0.82	0.16	0.81	0.18	0.81	0.17
All Contacts	0.70	0.17	0.68	0.19	0.69	0.18

The mean clustering coefficient was not found to significantly change during between the AM shift and the PM shift, adjusted for the correlations within each contact group (p-value=0.76). The mean clustering coefficient was 0.72(SE: 0.06) for the AM shift and 0.72 (SE: 0.07) for the PM shift. An exchangeable correlation structure was assumed.

4.3.5.4. By Occurrence on Weekend versus Weekday

Table 26	Clustering Coefficient					
	Occurred on Weekend				Total	
	No		Yes			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	0.68	0.20	0.66	0.25	0.68	0.21
Staff-Patient	0.00	0.00	0.00	0.00	0.00	0.00
Staff-Staff	0.82	0.17	0.81	0.18	0.81	0.17
All Contacts	0.70	0.18	0.68	0.20	0.69	0.18

The mean clustering coefficient was not found to significantly change during between the weekend shifts and the non-weekend shifts, adjusted for the correlation structure within each contact group (p-value=0.88). The mean clustering coefficient was 0.74 (SE: 0.09) for the AM shift and 0.73 (SE: 0.05) for the PM shift. An exchangeable correlation structure was assumed.

4.3.5.5. By Occurrence during H1N1 Season versus non-H1N1 Season

Table 27	Clustering Coefficient					
	H1N1 Season				Total	
	No		Yes			
	Mean	SD	Mean	SD	Mean	SD
Contact						
Patient-Patient	0.70	0.21	0.61	0.21	0.68	0.21
Staff-Patient	0.00	0.00	0.00	0.00	0.00	0.00
Staff-Staff	0.81	0.18	0.82	0.15	0.81	0.17
All Contacts	0.71	0.19	0.67	0.17	0.69	0.18

The mean clustering coefficient was not found to significantly change during between the H1N1 season shifts and the non-H1N1 season shifts, adjusted for the correlations within each contact group (p-value=0.35). The mean clustering coefficient was 0.70 (SE: 0.09) for the H1N1 season shifts and 0.76 (SE: 0.06) for the non-H1N1 season shifts. An exchangeable correlation structure was assumed.

5. Discussion

5.1. Public Health Implications

Examining each factor on the social network measures we collected, we can better understand how disease transmission occurs in the emergency department of a hospital. This will enable hospital officials to develop surveillance, prevention, and control methods in the ED.

5.1.1. Degree

There was a significant difference in how much time patients and staff spent with each other (p-value<0.001). Based on the fact that diseases like influenza transmit more easily the more contact there is between individuals, influenza would transmit more easily among staff compared to staff to patient contact and patient to patient contact. None of the other factor made a significant difference in how many hours an individual spent with other individuals in the ED.

5.1.2. Shortest Path

We did find that the mean weighted shortest paths increase significantly over time (p<0.001). This implies that the number of individuals between any two people in the ED increased over time. This would decrease the transmission of disease since the probability of contacting an infected person decreases as the shortest path increases.

5.1.3. Distance

Among the factors that we examined, no significant results were found. A network with a small diameter, generally considered to be less than unweighted diameter of 6 – ours is 4.1 (SE: 0.76), is considered to be a “small world”. That means that every individual in the network is not far from every other individual. This makes disease transmission easier than a wide network. The ED network can be considered small, but does not vary according to the factors we examined.

5.1.4. Density

Density was not found to vary significantly according to the factor we analyzed. Density is important in the study of disease transmission because the denser a network, the higher the probability an individual will come into contact with an infected person. Staff interactions with other staff resulted higher density, therefore disease may potentially transmit through ED staff more easily than through other contact groups.

5.1.5. Clustering Coefficient

The clustering coefficient did not vary significantly according to the factors we analyzed. The clustering coefficient is like an individual's personal density. The higher it is the more likely disease can transmit if someone in your personal network is infected. The higher the network mean clustering coefficient is, the more likely a disease can transmit through the entire network. A high clustering coefficient (0.69 for all contacts), along with a small diameter (4.1 unweighted), indicates that the ED may be a "small world"; that is, every one is the network is within a few people contact with each other. Staff to staff interaction may be particularly susceptible to disease transmission with the highest mean clustering coefficient (0.81) and smallest diameter (3.4 unweighted) of any other group.

5.2. Future Directions

The next step in analyzing the data is to apply what we have learned about emergency department interaction into new, more sophisticated, epidemic models that do not assume equal mixing of populations. This would enable public health official to more accurately predict ways to intervene in a disease outbreak in not only an ED, but also similar urban environments.

Another step in the future is to allow the tracking of ED staff from day-to-day. A limitation of this study is that we could not take into account the day-to-day correlations from staff we were tracking. An ID system like that would enable more accurate information leading to better epidemic models.

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Table 1	Degree																			
	quarter																			
	1					2					3					4				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	927	15.22	9.83	71	1	1,053	15.63	8.26	46	1	1,075	16.96	9.49	51	1	1,217	19.07	9.62	54	1
Staff-Patient	1,335	13.57	11.37	68	1	1,657	14.38	10.93	60	1	1,395	10.37	9.37	61	1	1,335	8.39	10.07	65	1
Staff-Staff	493	18.00	8.87	36	1	722	17.39	9.16	38	1	664	11.73	8.09	33	1	390	7.50	4.47	24	1
All Contacts	1,436	28.62	18.33	100	1	1,801	29.34	17.07	88	1	1,629	24.32	14.77	79	1	1,632	22.88	14.29	77	1

	Degree				
	Total				
	N	Mean	SD	Max	Min
Contact					
Patient-Patient	4,272	16.86	9.44	71	1
Staff-Patient	5,722	11.82	10.76	68	1
Staff-Staff	2,269	14.16	9.07	38	1
All Contacts	6,498	26.30	16.39	100	1

Table 2	Weighted Degrees																			
	quarter																			
	1					2					3					4				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	927	5.50	7.64	84	0	1,053	7.26	9.01	53	0	1,075	10.21	10.93	70	0	1,217	14.03	16.64	92	0
Staff-Patient	1,335	3.57	5.91	66	0	1,657	5.81	9.75	97	0	1,395	5.08	9.05	69	0	1,335	4.85	9.97	106	0
Staff-Staff	493	26.54	26.01	107	0	722	29.69	27.45	113	0	664	18.86	19.63	84	0	390	12.59	14.52	60	0
All Contacts	1,436	15.98	21.46	119	0	1,801	21.50	25.59	153	0	1,629	18.05	19.96	109	0	1,632	17.44	21.21	126	0

	Weighted Degrees				
	Total				
	N	Mean	SD	Max	Min
Contact					
Patient-Patient	4,272	9.55	12.34	92	0
Staff-Patient	5,722	4.89	8.91	106	0
Staff-Staff	2,269	22.90	23.99	113	0
All Contacts	6,498	18.40	22.37	153	0

	Weighted Degrees / contact									
	quarter								Total	
	1		2		3		4			
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Contact										
Patient-Patient	0.28	0.24	0.38	0.38	0.51	0.49	0.68	0.81	0.48	0.56
Staff-Patient	0.21	0.25	0.32	0.36	0.38	0.42	0.42	0.55	0.33	0.41
Staff-Staff	1.22	1.06	1.51	1.19	1.34	1.03	1.34	1.39	1.37	1.16
All Contacts	0.44	0.49	0.64	0.76	0.64	0.64	0.70	0.84	0.61	0.71

Degrees of Individuals in ED Network by day of week

	Degree																			
	Day of Week																			
	Sun					Mon					Tues					Wed				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	425	13.43	8.20	39	1	950	19.60	10.02	71	1	610	18.47	9.84	48	1	631	15.75	7.75	37	1
Staff-Patient	625	12.12	9.64	52	1	1,241	11.88	11.58	65	1	743	11.04	10.49	65	1	924	13.39	10.90	68	1
Staff-Staff	286	16.12	8.46	33	1	439	12.51	9.17	38	1	300	12.62	7.54	33	1	408	16.50	9.73	37	1
All Contacts	717	24.96	15.54	79	1	1,383	28.01	17.08	94	1	910	25.45	15.70	88	1	1,019	28.24	16.90	100	1

	Degree																			
	Day of Week																			
	Thurs					Fri					Sat					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	464	15.41	8.97	48	1	630	16.50	9.78	51	1	562	15.91	9.11	46	1	4,272	16.86	9.44	71	1
Staff-Patient	652	12.56	11.27	62	1	873	12.22	10.70	61	1	664	8.81	9.04	51	1	5,722	11.82	10.76	68	1
Staff-Staff	252	17.06	9.13	35	1	377	13.51	9.22	36	1	207	10.29	7.03	28	1	2,269	14.16	9.07	38	1
All Contacts	723	27.16	17.62	89	1	981	26.31	16.71	86	1	765	22.07	13.15	71	1	6,498	26.30	16.39	100	1

Degrees of Individuals in ED Network by day of week

	Weighted Degrees																			
	Day of Week																			
	Sun					Mon					Tues					Wed				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	425	7.56	11.61	53	0	950	12.16	12.97	84	0	610	11.24	12.58	65	0	631	7.09	7.97	42	0
Staff-Patient	625	4.74	8.85	65	0	1,241	5.41	9.79	66	0	743	5.01	10.17	97	0	924	5.36	7.74	66	0
Staff-Staff	286	25.68	23.38	81	0	439	18.72	21.04	90	0	300	24.17	22.53	80	0	408	28.43	27.40	113	0
All Contacts	717	18.85	22.68	94	0	1,383	19.04	21.38	119	0	910	19.43	22.06	153	0	1,019	20.20	24.06	113	0

	Weighted Degrees																			
	Day of Week																			
	Thurs					Fri					Sat					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	464	5.84	6.91	41	0	630	10.71	17.11	92	0	562	9.34	11.14	58	0	4,272	9.55	12.34	92	0
Staff-Patient	652	3.86	6.43	60	0	873	4.66	8.91	106	0	664	4.56	9.29	69	0	5,722	4.89	8.91	106	0
Staff-Staff	252	29.62	30.27	107	0	377	18.48	20.16	85	0	207	15.04	17.23	64	0	2,269	22.90	23.99	113	0
All Contacts	723	17.55	24.06	112	0	981	17.69	22.76	126	0	765	14.86	19.06	100	0	6,498	18.40	22.37	153	0

Degrees of Individuals in ED Network
by day of week

	Weighted Degrees / contact																			
	Day of Week																			
	Sun					Mon					Tues					Wed				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	425	0.40	0.49	2	0	950	0.54	0.47	3	0	610	0.63	0.88	6	0	631	0.38	0.37	2	0
Staff-Patient	625	0.31	0.40	3	0	1,241	0.37	0.45	3	0	743	0.33	0.37	2	0	924	0.34	0.38	3	0
Staff-Staff	286	1.44	1.14	6	0	439	1.22	1.02	6	0	300	1.66	1.36	6	0	408	1.50	1.15	5	0
All Contacts	717	0.63	0.73	4	0	1,383	0.59	0.59	6	0	910	0.75	0.93	6	0	1,019	0.62	0.72	4	0

	Weighted Degrees / contact																			
	Day of Week																			
	Thurs					Fri					Sat					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	464	0.32	0.29	2	0	630	0.52	0.69	3	0	562	0.47	0.46	3	0	4,272	0.48	0.56	6	0
Staff-Patient	652	0.24	0.27	2	0	873	0.30	0.35	2	0	664	0.42	0.58	4	0	5,722	0.33	0.41	4	0
Staff-Staff	252	1.43	1.32	5	0	377	1.16	1.03	5	0	207	1.20	1.06	4	0	2,269	1.37	1.16	6	0
All Contacts	723	0.54	0.70	5	0	981	0.59	0.71	5	0	765	0.54	0.55	3	0	6,498	0.61	0.71	6	0

Degrees of Individuals in ED Network by shift(AM/PM)

	Degree														
	Shift										Total				
	AM					PM									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	2,445	17.03	9.08	71	1	1,827	16.63	9.90	54	1	4,272	16.86	9.44	71	1
Staff-Patient	3,385	13.23	11.62	68	1	2,337	9.77	8.99	61	1	5,722	11.82	10.76	68	1
Staff-Staff	1,248	15.23	9.31	37	1	1,021	12.86	8.58	38	1	2,269	14.16	9.07	38	1
All Contacts	3,681	28.54	17.08	100	1	2,817	23.37	14.93	81	1	6,498	26.30	16.39	100	1

Degrees of Individuals in ED Network by shift(AM/PM)

	Weighted Degrees														
	Shift										Total				
	AM					PM									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	2,445	10.26	13.11	92	0	1,827	8.60	11.15	70	0	4,272	9.55	12.34	92	0
Staff-Patient	3,385	5.60	9.55	106	0	2,337	3.86	7.80	65	0	5,722	4.89	8.91	106	0
Staff-Staff	1,248	22.81	22.65	113	0	1,021	23.00	25.55	107	0	2,269	22.90	23.99	113	0
All Contacts	3,681	19.55	22.59	153	0	2,817	16.88	21.98	114	0	6,498	18.40	22.37	153	0

Degrees of Individuals in ED Network
by shift(AM/PM)

	Weighted Degrees / contact														
	Shift										Total				
	AM					PM									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	2,445	0.50	0.51	3	0	1,827	0.46	0.63	6	0	4,272	0.48	0.56	6	0
Staff-Patient	3,385	0.36	0.40	3	0	2,337	0.30	0.43	4	0	5,722	0.33	0.41	4	0
Staff-Staff	1,248	1.32	1.07	6	0	1,021	1.43	1.26	6	0	2,269	1.37	1.16	6	0
All Contacts	3,681	0.59	0.62	5	0	2,817	0.63	0.81	6	0	6,498	0.61	0.71	6	0

egrees of Individuals in ED Network
by H1N1 Season

	Degree														
	H1N1 Season										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,028	17.22	9.61	54	1	1,244	15.98	8.95	71	1	4,272	16.86	9.44	71	1
Staff-Patient	3,857	10.17	9.90	65	1	1,865	15.23	11.62	68	1	5,722	11.82	10.76	68	1
Staff-Staff	1,545	12.48	8.62	38	1	724	17.77	8.95	36	1	2,269	14.16	9.07	38	1
All Contacts	4,502	24.38	15.19	86	1	1,996	30.63	18.08	100	1	6,498	26.30	16.39	100	1

Degrees of Individuals in ED Network by H1N1 Season

	Weighted Degrees														
	H1N1 Season										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,028	10.78	13.53	92	0	1,244	6.56	8.03	84	0	4,272	9.55	12.34	92	0
Staff-Patient	3,857	4.71	9.10	106	0	1,865	5.25	8.51	97	0	5,722	4.89	8.91	106	0
Staff-Staff	1,545	21.20	24.25	113	0	724	26.52	23.02	80	0	2,269	22.90	23.99	113	0
All Contacts	4,502	18.30	22.46	126	0	1,996	18.62	22.15	153	0	6,498	18.40	22.37	153	0

Degrees of Individuals in ED Network by H1N1 Season

	Weighted Degrees / contact														
	H1N1 Season										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,028	0.54	0.64	6	0	1,244	0.34	0.28	2	0	4,272	0.48	0.56	6	0
Staff-Patient	3,857	0.36	0.45	4	0	1,865	0.28	0.31	3	0	5,722	0.33	0.41	4	0
Staff-Staff	1,545	1.39	1.22	6	0	724	1.32	1.02	4	0	2,269	1.37	1.16	6	0
All Contacts	4,502	0.66	0.77	6	0	1,996	0.51	0.55	4	0	6,498	0.61	0.71	6	0

Degrees of Individuals in ED Network
by weekday/weekend

	Degree														
	Occured on Weekend										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,285	17.46	9.54	71	1	987	14.84	8.81	46	1	4,272	16.86	9.44	71	1
Staff-Patient	4,433	12.22	11.07	68	1	1,289	10.42	9.48	52	1	5,722	11.82	10.76	68	1
Staff-Staff	1,776	14.30	9.24	38	1	493	13.67	8.40	33	1	2,269	14.16	9.07	38	1
All Contacts	5,016	27.14	16.83	100	1	1,482	23.47	14.42	79	1	6,498	26.30	16.39	100	1

Degrees of Individuals in ED Network
by weekday/weekend

	Weighted Degrees														
	Occured on Weekend										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,285	9.84	12.60	92	0	987	8.57	11.37	58	0	4,272	9.55	12.34	92	0
Staff-Patient	4,433	4.96	8.86	106	0	1,289	4.65	9.08	69	0	5,722	4.89	8.91	106	0
Staff-Staff	1,776	23.37	24.59	113	0	493	21.21	21.65	81	0	2,269	22.90	23.99	113	0
All Contacts	5,016	18.87	22.74	153	0	1,482	16.79	20.98	100	0	6,498	18.40	22.37	153	0

Degrees of Individuals in ED Network by weekday/weekend

	Weighted Degrees / contact														
	Occured on Weekend										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,285	0.49	0.59	6	0	987	0.44	0.47	3	0	4,272	0.48	0.56	6	0
Staff-Patient	4,433	0.32	0.38	3	0	1,289	0.36	0.51	4	0	5,722	0.33	0.41	4	0
Staff-Staff	1,776	1.38	1.17	6	0	493	1.33	1.11	6	0	2,269	1.37	1.16	6	0
All Contacts	5,016	0.62	0.73	6	0	1,482	0.58	0.64	4	0	6,498	0.61	0.71	6	0

Shortest Path of Individuals in ED Network by quarter

	Shortest Path																			
	quarter																			
	1					2					3					4				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	927	2.14	0.49	4	1	1,053	1.97	0.42	5	1	1,075	1.83	0.44	4	1	1,217	1.97	0.85	9	1
Staff-Patient	1,335	2.32	0.37	5	1	1,657	2.26	0.37	4	1	1,395	2.22	0.42	5	1	1,335	2.26	0.44	4	1
Staff-Staff	493	1.50	0.34	3	1	722	1.60	0.37	3	1	664	1.55	0.42	3	1	390	1.70	0.56	4	1
All Contacts	1,436	1.83	0.31	4	1	1,801	1.78	0.31	4	1	1,629	1.81	0.41	6	1	1,632	1.87	0.42	4	1

	Shortest Path				
	Total				
	N	Mean	SD	Max	Min
Contact					
Patient-Patient	4,272	1.97	0.60	9	1
Staff-Patient	5,722	2.26	0.40	5	1
Staff-Staff	2,269	1.58	0.42	4	1
All Contacts	6,498	1.82	0.37	6	1

Weighted Shortest Path of Individuals in ED Network
by quarter
total contact hours

	Weighted Shortest Path																			
	quarter																			
	1					2					3					4				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	927	153.54	237.68	5240	49	1,053	190.87	406.33	9419	22	1,075	268.53	488.95	4670	17	1,217	914.83	2,966.44	18803	26
Staff-Patient	1,335	167.89	478.25	11705	30	1,657	193.94	310.23	5298	44	1,395	431.44	709.59	8835	30	1,335	703.45	1,186.57	12472	18
Staff-Staff	493	172.08	530.55	11252	11	722	341.98	803.30	11918	39	664	780.45	1,591.55	14761	21	390	1,623.55	2,467.06	15639	1
All Contacts	1,436	57.50	159.86	5218	10	1,801	94.87	412.46	9510	16	1,629	128.77	441.10	9945	10	1,632	680.18	2,684.13	18926	22

	Weighted Shortest Path				
	Total				
	N	Mean	SD	Max	Min
Contact					
Patient-Patient	4,272	408.55	1,649.91	18803	17
Staff-Patient	5,722	364.64	759.95	12472	18
Staff-Staff	2,269	653.66	1,516.05	15639	1
All Contacts	6,498	242.11	1,405.39	18926	10

Shortest Path of Individuals in ED Network by day of week

	Shortest Path																			
	Day of Week																			
	Sun					Mon					Tues					Wed				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	425	2.18	0.57	4	1	950	1.86	0.36	4	1	610	1.77	0.41	4	1	631	1.93	0.41	5	1
Staff-Patient	625	2.31	0.42	4	1	1,241	2.28	0.43	5	1	743	2.17	0.36	4	1	924	2.25	0.36	4	1
Staff-Staff	286	1.55	0.38	3	1	439	1.70	0.50	4	1	300	1.56	0.49	3	1	408	1.51	0.34	3	1
All Contacts	717	1.87	0.42	4	1	1,383	1.81	0.34	4	1	910	1.77	0.34	3	1	1,019	1.78	0.30	4	1

	Shortest Path																			
	Day of Week																			
	Thurs					Fri					Sat					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	464	1.96	0.41	4	1	630	1.93	0.46	4	1	562	2.30	1.15	9	1	4,272	1.97	0.60	9	1
Staff-Patient	652	2.27	0.37	4	1	873	2.25	0.42	5	1	664	2.33	0.44	4	1	5,722	2.26	0.40	5	1
Staff-Staff	252	1.54	0.40	3	1	377	1.57	0.39	3	1	207	1.57	0.34	3	1	2,269	1.58	0.42	4	1
All Contacts	723	1.81	0.34	4	1	981	1.83	0.44	6	1	765	1.90	0.38	4	1	6,498	1.82	0.37	6	1

Shortest Path of Individuals in ED Network by day of week

	Weighted Shortest Path																			
	Day of Week																			
	Sun					Mon					Tues					Wed				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	425	345.85	702.14	4688	29	950	204.04	426.51	9419	44	610	1,100.65	3,896.31	18803	20	631	187.26	287.89	4531	22
Staff-Patient	625	312.96	748.13	11705	18	1,241	349.23	673.20	6778	32	743	333.76	434.35	5209	30	924	239.79	312.02	3313	60
Staff-Staff	286	335.00	800.69	11252	15	439	776.34	1,385.93	10828	31	300	1,078.45	2,271.63	15639	1	408	338.29	667.90	6854	29
All Contacts	717	195.99	709.67	4857	18	1,383	126.96	450.43	9346	10	910	772.58	3,448.77	18926	21	1,019	74.01	159.18	4118	16

	Weighted Shortest Path																			
	Day of Week																			
	Thurs					Fri					Sat					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	464	167.23	316.87	5240	27	630	590.86	1,476.91	7135	17	562	293.80	440.53	3511	36	4,272	408.55	1,649.91	18803	17
Staff-Patient	652	159.77	200.54	1784	43	873	316.13	418.56	5298	44	664	915.29	1,618.24	12472	86	5,722	364.64	759.95	12472	18
Staff-Staff	252	338.76	1,119.13	9477	11	377	886.18	2,034.96	14761	39	207	799.59	1,415.41	7151	73	2,269	653.66	1,516.05	15639	1
All Contacts	723	95.84	414.70	9510	17	981	247.41	755.45	9945	10	765	217.87	676.71	8040	27	6,498	242.11	1,405.39	18926	10

Shortest Path of Individuals in ED Network by shift(AM/PM)

	Shortest Path														
	Shift										Total				
	AM					PM									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	2,445	1.99	0.44	5	1	1,827	1.94	0.76	9	1	4,272	1.97	0.60	9	1
Staff-Patient	3,385	2.23	0.39	5	1	2,337	2.32	0.41	5	1	5,722	2.26	0.40	5	1
Staff-Staff	1,248	1.56	0.42	4	1	1,021	1.61	0.43	3	1	2,269	1.58	0.42	4	1
All Contacts	3,681	1.79	0.35	6	1	2,817	1.86	0.39	4	1	6,498	1.82	0.37	6	1

Shortest Path of Individuals in ED Network by shift(AM/PM)

	Weighted Shortest Path														
	Shift										Total				
	AM					PM									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	2,445	318.77	829.79	9419	17	1,827	528.71	2,328.17	18803	20	4,272	408.55	1,649.91	18803	17
Staff-Patient	3,385	334.61	611.41	11826	30	2,337	408.13	932.56	12472	18	5,722	364.64	759.95	12472	18
Staff-Staff	1,248	567.95	1,290.75	14761	39	1,021	758.42	1,747.50	15639	1	2,269	653.66	1,516.05	15639	1
All Contacts	3,681	119.53	398.20	9945	10	2,817	402.29	2,074.72	18926	10	6,498	242.11	1,405.39	18926	10

Shortest Path of Individuals in ED Network by H1N1 Season

	Shortest Path														
	H1N1 Season										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,028	1.95	0.65	9	1	1,244	2.02	0.44	5	1	4,272	1.97	0.60	9	1
Staff-Patient	3,857	2.28	0.42	5	1	1,865	2.23	0.35	4	1	5,722	2.26	0.40	5	1
Staff-Staff	1,545	1.60	0.44	4	1	724	1.54	0.36	3	1	2,269	1.58	0.42	4	1
All Contacts	4,502	1.84	0.39	6	1	1,996	1.77	0.30	4	1	6,498	1.82	0.37	6	1

Shortest Path of Individuals in ED Network by H1N1 Season

	Weighted Shortest Path														
	H1N1 Season										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,028	510.26	1,943.33	18803	17	1,244	160.98	264.98	5240	29	4,272	408.55	1,649.91	18803	17
Staff-Patient	3,857	461.27	870.67	12472	18	1,865	164.80	380.91	11705	30	5,722	364.64	759.95	12472	18
Staff-Staff	1,545	824.62	1,739.10	15639	1	724	288.83	745.17	11918	32	2,269	653.66	1,516.05	15639	1
All Contacts	4,502	323.71	1,679.11	18926	10	1,996	58.08	149.73	5218	10	6,498	242.11	1,405.39	18926	10

Shortest Path of Individuals in ED Network
by weekday/weekend

	Shortest Path														
	Occured on Weekend										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,285	1.89	0.41	5	1	987	2.25	0.95	9	1	4,272	1.97	0.60	9	1
Staff-Patient	4,433	2.25	0.39	5	1	1,289	2.32	0.43	4	1	5,722	2.26	0.40	5	1
Staff-Staff	1,776	1.58	0.44	4	1	493	1.56	0.36	3	1	2,269	1.58	0.42	4	1
All Contacts	5,016	1.80	0.36	6	1	1,482	1.89	0.40	4	1	6,498	1.82	0.37	6	1

Shortest Path of Individuals in ED Network by weekday/weekend

	Weighted Shortest Path														
	Occured on Weekend										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,285	436.30	1,854.72	18803	17	987	316.21	568.41	4688	29	4,272	408.55	1,649.91	18803	17
Staff-Patient	4,433	289.44	472.75	6778	30	1,289	623.24	1,307.60	12472	18	5,722	364.64	759.95	12472	18
Staff-Staff	1,776	687.96	1,606.64	15639	1	493	530.07	1,123.78	11252	15	2,269	653.66	1,516.05	15639	1
All Contacts	5,016	252.40	1,554.55	18926	10	1,482	207.28	692.71	8040	18	6,498	242.11	1,405.39	18926	10

Clustering Coefficient of Individuals in ED Network by quarter

	Clustering Coefficient																			
	quarter																			
	1					2					3					4				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	912	0.59	0.22	1	0	1,033	0.62	0.20	1	0	1,045	0.70	0.20	1	0	1,189	0.76	0.19	1	0
Staff-Patient	1,247	0.00	0.00	0	0	1,543	0.00	0.00	0	0	1,231	0.00	0.00	0	0	1,155	0.00	0.00	0	0
Staff-Staff	471	0.82	0.14	1	0	695	0.82	0.15	1	0	631	0.82	0.18	1	0	359	0.80	0.21	1	0
All Contacts	1,411	0.65	0.18	1	0	1,764	0.67	0.17	1	0	1,589	0.71	0.18	1	0	1,584	0.74	0.20	1	0

	Clustering Coefficient				
	Total				
	N	Mean	SD	Max	Min
Contact					
Patient-Patient	4,179	0.68	0.21	1	0
Staff-Patient	5,176	0.00	0.00	0	0
Staff-Staff	2,156	0.81	0.17	1	0
All Contacts	6,348	0.69	0.18	1	0

Clustering Coefficient of Individuals in ED Network by day of week

	Clustering Coefficient																			
	Day of Week																			
	Sun					Mon					Tues					Wed				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	405	0.63	0.26	1	0	940	0.71	0.18	1	0	601	0.72	0.19	1	0	617	0.65	0.20	1	0
Staff-Patient	561	0.00	0.00	0	0	1,138	0.00	0.00	0	0	683	0.00	0.00	0	0	849	0.00	0.00	0	0
Staff-Staff	271	0.82	0.16	1	0	419	0.79	0.20	1	0	286	0.84	0.16	1	0	392	0.83	0.14	1	0
All Contacts	695	0.67	0.20	1	0	1,361	0.71	0.17	1	0	889	0.72	0.18	1	0	997	0.69	0.16	1	0

	Clustering Coefficient																			
	Day of Week																			
	Thurs					Fri					Sat					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	452	0.61	0.20	1	0	613	0.68	0.23	1	0	551	0.68	0.25	1	0	4,179	0.68	0.21	1	0
Staff-Patient	593	0.00	0.00	0	0	764	0.00	0.00	0	0	588	0.00	0.00	0	0	5,176	0.00	0.00	0	0
Staff-Staff	239	0.82	0.15	1	0	357	0.82	0.17	1	0	192	0.79	0.20	1	0	2,156	0.81	0.17	1	0
All Contacts	705	0.66	0.17	1	0	950	0.71	0.18	1	0	751	0.68	0.20	1	0	6,348	0.69	0.18	1	0

Clustering Coefficient of Individuals in ED Network by shift(AM/PM)

	Clustering Coefficient														
	Shift										Total				
	AM					PM									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	2,403	0.68	0.22	1	0	1,776	0.67	0.21	1	0	4,179	0.68	0.21	1	0
Staff-Patient	3,125	0.00	0.00	0	0	2,051	0.00	0.00	0	0	5,176	0.00	0.00	0	0
Staff-Staff	1,192	0.82	0.16	1	0	964	0.81	0.18	1	0	2,156	0.81	0.17	1	0
All Contacts	3,608	0.70	0.17	1	0	2,740	0.68	0.19	1	0	6,348	0.69	0.18	1	0

Clustering Coefficient of Individuals in ED Network by H1N1 Season

	Clustering Coefficient														
	H1N1 Season										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	2,954	0.70	0.21	1	0	1,225	0.61	0.21	1	0	4,179	0.68	0.21	1	0
Staff-Patient	3,409	0.00	0.00	0	0	1,767	0.00	0.00	0	0	5,176	0.00	0.00	0	0
Staff-Staff	1,459	0.81	0.18	1	0	697	0.82	0.15	1	0	2,156	0.81	0.17	1	0
All Contacts	4,390	0.71	0.19	1	0	1,958	0.67	0.17	1	0	6,348	0.69	0.18	1	0

Clustering Coefficient of Individuals in ED Network by weekday/weekend

	Clustering Coefficient														
	Occured on Weekend										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	3,223	0.68	0.20	1	0	956	0.66	0.25	1	0	4,179	0.68	0.21	1	0
Staff-Patient	4,027	0.00	0.00	0	0	1,149	0.00	0.00	0	0	5,176	0.00	0.00	0	0
Staff-Staff	1,693	0.82	0.17	1	0	463	0.81	0.18	1	0	2,156	0.81	0.17	1	0
All Contacts	4,902	0.70	0.18	1	0	1,446	0.68	0.20	1	0	6,348	0.69	0.18	1	0

Diameter of Individuals in ED Network
by quarter

	Diameter																								
	quarter																								
	1					2					3					4					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																									
Patient-Patient	14	4.79	1.19	6	3	19	4.47	0.96	6	3	24	3.79	1.10	6	1	24	3.96	1.30	9	2	81	4.17	1.19	9	1
Staff-Patient	14	5.36	0.74	7	4	19	4.89	0.57	6	4	24	4.79	0.72	6	3	23	4.70	1.02	6	1	80	4.89	0.81	7	1
Staff-Staff	14	3.43	0.51	4	3	19	3.37	0.50	4	3	33	3.48	0.83	5	2	24	3.29	0.95	5	1	90	3.40	0.76	5	1
All Contacts	14	4.14	0.77	6	3	19	4.00	0.58	5	3	24	4.21	0.93	6	3	24	4.13	0.74	6	2	81	4.12	0.76	6	2

Weighted Diameter of Individuals in ED Network
by quarter
total contact hours

	Weighted Diameter																			
	quarter																			
	1					2					3					4				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	14	1,498.86	1,650.14	7021	221	19	2,147.26	2,568.01	11181	123	24	1,913.17	1,650.23	5656	55	24	2,601.71	4,170.32	19878	169
Staff-Patient	14	3,478.00	4,943.40	18012	346	19	2,876.89	2,416.82	10332	486	24	3,619.42	2,822.22	14779	691	23	5,476.70	5,658.02	21737	36
Staff-Staff	14	1,578.57	3,076.40	11967	175	19	3,464.37	3,770.71	13019	186	33	3,984.18	4,231.70	15975	160	24	4,968.00	5,323.88	17635	1
All Contacts	14	944.00	1,777.24	7021	109	19	2,207.42	3,206.76	9749	87	24	1,797.29	3,240.46	15975	176	24	3,662.92	4,778.81	19878	314

	Weighted Diameter				
	Total				
	N	Mean	SD	Max	Min
Contact					
Patient-Patient	81	2,100.48	2,803.40	19878	55
Staff-Patient	80	3,952.29	4,196.95	21737	36
Staff-Staff	90	3,762.59	4,381.86	17635	1
All Contacts	81	2,298.79	3,656.29	19878	87

Diameter of Individuals in ED Network by day of week

	Diameter																			
	Day of Week																			
	Sun					Mon					Tues					Wed				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	9	4.78	0.97	6	3	16	4.06	0.68	5	3	13	3.38	0.96	5	2	12	4.17	1.11	6	3
Staff-Patient	9	4.89	1.54	6	1	16	4.94	0.77	7	4	12	4.58	0.51	5	4	12	5.00	0.60	6	4
Staff-Staff	9	3.44	0.73	4	2	18	3.78	0.81	5	3	14	3.14	1.10	5	1	14	3.29	0.47	4	3
All Contacts	9	4.22	0.44	5	4	16	4.19	0.75	6	3	13	3.92	0.76	5	2	12	3.92	0.67	5	3

	Diameter																			
	Day of Week																			
	Thurs					Fri					Sat					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	8	4.38	1.06	6	3	13	4.08	1.32	6	1	10	4.80	1.81	9	3	81	4.17	1.19	9	1
Staff-Patient	8	4.88	0.64	6	4	13	4.85	0.80	6	3	10	5.10	0.74	6	4	80	4.89	0.81	7	1
Staff-Staff	8	3.38	0.52	4	3	16	3.25	0.68	5	2	11	3.45	0.69	4	2	90	3.40	0.76	5	1
All Contacts	8	4.25	0.89	6	3	13	4.38	1.04	6	3	10	4.00	0.67	5	3	81	4.12	0.76	6	2

Diameter of Individuals in ED Network by day of week

	Weighted Diameter																			
	Day of Week																			
	Sun					Mon					Tues					Wed				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	9	1,759.11	1,519.82	5052	221	16	2,326.31	2,684.21	11181	381	13	2,878.77	5,357.94	19878	98	12	1,691.92	1,489.88	5390	123
Staff-Patient	9	5,670.89	6,111.71	18012	36	16	3,855.25	2,956.50	10045	771	12	3,052.08	1,465.80	6117	691	12	2,422.50	943.35	4266	1E3
Staff-Staff	9	3,009.00	4,100.69	11967	129	18	4,296.89	4,531.77	14634	280	14	5,471.79	6,189.89	17635	1	14	2,726.14	2,883.34	7670	135
All Contacts	9	1,001.78	1,538.68	5052	155	16	2,684.88	4,035.59	14156	126	13	2,626.85	5,241.25	19878	151	12	1,265.17	1,174.24	4478	109

	Weighted Diameter																			
	Day of Week															Total				
	Thurs					Fri					Sat									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	8	2,047.63	2,220.36	7021	428	13	2,087.46	2,325.97	8422	55	10	1,584.10	1,468.11	5174	169	81	2,100.48	2,803.40	19878	55
Staff-Patient	8	1,874.13	1,048.08	3178	346	13	2,989.69	1,750.88	7543	486	10	8,390.70	7,996.99	21737	1E3	80	3,952.29	4,196.95	21737	36
Staff-Staff	8	3,680.50	5,125.26	13478	175	16	3,577.19	4,550.50	15975	186	11	2,978.00	2,258.19	8450	564	90	3,762.59	4,381.86	17635	1
All Contacts	8	2,526.75	3,693.29	9749	229	13	3,262.69	4,704.69	15975	87	10	2,226.80	2,495.55	8450	427	81	2,298.79	3,656.29	19878	87

Diameter of Individuals in ED Network
by shift(AM/PM)

	Diameter														
	Shift										Total				
	AM					PM									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	43	4.28	1.08	6	1	38	4.05	1.31	9	2	81	4.17	1.19	9	1
Staff-Patient	43	4.86	0.71	6	3	37	4.92	0.92	7	1	80	4.89	0.81	7	1
Staff-Staff	47	3.38	0.61	5	2	43	3.42	0.91	5	1	90	3.40	0.76	5	1
All Contacts	43	4.12	0.85	6	3	38	4.13	0.66	6	2	81	4.12	0.76	6	2

Diameter of Individuals in ED Network by shift(AM/PM)

	Weighted Diameter														
	Shift														
	AM					PM					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	43	2,114.14	2,197.09	11181	55	38	2,085.03	3,393.02	19878	98	81	2,100.48	2,803.40	19878	55
Staff-Patient	43	4,024.42	4,114.29	20435	346	37	3,868.46	4,346.45	21737	36	80	3,952.29	4,196.95	21737	36
Staff-Staff	47	3,209.98	3,586.94	15975	186	43	4,366.60	5,087.29	17635	1	90	3,762.59	4,381.86	17635	1
All Contacts	43	1,838.65	2,996.86	15975	87	38	2,819.47	4,264.44	19878	183	81	2,298.79	3,656.29	19878	87

Diameter of Individuals in ED Network by H1N1 Season

	Diameter														
	H1N1 Season										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	61	4.03	1.18	9	1	20	4.60	1.14	6	3	81	4.17	1.19	9	1
Staff-Patient	60	4.87	0.87	7	1	20	4.95	0.60	6	4	80	4.89	0.81	7	1
Staff-Staff	70	3.41	0.83	5	1	20	3.35	0.49	4	3	90	3.40	0.76	5	1
All Contacts	61	4.15	0.75	6	2	20	4.05	0.83	6	3	81	4.12	0.76	6	2

Diameter of Individuals in ED Network by H1N1 Season

	Weighted Diameter														
	H1N1 Season										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	61	2,232.16	3,085.53	19878	55	20	1,698.85	1,673.46	7021	221	81	2,100.48	2,803.40	19878	55
Staff-Patient	60	4,283.12	4,276.63	21737	36	20	2,959.80	3,881.02	18012	346	80	3,952.29	4,196.95	21737	36
Staff-Staff	70	4,016.41	4,498.35	17635	1	20	2,874.20	3,922.55	13019	186	90	3,762.59	4,381.86	17635	1
All Contacts	61	2,752.43	4,022.81	19878	155	20	915.20	1,583.77	7021	87	81	2,298.79	3,656.29	19878	87

Diameter of Individuals in ED Network by weekday/weekend

	Diameter														
	Occured on Weekend										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	62	3.98	1.05	6	1	19	4.79	1.44	9	3	81	4.17	1.19	9	1
Staff-Patient	61	4.85	0.68	7	3	19	5.00	1.15	6	1	80	4.89	0.81	7	1
Staff-Staff	70	3.39	0.79	5	1	20	3.45	0.69	4	2	90	3.40	0.76	5	1
All Contacts	62	4.13	0.82	6	2	19	4.11	0.57	5	3	81	4.12	0.76	6	2

Diameter of Individuals in ED Network by weekday/weekend

	Weighted Diameter														
	Occured on Weekend										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	62	2,233.32	3,099.54	19878	55	19	1,667.00	1,453.39	5174	169	81	2,100.48	2,803.40	19878	55
Staff-Patient	61	2,971.11	1,978.39	10045	346	19	7,102.37	7,108.02	21737	36	80	3,952.29	4,196.95	21737	36
Staff-Staff	70	3,982.77	4,675.05	17635	1	20	2,991.95	3,124.81	11967	129	90	3,762.59	4,381.86	17635	1
All Contacts	62	2,498.68	4,001.68	19878	87	19	1,646.53	2,135.66	8450	155	81	2,298.79	3,656.29	19878	87

Density of Individuals in ED Network
by quarter

	Density																								
	quarter																								
	1					2					3					4					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																									
Patient-Patient	14	0.24	0.11	1	0	19	0.29	0.07	0	0	24	0.41	0.19	1	0	24	0.35	0.09	1	0	81	0.33	0.14	1	0
Staff-Patient	14	0.14	0.04	0	0	19	0.16	0.03	0	0	24	0.17	0.06	0	0	23	0.17	0.19	1	0	80	0.16	0.11	1	0
Staff-Staff	14	0.53	0.08	1	0	19	0.47	0.08	1	0	33	0.50	0.14	1	0	24	0.47	0.18	1	0	90	0.49	0.14	1	0
All Contacts	14	0.27	0.08	0	0	19	0.31	0.06	0	0	24	0.34	0.08	1	0	24	0.30	0.08	0	0	81	0.31	0.08	1	0

Density of Individuals in ED Network
by day of week

	Density																			
	Day of Week																			
	Sun					Mon					Tues					Wed				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	9	0.28	0.13	1	0	16	0.33	0.08	0	0	13	0.39	0.17	1	0	12	0.33	0.12	1	0
Staff-Patient	9	0.25	0.28	1	0	16	0.14	0.05	0	0	12	0.17	0.05	0	0	12	0.16	0.04	0	0
Staff-Staff	9	0.53	0.12	1	0	18	0.42	0.11	1	0	14	0.57	0.20	1	0	14	0.51	0.09	1	0
All Contacts	9	0.29	0.06	0	0	16	0.31	0.07	0	0	13	0.33	0.10	1	0	12	0.32	0.04	0	0

	Density																			
	Day of Week																			
	Thurs					Fri					Sat					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact																				
Patient-Patient	8	0.28	0.10	0	0	13	0.38	0.22	1	0	10	0.29	0.10	0	0	81	0.33	0.14	1	0
Staff-Patient	8	0.14	0.05	0	0	13	0.16	0.06	0	0	10	0.13	0.05	0	0	80	0.16	0.11	1	0
Staff-Staff	8	0.51	0.13	1	0	16	0.48	0.12	1	0	11	0.42	0.12	1	0	90	0.49	0.14	1	0
All Contacts	8	0.31	0.11	0	0	13	0.32	0.07	0	0	10	0.28	0.08	0	0	81	0.31	0.08	1	0

	Density														
	Shift										Total				
	AM					PM									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	43	0.32	0.15	1	0	38	0.35	0.13	1	0	81	0.33	0.14	1	0
Staff-Patient	43	0.16	0.05	0	0	37	0.16	0.15	1	0	80	0.16	0.11	1	0
Staff-Staff	47	0.49	0.13	1	0	43	0.49	0.15	1	0	90	0.49	0.14	1	0
All Contacts	43	0.32	0.07	1	0	38	0.29	0.08	0	0	81	0.31	0.08	1	0

	Density														
	H1N1 Season														
	No					Yes					Total				
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	61	0.35	0.15	1	0	20	0.27	0.10	1	0	81	0.33	0.14	1	0
Staff-Patient	60	0.16	0.12	1	0	20	0.16	0.04	0	0	80	0.16	0.11	1	0
Staff-Staff	70	0.48	0.15	1	0	20	0.50	0.09	1	0	90	0.49	0.14	1	0
All Contacts	61	0.31	0.08	1	0	20	0.31	0.07	0	0	81	0.31	0.08	1	0

	Density														
	Occured on Weekend										Total				
	No					Yes									
	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min	N	Mean	SD	Max	Min
Contact															
Patient-Patient	62	0.35	0.15	1	0	19	0.28	0.11	1	0	81	0.33	0.14	1	0
Staff-Patient	61	0.15	0.05	0	0	19	0.18	0.20	1	0	80	0.16	0.11	1	0
Staff-Staff	70	0.49	0.14	1	0	20	0.47	0.13	1	0	90	0.49	0.14	1	0
All Contacts	62	0.32	0.08	1	0	19	0.28	0.07	0	0	81	0.31	0.08	1	0

Appendix B: SAS Program Code:

Formats Code into Form Compatible with Social Network Analysis Software

```
/**********************************************************************
Eric Hill and George Cotsonis


Metrics of the Social Contact Networks of Patients and Staff in
   the Emergency Department

Emory University, 2011

**********************************************************************/



libname t '/home/ehill22/Desktop/ipirc';
libname e '/home/ehill22';

*libname t 'H:\Social Network Thesis\Datafiles';

options ls=80 ps=52;

proc format;
value fmtstaff 0='Patient'
            1='Staff'
            ;
value fmtcombo 0='PP'  /* Patient-Patient */
            1='SP'  /* Staff-Patient */
            2='SS'  /* Staff-Staff */
            ;
value fmtday 1='Sun'
          2='Mon'
          3='Tues'
          4='Wed'
          5='Thurs'
          6='Fri'
          7='Sat'
          ;
value fmtshift 1='AM'
            2='PM'
            ;
value fmtweekday 0='Weekend'
              1='Weekday'
              ;
value fmtflu 0='Non-H1N1'
          1='H1N1'
          ;
run;

%macro unique( mon, day, n, n2, out);

data z1a;
```

```
  set t.completestaff;
  if mon=&mon and day=&day ;
  staff=1;
data z1b;
  set t.completepat;
  if mon=&mon and day=&day ;
  staff=0;
data z1;
   set z1a z1b;
run;
data node1;
   set z1;

newsid=_n_;

keep floc1-floc43202;
run;

proc transpose data=node1 out=transall;
run;

data node3;
    set transall;
    array floc(&n) col1-col&n;
    array pairs(&n2) p1-p&n2 (0);

    ij=0;

   n=&n;
    do i=1 to n-1;
       do j=i+1 to n;
           ij=ij+1;
           if (floc(i) eq floc(j)) and floc(i) ne . then
              pairs(ij)=1;
              else pairs(ij)=0;
       end;
   end;
con=sum (of p1-p&n2);
keep p1-p&n2 con ij;
run;

proc means noprint ;
 var p1-p&n2;
 output out=mean1 sum=p1-p&n2;
run;

data node4;
  set mean1;
  array pairs(&n2) p1-p&n2 ;
   ij=0;
   n=&n;
    do i=1 to n-1;
       do j=i+1 to n;
           ij=ij+1;
           p=pairs(ij);
```

```
          any=(p > 0);
          output;
       end;
    end;
keep i j any p;
run;

data staff;
  set z1 (keep= staff);


 keep staff;

run;

proc transpose data=staff out=staff1;
run;

data staff2;
  set staff1;
  array staff (&n) col1-col&n;
  n=&n;
  do i=1 to n-1;
    do j=i+1 to n;
       staffi=staff(i);
       staffj=staff(j);
       combo=0;                              /* patient-patient => combo=0 */
       if staffi=1 and staffj=1 then combo=2;   /* staff-staff => combo=2 */
       if staffi ne staffj then combo=1;        /* staff-patient => combo=1*/
       output;
    end;
  end;
  keep i j staffi staffj combo;
run;
**********************************************;
 /* link staff code to each contact */
proc sort data=node4;
   by i j;
run;

proc sort data=staff2;
   by i j;
run;

data combine;
merge node4 staff2;
     by i j;

  mon= &mon;
  day= &day;
year=2009;
if mon <=6 then year=2010;
idi= cats(&mon , &day , year , i);   /* create unique ids */
idj= cats(&mon , &day , year , j);
```

```
  d8= mdy(mon, day, year);
  format d8 date9.;

/* create quarter variable */
  if mon in (7 8 9) and year=2009 then quarter=1;         /* July, Aug, Sept 2009 => quarter=1 */
  else if mon in (10 11 12) and year=2009 then quarter=2;  /* Oct, Nov, Dec 2009 => quarter=2 */
  else if mon in (1 2 3) and year=2010 then quarter=3;     /* Jan, Feb, Mar 2010 => quarter=3 */
  else quarter=4;                                         /* April, May, Jun 2010 => quarter=4 */

/* create day and night shift variable */
  if d8 in ('18Jul2009'd '23Jul2009'd '31Jul2009'd '02Aug2009'd            '15Aug2009'd '18Aug2009'd '24Aug2009'd
          '02Sep2009'd '09Sep2009'd '13Sep2009'd '24Sep2009'd'02Oct2009'd '07Oct2009'd '12Oct2009'd
          '20Oct2009'd '30Oct2009'd '09Nov2009'd '14Nov2009'd '17Nov2009'd '23Nov2009'd '30Nov2009'd
          '06Dec2009'd '18Dec2009'd '23Dec2009'd '27Dec2009'd            '03Jan2010'd '15Jan2010'd '21Jan2010'd
          '30Jan2010'd '05Feb2010'd '07Feb2010'd '16Feb2010'd '23Feb2010'd '02Mar2010'd '12Mar2010'd
          '17Mar2010'd '27Mar2010'd '31Mar2010'd '05Apr2010'd            '17Apr2010'd '20Apr2010'd '27Apr2010'd
          '08May2010'd '10May2010'd '21May2010'd '24May2010'd          '04Jun2010'd '11Jun2010'd '14Jun2010'd
          '26Jun2010'd '28Jun2010'd)
   then shift=1;   /* AM => shift=1 */
   else shift=2;   /* PM => shift=2 */

   /* Weekend - Weekday Variable */
  d9= d8;
  format d9 weekday.;

  if d9 in (2 3 4 5 6) then weekday=1;  /* Mon - Fri => weekend = 1 */
  else weekday=0;                       /* Sat - Sun => weekend = 0 */

  if (d8 ge '08Aug2009'd and d8 le '28Nov2009'd) then H1N1=1;    /* H1N1 period */
  else H1N1=0;

  keep i j staffi staffj any p combo idi idj quarter d8 d9 shift weekday H1N1;

run;



/* node contact file */
data uni&out;
   set combine;
   if any=1;
run;

************************************************;

/* node attribute file */
data attrib&out;
   set staff2;

  mon= &mon;
  day= &day;

year = 2009;
if mon <=6 then year=2010;
```

```
idi= cats(&mon , &day , year , i);   /* create unique ids */
idj= cats(&mon , &day , year , j);



  *year= &yr;
  d8= mdy(mon, day, year);
  format d8 date9.;

/* create quarter variable */
  if mon in (7 8 9) and year=2009 then quarter=1;         /* July, Aug, Sept 2009 => quarter=1 */
  else if mon in (10 11 12) and year=2009 then quarter=2;  /* Oct, Nov, Dec 2009 => quarter=2 */
  else if mon in (1 2 3) and year=2010 then quarter=3;     /* Jan, Feb, Mar 2010 => quarter=3 */
  else quarter=4;                                         /* April, May, Jun 2010 => quarter=4 */

/* create day and night shift variable */
  if d8 in ('18Jul2009'd '23Jul2009'd '31Jul2009'd '02Aug2009'd           '15Aug2009'd '18Aug2009'd '24Aug2009'd
          '02Sep2009'd '09Sep2009'd '13Sep2009'd '24Sep2009'd'02Oct2009'd '07Oct2009'd '12Oct2009'd
          '20Oct2009'd '30Oct2009'd '09Nov2009'd '14Nov2009'd '17Nov2009'd '23Nov2009'd '30Nov2009'd
          '06Dec2009'd '18Dec2009'd '23Dec2009'd '27Dec2009'd           '03Jan2010'd '15Jan2010'd '21Jan2010'd
          '30Jan2010'd '05Feb2010'd '07Feb2010'd '16Feb2010'd '23Feb2010'd '02Mar2010'd '12Mar2010'd
          '17Mar2010'd '27Mar2010'd '31Mar2010'd '05Apr2010'd           '17Apr2010'd '20Apr2010'd '27Apr2010'd
          '08May2010'd '10May2010'd '21May2010'd '24May2010'd        '04Jun2010'd '11Jun2010'd '14Jun2010'd
          '26Jun2010'd '28Jun2010'd)
   then shift=1;   /* AM => shift=1 */
   else shift=2;   /* PM => shift=2 */

   /* Weekend - Weekday Variable */
  d9= d8;
  format d9 weekday.;

  if d9 in (2 3 4 5 6) then weekday=1;  /* Mon - Fri => weekend = 1 */
  else weekday=0;                       /* Sat - Sun => weekend = 0 */

  if (d8 ge '08Aug2009'd and d8 le '28Nov2009'd) then H1N1=1;    /* H1N1 period */
  else H1N1=0;

out = &out;
run;


%mend;

***********************************************************************;

options nomprint nosymbolgen nomlogic;
*************************************;


%unique(7 ,9,102,5151,1)
%unique(7 ,16,112,6216,2)
%unique(7 ,18,92,4186,3)
%unique(7 ,25,242,29161,4)    *do not use;
%unique(7 ,27,126,7875,5)
%unique(8 ,2,81,3240,6)
```

%*unique*(8 ,15,113,6328,7)
%*unique*(8 ,20,116,6670,8)
%*unique*(8 ,24,116,6670,9)
%*unique*(8 ,30,79,3081,10)
%*unique*(9 ,2,119,7021,11)
%*unique*(9 ,9,125,7750,12)
%*unique*(9 ,13,105,5460,13)
%*unique*(9 ,24,101,5050,14)
%*unique*(9 ,27,83,3403,15)
%*unique*(10 ,2,116,6670,16)
%*unique*(10 ,7,105,5460,17)
%*unique*(10 ,9,93,4278,18)
%*unique*(10 ,12,107,5671,19)
%*unique*(10 ,14,106,5565,20)
%*unique*(10 ,18,100,4950,21)
%*unique*(10 ,20,74,2701,22)
%*unique*(10 ,28,102,5151,23)
%*unique*(10 ,30,96,4560,24)
%*unique*(11 ,17,98,4753,25)
%*unique*(11 ,23,96,4560,26)
%*unique*(11 ,30,98,4753,27)
%*unique*(12 ,3,82,3321,28)
%*unique*(12 ,10,93,4278,29)
%*unique*(12 ,16,88,3828,30)
%*unique*(12 ,18,100,4950,31)
%*unique*(12 ,21,107,5671,32)
%*unique*(12 ,23,99,4851,33)
%*unique*(12 ,27,97,4656,34)
%*unique*(1 ,3,81,3240,35)
%*unique*(1 ,5,64,2016,36)
%*unique*(1 ,13,71,2485,37)
%*unique*(1 ,15,101,5050,38)
%*unique*(1 ,19,79,3081,39)
%*unique*(1 ,21,93,4278,40)
%*unique*(1 ,25,81,3240,41)
%*unique*(1 ,30,70,2415,42)
%*unique*(2 ,2,73,2628,43)
%*unique*(2 ,5,26,325,44)
%*unique*(2 ,7,83,3403,45)
%*unique*(2 ,10,45,990,46)
%*unique*(2 ,16,66,2145,47)
%*unique*(2 ,19,71,2485,48)
%*unique*(2 ,23,74,2701,49)
%*unique*(2 ,26,86,3655,50)
%*unique*(3 ,5,61,1830,51)
%*unique*(3 ,8,61,1830,52)
%*unique*(3 ,12,59,1711,53)
%*unique*(3 ,17,54,1431,54)
%*unique*(3 ,23,70,2415,55)
%*unique*(3 ,27,86,3655,56)
%*unique*(3 ,29,80,3160,57)
%*unique*(3 ,31,68,2278,58)
%*unique*(4 ,5,55,1485,59)
%*unique*(4 ,10,42,861,60)
%*unique*(4 ,12,75,2775,61)

```
%unique(4 ,17,80,3160,62)
%unique(4 ,20,95,4465,63)
%unique(4 ,23,62,1891,64)
%unique(4 ,27,100,4950,65)
%unique(4 ,29,48,1128,66)
%unique(5 ,2,32,496,67)
%unique(5 ,8,82,3321,68)
%unique(5 ,10,82,3321,69)
%unique(5 ,12,76,2850,70)
%unique(5 ,17,89,3916,71)
%unique(5 ,21,73,2628,72)
%unique(5 ,24,101,5050,73)
%unique(5 ,29,86,3655,74)
%unique(6 ,1,41,820,75)
%unique(6 ,4,77,2926,76)
%unique(6 ,8,74,2701,77)
%unique(6 ,14,72,2556,78)
%unique(6 ,19,74,2701,79)
%unique(6 ,22,42,861,80)
%unique(6 ,26,72,2556,81)
%unique(6 ,28,75,2775,82)

                /* Total */


data cytoscape;
  set uni1-uni3 uni5-uni82 ;

  *file "H:\Social Network Thesis\Datafiles\GradTotal.csv" DLM=',';   /* PC */
  file "/home/ehill22/CytoTotal.csv" DLM=',';   /* cluster */
  if _n_=1 then put 'idi' ',' 'idj' ',' 'weight' ',' 'Quarter' ',' 'Date' ',' 'DayOfWeek' ',' 'Shift' ',' 'weekday' ',' 'H1N1';

  put idi idj p quarter d8 d9 shift  weekday H1N1;


  run;

************************************************************;
************************************************************;

                /* Quarter 1 */

%macro QtrOne;

%do filename = 1 %to 15;   * number of days;

data cytoscape&filename ;
  set uni&filename ;
  %do staff = 0 %to 2;  *0=pp | 1=sp | 2=ss;
run;

data cytoscape&filename.1 ;
  set cytoscape&filename ;
  if combo = &staff ;
run;
```

```
data cytoscape&filename.&staff;
  set cytoscape&filename.1;
  file "/home/ehill22/CytoQtr1Staff&staff._&filename..csv" DLM=',';   * cluster;
  if _n_=1 then put 'idi' ',' 'idj' ',' 'weight' ',' 'Quarter' ',' 'Date' ',' 'DayOfWeek' ',' 'Shift' ',' 'H1N1';

  put idi idj p quarter d8 d9 shift  H1N1;


  run;
  %end;
%end;
%mend;

%QtrOne;


**********************************************************;

                    /* Quarter 2 */

%macro QtrTwo;

%do filename = 16 %to 34;   /* number of days */

data cytoscape&filename ;
  set uni&filename ;
  %do staff=0 %to 2;  /* 0=pp | 1=sp | 2=ss */
run;

data cytoscape&filename.1 ;
  set cytoscape&filename ;
  if combo = &staff ;
run;

data cytoscape&filename.&staff;
  set cytoscape&filename.1;
  file "/home/ehill22/CytoQtr2Staff&staff._&filename..csv" DLM=',';   * cluster;
  if _n_=1 then put 'idi' ',' 'idj' ',' 'weight' ',' 'Quarter' ',' 'Date' ',' 'DayOfWeek' ',' 'Shift' ',' 'H1N1';

  put idi idj p quarter d8 d9 shift  H1N1;


  run;
  %end;
%end;
%mend;

%QtrTwo;


**********************************************************;
                    /* Quarter 3 */

%macro QtrThree;
```

```
%do filename = 35 %to 58;   /* number of days */

data cytoscape&filename ;
  set uni&filename ;
  %do staff=0 %to 2;  /* 0=pp | 1=sp | 2=ss */
run;

data cytoscape&filename.1 ;
  set cytoscape&filename ;
  if combo = &staff ;
run;

data cytoscape&filename.&staff;
  set cytoscape&filename.1;
  file "/home/ehill22/CytoQtr3Staff&staff._&filename..csv" DLM=',';   *cluster;
  if _n_=1 then put 'idi' ',' 'idj' ',' 'weight' ',' 'Quarter' ',' 'Date' ',' 'DayOfWeek' ',' 'Shift' ',' 'H1N1';

  put idi idj p quarter d8 d9 shift  H1N1;


  run;
  %end;
%end;
%mend;

%QtrThree;


**********************************************************;
                    /* Quarter 4 */

%macro QtrFour;

%do filename = 59 %to 82;   /* number of days */

data cytoscape&filename ;
  set uni&filename ;
  %do staff=0 %to 2;  /* 0=pp | 1=sp | 2=ss */
run;

data cytoscape&filename.1 ;
  set cytoscape&filename ;
  if combo = &staff ;
run;

data cytoscape&filename.&staff;
  set cytoscape&filename.1;
  file "/home/ehill22/CytoQtr4Staff&staff._&filename..csv" DLM=',';   *cluster;
  if _n_=1 then put 'idi' ',' 'idj' ',' 'weight' ',' 'Quarter' ',' 'Date' ',' 'DayOfWeek' ',' 'Shift' ',' 'H1N1';

  put idi idj p quarter d8 d9 shift H1N1;


  run;
```

```
  %end;
%end;
%mend;

%QtrFour;

*********************************************************;


                /* Quarter 1 */

%macro QtrOne;

%do filename = 1 %to 15;   /* number of days */

data cytoscape&filename.1 ;
  set uni&filename ;
run;

data cytoscape&filename;
  set cytoscape&filename.1;
  file "/home/ehill22/CytoQtr1StaffTotal_&filename..csv" DLM=',';   *cluster;
  if _n_=1 then put 'idi' ',' 'idj' ',' 'weight' ',' 'Quarter' ',' 'Date' ',' 'DayOfWeek' ',' 'Shift' ',' 'H1N1';

  put idi idj p quarter d8 d9 shift  H1N1;


  run;
%end;
%mend;

%QtrOne;


*********************************************************;

                /* Quarter 2 */

%macro QtrTwo;
%do filename = 16 %to 34;   /* number of days */

data cytoscape&filename.1 ;
  set uni&filename ;
run;

data cytoscape&filename;
  set cytoscape&filename.1;
  file "/home/ehill22/CytoQtr2StaffTotal_&filename..csv" DLM=',';   *cluster;
  if _n_=1 then put 'idi' ',' 'idj' ',' 'weight' ',' 'Quarter' ',' 'Date' ',' 'DayOfWeek' ',' 'Shift' ',' 'H1N1';

  put idi idj p quarter d8 d9 shift  H1N1;


  run;
%end;
```

```
%mend;

%QtrTwo;

***********************************************************;
                    /* Quarter 3 */

%macro QtrThree;

%do filename = 35 %to 58;   /* number of days */

data cytoscape&filename.1 ;
  set uni&filename ;
run;

data cytoscape&filename;
  set cytoscape&filename.1 ;
  file "/home/ehill22/CytoQtr3StaffTotal_&filename..csv" DLM=',';   *cluster;
  if _n_=1 then put 'idi' ',' 'idj' ',' 'weight' ',' 'Quarter' ',' 'Date' ',' 'DayOfWeek' ',' 'Shift' ',' 'H1N1';

  put idi idj p quarter d8 d9 shift H1N1;


  run;
%end;
%mend;

%QtrThree;

***********************************************************;
                  /* Quarter 4 */

%macro QtrFour;

%do filename = 59 %to 82;   /* number of days */

data cytoscape&filename.1 ;
  set uni&filename ;
run;

data cytoscape&filename;
  set cytoscape&filename.1;
  file "/home/ehill22/CytoQtr4StaffTotal_&filename..csv" DLM=',';   *cluster;
  if _n_=1 then put 'idi' ',' 'idj' ',' 'weight' ',' 'Quarter' ',' 'Date' ',' 'DayOfWeek' ',' 'Shift' ',' 'H1N1';

  put idi idj p quarter d8 d9 shift H1N1;


  run;
%end;
%mend;

%QtrFour;
                   /* node attribute file */
```

```
*******************************************;

data attribi;
set attrib1-attrib82;
keep idi staffi quarter d8 d9 shift H1N1 out;
run;

data attribj;
set attrib1-attrib82;
keep idj staffj quarter d8 d9 shift H1N1 out;
run;

data attribj;
set attribj;
idi=idj; staffi=staffj;
drop idj staffj;
run;

data attribm;
set attribi attribj;
run;

proc sql;
create table attriball as
select unique * from attribm
order by idi;
quit;

data attriball;
  set attriball;
  file "/home/ehill22/AttribTotal.csv";          /* cluster */

  if _n_ =1 then put 'idi' ',' 'staff' ',' 'Quarter' ',' 'Date' ',' 'DayOfWeek' ',' 'Shift' ',' 'H1N1' ',' 'Order';
  put idi ',' staffi ',' quarter  ',' d8 ','  d9  ',' shift ','  H1N1 ',' out;
  run;

***end;
```

#R Code for Creation of Social Network Datafile .csv file of all metrics and attribute data

```
library("igraph")

setwd("C:/Users/Eric Hill/Desktop/NetworkData/R")


xx <- expand.grid(x=0:2,n=1:4)
file.list <- paste("Staff",xx$x,"_qtr",xx$n,".txt",sep="")

for(u in file.list){
tt01 <- try(as.character(read.csv(u,header=FALSE)[,1]))

if(class(tt01)!="try-error"){


for( name in tt01){

Table01 <- try(read.csv(name, header=T))
if(class(Table01)=="try-error"){
  print(c(u,name))
}else{

attriba01 <- read.csv("AttribTotal.csv", header=T)

#to make subset of large attribute data frame
attrib01 <- attriba01[attriba01$idi %in% c(Table01$idi,Table01$idj),]
Graph01 <- graph.data.frame(Table01, vertices=attrib01, directed=F)

#number of nodes
nodecount<-vcount(Graph01)

#Qtr
Qtr <- mean(V(Graph01)$Quarter)

#Graph order
Order <- mean(V(Graph01)$Order)

#Date
Date <- max(V(Graph01)$Date)

#Day of Week
DayWeek <- mean(V(Graph01)$DayOfWeek)

#Shift
Shift <- mean(V(Graph01)$Shift)

#H1N1
H1N1 <- mean(V(Graph01)$H1N1)

#Order
Order <- mean(V(Graph01)$Order)

#degree
```

```
degree01 <- degree(Graph01)

#weighted degree
wtdegree01 <- graph.strength(Graph01, weights=Table01$weight)


#global path length
avgpath <- average.path.length(Graph01)

#diameter
diam01 <- diameter(Graph01, directed=FALSE, weights=NA)

#weighted diameter
wtdiam01 <- diameter(Graph01, directed=FALSE, weights=Graph01$weight)

#local mean shortest paths
sp01 <- shortest.paths(Graph01, weights=NA)
sp01[sp01==Inf]<-diam01    #If path is seen as Inf, then make it diameter, but maybe need to make it number of
nodes (large)
sp01_mean <- vector()

for (i in 1:vcount(Graph01)){
sp01_mean[i] <- mean(sp01[i, ])
}

#local mean weighted shortest paths
wtsp01 <- shortest.paths(Graph01, weights=Graph01$weight)
wtsp01[wtsp01==Inf] <-wtdiam01
wtsp01_mean <- vector()

for (j in 1:vcount(Graph01)){
wtsp01_mean[j] <- mean(wtsp01[j, ])
}

#local transitivity - clustering coefficient
clust_ce01 <- transitivity(Graph01, type="localundirected")

#clustering
cluster01 <- clusters(Graph01)


#density
density01 <- graph.density(Graph01, loops=FALSE)

#eigenvectors
#eigenvect01_temp <- evcent(Graph01)
#eigenvect01 <- eigenvect01_temp$vector

#number of cliques
clique_num01 <- clique.number(Graph01)
clique_large01 <- largest.cliques(Graph01)
clique_max01 <- maximal.cliques(Graph01)

#betweenness
between <- betweenness(Graph01)
```

```
#closeness
closeness <- closeness(Graph01)


#####################

nodelevel <- cbind(attrib01, degree01, wtdegree01, sp01_mean, wtsp01_mean, clust_ce01, closeness, between)
networklevel <-
cbind(avgpath,diam01,wtdiam01,density01,clique_num01,Qtr,Date,DayWeek,Shift,H1N1,nodecount,Order)

#####################

colnames(degree01) <- NULL
colnames(wtdegree01) <- NULL
colnames(sp01_mean) <- NULL
colnames(wtsp01_mean) <- NULL
colnames(clust_ce01) <- NULL
colnames(diam01) <- NULL
colnames(wtdiam01) <- NULL
colnames(density01) <- NULL
colnames(cluster01) <- NULL
colnames(clique_large01) <- NULL
colnames(clique_num01) <- NULL
colnames(avgpath) <- NULL
colnames(closeness) <- NULL
colnames(between) <- NULL
colnames(nodelevel) <- NULL
colnames(networklevel) <- NULL

#####################

#write.table(degree01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\degree-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(wtdegree01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\wtdegree-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(sp01_mean,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\sp_mean-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(wtsp01_mean,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\wtsp_mean-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(clust_ce01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\clustcc-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(diam01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\diameter-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(wtdiam01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\wtdiamter-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(density01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\density-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(cluster01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\cluster-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(clique_large01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\clique_largest-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(clique_num01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\clique_num-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
```

```
#write.table(eigenvect01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\eigenvect-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(path,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\mean_path-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)


write.table(nodelevel,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\nodelevel-",u,sep=""),sep=",",
row.names=FALSE, col.names=FALSE, append=TRUE)
write.table(networklevel,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\networklevel-
",u,sep=""),sep=",", row.names=FALSE, col.names=FALSE, append=TRUE)

}
}
}
}

#End
```

```
library("igraph")

setwd("C:/Users/Eric Hill/Desktop/NetworkData/R")

xx <- expand.grid(x=1:4)
file.list <- paste("total_qtr",xx$x,".txt",sep="")

for(u in file.list){
tt01 <- try(as.character(read.csv(u,header=FALSE)[,1]))

if(class(tt01)!="try-error"){



for( name in tt01){

Table01 <- try(read.csv(name, header=T))
if(class(Table01)!="try-error"){
#Table01 <- Table01[!is.na(Table01$idj),]

attriba01 <- read.csv("AttribTotal.csv", header=T)

#to make subset of large attribute data frame
attrib01 <- attriba01[attriba01$idi %in% c(Table01$idi,Table01$idj),]
Graph01 <- graph.data.frame(Table01, vertices=attrib01, directed=F)

#number of nodes
nodecount<-vcount(Graph01)

#Qtr
Qtr <- mean(V(Graph01)$Quarter)

#Graph order
Order <- mean(V(Graph01)$Order)

#Date
Date <- max(V(Graph01)$Date)

#Day of Week
DayWeek <- mean(V(Graph01)$DayOfWeek)

#Shift
Shift <- mean(V(Graph01)$Shift)

#H1N1
H1N1 <- mean(V(Graph01)$H1N1)

#Order
Order <- mean(V(Graph01)$Order)

#degree
degree01 <- degree(Graph01)

#weighted degree
wtdegree01 <- graph.strength(Graph01, weights=Table01$weight)
```

```
#global path length
avgpath <- average.path.length(Graph01)

#diameter
diam01 <- diameter(Graph01, directed=FALSE, weights=NA)

#weighted diameter
wtdiam01 <- diameter(Graph01, directed=FALSE, weights=Graph01$weight)

#local mean shortest paths
sp01 <- shortest.paths(Graph01, weights=NA)
sp01[sp01==Inf]<-diam01    #If path is seen as Inf, then make it diameter, but maybe need to make it number of
nodes (large)
sp01_mean <- vector()

for (i in 1:vcount(Graph01)){
sp01_mean[i] <- mean(sp01[i, ])
}

#local mean weighted shortest paths
wtsp01 <- shortest.paths(Graph01, weights=Graph01$weight)
wtsp01[wtsp01==Inf] <-wtdiam01
wtsp01_mean <- vector()

for (j in 1:vcount(Graph01)){
wtsp01_mean[j] <- mean(wtsp01[j, ])
}

#local transitivity - clustering coefficient
clust_ce01 <- transitivity(Graph01, type="localundirected")

#clustering
cluster01 <- clusters(Graph01)


#density
density01 <- graph.density(Graph01, loops=FALSE)

#eigenvectors
eigenvect01_temp <- evcent(Graph01)
eigenvect01 <- eigenvect01_temp$vector

#number of cliques
clique_num01 <- clique.number(Graph01)
clique_large01 <- largest.cliques(Graph01)
clique_max01 <- maximal.cliques(Graph01)

#betweenness
between <- betweenness(Graph01)

#closeness
closeness <- closeness(Graph01)
```

```
######################

nodelevel <- cbind(attrib01, degree01, wtdegree01, sp01_mean, wtsp01_mean, clust_ce01, eigenvect01, closeness,
between)
networklevel <-
cbind(avgpath,diam01,wtdiam01,density01,clique_num01,Qtr,Date,DayWeek,Shift,H1N1,nodecount,Order)

######################

colnames(degree01) <- NULL
colnames(wtdegree01) <- NULL
colnames(sp01_mean) <- NULL
colnames(wtsp01_mean) <- NULL
colnames(clust_ce01) <- NULL
colnames(diam01) <- NULL
colnames(wtdiam01) <- NULL
colnames(density01) <- NULL
colnames(cluster01) <- NULL
colnames(clique_large01) <- NULL
colnames(clique_num01) <- NULL
colnames(avgpath) <- NULL
colnames(closeness) <- NULL
colnames(between) <- NULL
colnames(nodelevel) <- NULL
colnames(networklevel) <- NULL

######################

#write.table(degree01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\degree-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(wtdegree01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\wtdegree-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(sp01_mean,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\sp_mean-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(wtsp01_mean,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\wtsp_mean-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(clust_ce01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\clustcc-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(diam01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\diameter-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(wtdiam01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\wtdiamter-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(density01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\density-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(cluster01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\cluster-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(clique_large01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\clique_largest-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(clique_num01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\clique_num-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(eigenvect01,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\eigenvect-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
#write.table(path,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\mean_path-
",u,sep=""),sep=",",col.names=FALSE, append=TRUE)
```

```
write.table(nodelevel,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\nodeleveltotal-
",u,sep=""),sep=",", row.names=FALSE, col.names=FALSE, append=TRUE)
write.table(networklevel,file=paste("C:\\Users\\Eric Hill\\Desktop\\NetworkData\\Data\\networkleveltotal-
",u,sep=""),sep=",", row.names=FALSE, col.names=FALSE, append=TRUE)

}
}
}
}


# END /
```

- Pull Social Network Data into SAS ;

```
proc format;
value fmtstaff 0='Patient'
            1='Staff'
            ;
value fmtcontact 0='PP'  /* Patient-Patient */
             1='SP'  /* Staff-Patient */
             2='SS'  /* Staff-Staff */
                                              3='ALL'
             ;
value fmtcont 0='Patient-Patient'
           1='Staff-Patient'
           2='Staff-Staff'
                                   3='All Contacts'
           ;
value fmtday 1='Sun'
          2='Mon'
          3='Tues'
          4='Wed'
          5='Thurs'
          6='Fri'
          7='Sat'
          ;
value fmtshift 1='AM'
            2='PM'
            ;
value fmtflu 0='No'
          1='Yes'
          ;
value fmtweekend 0='No'
             1='Yes'
                                              ;
run;

*********************************************;
options nomprint nosymbolgen nomlogic;
************************************;
%macro NetworkTotal;
%do i=1 %to 4;

data NetworkTotal_&i ;
  infile "H:\Social Network Thesis\Data\Data\networkleveltotal-total_qtr&i..txt" dsd;
  input avgpath diameter wtdiameter density cliquenum Qtr Date $ DayOfWeek Shift H1N1_Season nodecount
Order;
run;
%end;
%mend;
%NetworkTotal;

data NetworkTotal ;
set NetworkTotal_1 NetworkTotal_2 NetworkTotal_3 NetworkTotal_4;
Contact=3;
run;
```

```
********************************************;

%macro NodeTotal;
%do i=1 %to 4;

data NodeTotal_&i ;
  infile "H:\Social Network Thesis\Data\Data\nodeleveltotal-total_qtr&i..txt" dsd;
  input ID Staff Qtr Date $ DayOfWeek Shift H1N1_Season Order Degree wtDegree ShortPathMean
wtShortPathMean
        ClusterCE Closeness Betweenness;
run;
%end;
%mend;
%NodeTotal;

data NodeTotal ;
set NodeTotal_1 NodeTotal_2 NodeTotal_3 NodeTotal_4;
Contact=3;
format DayOfWeek fmtday. Shift fmtshift. H1N1_Season fmtflu. Contact fmtcontact.;
run;


********************************************;
%macro network;
%do i=0 %to 2;
  %do j=1 %to 4;

data NetworkStaff&i._&j ;
  infile "H:\Social Network Thesis\Data\Data\networklevel-Staff&i._qtr&j..txt" dsd;
  input avgpath diameter wtdiameter density cliquenum Qtr Date $ DayOfWeek Shift H1N1_Season nodecount
Order;
run;

  %end;
%end;
%mend;
%network;

data NetworkStaff0 ;
set NetworkStaff0_1 NetworkStaff0_2 NetworkStaff0_3 NetworkStaff0_4;
Contact=0;
run;


data NetworkStaff1 ;
set NetworkStaff1_1 NetworkStaff1_2 NetworkStaff1_3 NetworkStaff1_4;
Contact=1;
run;


data NetworkStaff2 ;
set NetworkStaff2_1 NetworkStaff2_2 NetworkStaff2_3 NetworkStaff2_4;
Contact=2;
run;
```

```
data Network;
set NetworkStaff0 NetworkStaff1 NetworkStaff2 NetworkTotal;
if Order=4 then delete;
if DayOfWeek in (1 7) then WeekEnd=1; else if DayOfWeek in (2 3 4 5 6) then WeekEnd=0;
format DayOfWeek fmtday. Shift fmtshift. H1N1_Season fmtflu. Contact fmtcontact. WeekEnd fmtweekend.;
run;

**********************************************************************;

%macro node;
%do i=0 %to 2;
  %do j=1 %to 4;

data NodeStaff&i._&j ;
  infile "H:\Social Network Thesis\Data\Data\nodelevel-Staff&i._qtr&j..txt" dsd;
  input ID Staff Qtr Date $ DayOfWeek Shift H1N1_Season Order Degree wtDegree ShortPathMean
wtShortPathMean
        ClusterCE Closeness Betweenness;
run;
  %end;
%end;
%mend;
%node;

data NodeStaff0 ;
set NodeStaff0_1 NodeStaff0_2 NodeStaff0_3 NodeStaff0_4;
Contact=0;
run;


data NodeStaff1 ;
set NodeStaff1_1 NodeStaff1_2 NodeStaff1_3 NodeStaff1_4;
Contact=1;
run;


data NodeStaff2 ;
set NodeStaff2_1 NodeStaff2_2 NodeStaff2_3 NodeStaff2_4;
Contact=2;
run;

data Node;
set NodeStaff0 NodeStaff1 NodeStaff2 NodeTotal;
if Order=4 then delete;
wtDegreeHr=wtDegree/(60*60);  *Total Contact Hours;
wtDegreeHrPerCont=wtDegreeHr/Degree; *Contact Hours Per Contact;
if DayOfWeek in (1 7) then WeekEnd=1;
else if DayOfWeek in (2 3 4 5 6) then WeekEnd=0;
format DayOfWeek fmtday. Shift fmtshift. H1N1_Season fmtflu. Contact fmtcontact. staff fmtstaff. WeekEnd
fmtweekend.;
run;
```

- END;

Appendix C: Map of Emory University Midtown Hospital Emergency Department
with location IDs

Location ID	Location Name	Location ID	Location Name	Location ID	Location Name	Location ID	Location Name
1	ED RADIOLOGY	24	CLEAN UTILITY	47	CDU RM 2	70	ED CONF. ROOM
2	ED ROOM 1	25	SOILED UTILITY	48	CDU RM 3	71	FAMILY WAIT 1-3
3	ED ROOM 2	26	ED HALL RM 11 - 13	49	CDU RM 4	72	ED EXIT 1
4	ED ROOM 3	27	ED HALL RM 8 - 10	50	CDU RM 5	73	ED MAIN ENTRANCE
5	ED ROOM 4	28	ED NURSE STN R	51	CDU RM 6	74	OFFICE AREA
6	ED ROOM 5	29	ED NURSE STN L	52	CDU RM 7	75	ED EXIT 2
7	ED ROOM 6	30	ED HALL RM 13 - 15	53	CDU RM 8	76	OFFICE AREA
8	ED ROOM 7	31	ED HALL RM 15 - 17	54	DECON-EMS STORAGE	77	STAFF BREAK AREA
9	ED ROOM 8	32	EXPRESS CARE RM 1	55	AMBULANCE ENTRANCE	78	EMERG LAB AREA
10	ED ROOM 9	33	EXPRESS CARE RM 2	56	POLICE, EMS and STRG	79	SRVC ELEV AREA
11	ED ROOM 10	34	EXPRESS CARE RM 3	57	CDU N.S. HALL AREA	80	FAMILY WAIT 4-5
12	ED ROOM 11	35	EXPRESS CARE RM 4	58	CDU UTIL. HALL AREA	81	PUBLIC RESTROOM HALL
13	ED ROOM 12	36	EXPRESS CARE RM 5	59	CDU UTILITY-STORAGE	82	FAMILY WAITING HALL
14	ED ROOM 13	37	EXPRESS CARE RM 6	60	CDU NURSE STATION 2	83	TRIAGE RM 1
15	ED ROOM 14	38	EXPRESS CARE RM 7	61	CDU NURSE STATION	84	TRIAGE RM 2
16	ED ROOM 16	39	EXPRESS CARE RM 8	62	CDU PT RESTROOM	85	TRIAGE
17	ED ROOM 15	40	ED HALL RM 16	63	HALL ED RM 16 - 20	86	TRIAGE RECEPTION
18	ED ROOM 17	41	EXPRESS CARE N.S.	64	HALL EXPRESS RM 6-7	87	ELEV HALL AREA
19	ED ROOM 18	42	EXPRESS CARE R	65	HALL CDU ON CALL	88	TRIAGE REGISTRATION
20	ED ROOM 20	43	EXPRESS CARE L	66	ED STORAGE	89	TRIAGE WORKROOM
21	ED ROOM 21	44	NEW TREATMENT AREA 2	67	IMAGING AND CONF RM	90	TRIAGE STORAGE
22	DECONTAMINATION	45	NEW TREATMENT AREA	68	IMAGING HALL AREA	91	TRIAGE HALL AREA
23	ED ROOM 19	46	CDU RM 1	69	PUBLIC RESTROOMS	92	ED WAITING AREA
						93	EQUIPMENT PARKING