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Contact networks in the emergency department: Effects of time, environment, patient characteristics, and staff role

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ABSTRACT

Emergency departments play a critical role in the public health system, particularly in times of pandemic. Infectious patients presenting to emergency departments bring a risk of cross-infection to other patients and staff through close proximity interactions or contacts. To understand factors associated with cross-infection risk, we measured close proximity interactions of emergency department staff and patients by radiofrequency identification in a working emergency department. The number of contacts (degree) is not related to patient demographic characteristics. However, the amount of time in close proximity (weighted degree) of patients with ED personnel did differ, with black patients having approximately 15 min more contact with staff than non-white patients. Patients arriving by EMS had fewer contacts with other patients than patients arriving by other means. There are differences in the number of contacts based on staff role and arrival mode. When crowding is low, providers have the most contact time with patients, while administrative staff have the least. However, when crowding is high, this differential is reversed. The effect of arrival mode is modified by the extent of crowding. When crowding is low, patients arriving by EMS had longer contact with administrative staff, compared to patients arriving by other means. However, when crowding is high, patients arriving by EMS had less contact with administrative staff compared to patients arriving by other means. Our findings should help designers of emergency care focus on higher risk situations for transmission of dangerous pathogens in an emergency department. For instance, the effects of arrival and crowding should be considered as targets for engineering or architectural interventions that could artificially increase social distances.

1. Introduction

1.1. Background

Within the last decade the world was swept by the H1N1 pandemic, beginning with cases in Mexico detected in March 2009 (WH Organization, 2009). The first US cases appeared in California in mid-April 2009 (Ginsberg et al., 2009). Vaccine was rushed into production, and was available in October. In January 2010 the CDC declared vaccine had been successfully made available to targeted populations (Centers for Disease Control and Prevention, 2010). The H1N1 epidemic is of particular interest in academic emergency medicine. It is a time when the public health system, in which emergency departments (EDs) play a key role, should have been operating optimally due to heightened awareness of infection control efforts.

Close proximity interactions (contacts) provide a means for cross infection when a susceptible individual inhales airborne microbes shed as large droplets by an infectious individual for diseases such as influenza and severe acute respiratory syndrome (SARS) (Bridges et al., 2003; Tellier, 2006; Wenzel and Edmond, 2003). One setting where contacts between susceptible and infectious individuals occur frequently is the ED, as was dramatically demonstrated in the 2003 SARS epidemic (Varia et al., 2003). Understanding the temporal, environmental, and individual factors associated with contacts may lead to improved infection control

Abbreviations: ED, emergency department; EHR, electronic health record; EMS, emergency medical services; GI, gastrointestinal; PP, patient with patient; PS, patient with staff; RFID, radiofrequency identification; RTLS, real time location sensing; SARS, severe acute respiratory syndrome; SP, staff with patient; SS, staff with staff.

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efforts in the ED, which may prove to be particularly important in times of pandemic concern.

1.2. Importance

Recent developments in technology have enabled precise measurement of movements of humans and resulting interactions. Researchers are increasingly using real time location sensing (RTLS) systems such as radiofrequency identification (RFID) systems to measure occurrence, duration, and location of contacts typically defined as distance between two individuals of some small fixed distance such as 1 meter (m) by line of sight (Gundlapalli et al., 2009; Hornbeck et al., 2012; Isella et al., 2011a,b; Lucet et al., 2012; Stehle et al., 2011; Vanhems et al., 2013; Salathe et al., 2010).

Sensors have been used to study the interactions of patients and staff in a hospital ICU (Hornbeck et al., 2012), a hospital pediatric ward (Isella et al., 2011a), a hospital geriatric ward (Vanhems et al., 2013), and a hospital ward in which patients were under airborne precautions (Lucet et al., 2012). Sensor data have been examined in comparison to electronic medical system log-in information in an ED setting to determine if the latter has utility in determining contacts (Gundlapalli et al., 2009). Other settings in which such technology has been used include schools (Stehle et al., 2011; Salathe et al., 2010) and scientific conferences (Isella et al., 2011b). Due to the costs associated with such technology, these investigations of contacts have been, with few exceptions, one-time investigations of short duration, e.g., 1 week or less. Such snapshots may not be representative of relationships throughout time, in particular failing to account for seasonal or even week-to-week variation. One study in high school students (Fournet and Barrat, 2014) for 11 days in two years showed that there was little variation in contact matrices by time of day, between days, and between years. However it is not clear how these results generalize to other populations. In general, the few studies involving longer periods of time report summary network measures for the period that do not permit inference to the general population of such networks. There is little information on contacts of patients as they interact with staff and with other patients. It is unknown if there are differences associated with patient age, sex, race, or clinical syndrome. There is also limited information about contacts of staff as they interact with other staff and with patients, particularly with respect to staff role (i.e., provider, nurse, administrative).

1.3. Goals of this investigation

A better understanding of the nature of contacts may lead to improvements in infection control in the ED. We measured contacts among patients and staff of the ED of a large urban hospital in Atlanta, GA (Lowery-North et al., 2013). In this paper we describe a secondary analysis of those data. In particular we examine here the characteristics of the resulting contact networks, relating nodal- and network-level metrics with shift characteristics such as time (i.e., season of year, weekday vs. weekend, day vs. night) and environment (e.g., volume of patients, percent high acuity patients). We also describe relationships between patient contacts and patient characteristics as well as between staff contacts and staff role.

2. Methods

2.1. Design

This is a prospective study. We measured contacts among patients and staff of the ED of a large urban hospital in Atlanta, GA during 81 randomly selected 12-h shifts between 1 July 2009 and 30 June 2010 (Lowery-North et al., 2013).

2.2. Setting

As detailed in Lowery-North et al. (2013), we installed an RFID system to determine contacts ≤1 meter (m) between and within patients and staff in a busy hospital ED of modern design, part of an urban academic center. This is a modern ED with centralized workspaces and walled patient treatment rooms. The ED was designed for 50,000 patient encounters annually; over the year of the study there were over 57,000 patient encounters.

2.3. Participants

We placed permanent RFID tags on all staff, and placed temporary RFID tags on all patients during predetermined, randomly chosen shifts. The protocol was reviewed and approved by the Emory University Institutional Review Board. All ED staff were invited to participate. Staff participation was voluntary and anonymous. All non-incarcerated patients who were not mentally incapacitated were eligible. Patient participation was voluntary as well.

2.4. Observation periods

In this paper we restrict our analysis to data from the first 6 months of the study (35 shifts of the 81 observed). Data limitations that led to restricted analysis on a subset of shifts are as follows: examination of participation by patients and staff across the year showed a significant decline. We attribute staff participation decline to a system failure that did not alert us to battery depletion in permanent tags worn by staff. There is no similar physical reason for decline in patient participation, thus we attribute it to waning abilities of the research team to keep up with a task that was too large for them alone. Biases in estimates of measures of interest can result from missing individuals and their concomitant contacts.

We restricted analyses to shifts in the first 6 months of our observation period for two reasons: (1) the decline in staff participation starts at the beginning of the second half of the year and thus these observations should not be biased by the presence missing data; (2) the H1N1 epidemic swept through the state of Georgia during these first six months.

2.5. Variables

2.5.1. Outcome variables

The RFID data were used to create a contact network for each shift depicting interactions (the edges) between patient and staff participants (the nodes), resulting in weighted and unweighted adjacency matrices (Lowery-North et al., 2013; Newman, 2010). From these matrices, the following node-level measures were calculated for each participant: degree (number of contacts), time-weighted degree (time-weighted contacts), relative degree (number of contacts normalized to the interval (0, 1)), closeness centrality (inverse of the average shortest path to all other individuals; range is 0–1), and eigenvector centrality (how well they were associated with other central individuals) (Newman, 2010). In addition, for each shift, the following network-level measures were calculated from these matrices: density, average path length, diameter, time-weighted diameter, radius, maximum spectral gap, number of weak components, and average clustering coefficient (transitivity) (Newman, 2010).

2.5.2. Participant-level independent variables

The only information associated with staff RFID tag number was role (provider, nurse, other). Providers comprised attending and resident physicians, nurse practitioners, and physician assistants.