American Journal of Infection Control ■■ (2017) ■■-■■

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Contact tracing with a real-time location system: A case study of increasing relative effectiveness in an emergency department

Thomas R. Hellmich MD [a,b], Casey M. Clements MD, PhD [a,b], Nibras El-Sherif MBBS [b,c], Kalyan S. Pasupathy PhD [b,c], David M. Nestler MD, MS [a,b], Andy Boggust MD [a], Vickie K. Ernste DNP, RN [a], Gomathi Marisamy BS [d], Kyle R. Koenig BS [c], M. Susan Hallbeck PhD, CPE, PE [b,c,d,*]

[a] Department of Emergency Medicine, Mayo Clinic, Rochester, MN
[b] Robert D. and Patricia E. Kern Center for the Science of Health Care Delivery, Mayo Clinic, Rochester, MN
[c] Department of Health Sciences Research, Mayo Clinic, Rochester, MN
[d] Departments of Surgery and Critical Care Systems, Mayo Clinic, Rochester, MN

Key Words:
Infectious disease
Pertussis

Background: Contact tracing is the systematic method of identifying individuals potentially exposed to infectious diseases. Electronic medical record (EMR) use for contact tracing is time-consuming and may miss exposed individuals. Real-time location systems (RTLSs) may improve contact identification. Therefore, the relative effectiveness of these 2 contact tracing methodologies were evaluated.

Methods: During a pertussis outbreak in the United States, a retrospective case study was conducted between June 14 and August 31, 2016, to identify the contacts of confirmed pertussis cases, using EMR and RTLS data in the emergency department of a tertiary care medical center. Descriptive statistics and a paired *t* test ($\alpha = 0.05$) were performed to compare contacts identified by EMR versus RTLS, as was correlation between pertussis patient length of stay and the number of potential contacts.

Results: Nine cases of pertussis presented to the emergency department during the identified time period. RTLS doubled the potential exposure list ($P < .01$). Length of stay had significant positive correlation with contacts identified by RTLS ($\rho = 0.79$; $P = .01$) but not with EMR ($\rho = 0.43$; $P = .25$).

Conclusions: RTLS doubled the potential pertussis exposures beyond EMR-based contact identification. Thus, RTLS may be a valuable addition to the practice of contact tracing and infectious disease monitoring.

Contact tracing is a critical strategy required for timely prevention and control of infectious disease outbreaks.[1,2] However, conventional contact tracing methods are time-consuming and can miss a significant number of potential exposures.[3,4] Medical record review and staff interview methods fail to capture all potentially exposed individuals because of incomplete or missing documentation and recall bias.[5,6] Failure to identify persons in contact with infected patients increases the risk of transmission, placing many health care workers and vulnerable patients (eg, infants and comorbid patients) at risk.[7] This transmission may cause significant health complications, especially for vulnerable patients, and increase morbidity and mortality.[7] Failure to adequately trace infectious disease contacts disrupts routine health care services[8] and results in substantial cost for health care systems.[9,10] Current contact tracing methodologies for contagious diseases are imperfect, and new technological interventions should be investigated to identify close contacts in a timely, efficient, and exhaustive manner to prevent subsequent transmission to other patients and health care workers for effective outbreak management.

Advances in technology have made tracking individuals possible and increasingly affordable using several types of real-time location system (RTLS). One such RTLS uses radiofrequency identification (RFID) tracking. RFID has been used in a variety of settings such as schools[11,12] and academic conferences[13,14] to facilitate and accelerate the process of understanding face-to-face contact, human interactions, and social networks accurately and efficiently within

* Address correspondence to M. Susan Hallbeck, PhD, CPE, PE, Robert D. and Patricia E. Kern Center for the Science of Health Care Delivery, Mayo Clinic, Division of Health Care Policy and Research, Department of Health Sciences Research, Mayo Clinic, 200 First St SW, Rochester, MN 55905.
E-mail address: hallbeck.susan@mayo.edu (M.S. Hallbeck).

Supported by funds from the Mayo Clinic Robert D. and Patricia E. Kern Center for the Science of Health Care Delivery and contributions from the Mayo Clinic ED-Clinical Engineering Learning Lab.
Conflicts of interest: None to report.

0196-6553/
http://dx.doi.org/10.1016/j.ajic.2017.08.014

Table 1
Nine pertussis cases and potential exposure identified by electronic medical record (EMR) and real-time location system (RTLS)

Case No.	Age, y	Emergency department length of stay, min	No. by EMR review	No. by RTLS review	No. by EMR (but not RTLS)	No. by RTLS (but not EMR)	Total unique contacts	Increase above EMR only, %
1	1.6	91	4	8	2	6	10	150.0
2	18	152	5	9	1	5	10	100.0
3	11	144	7	9	1	3	10	42.9
4	2.1	68	5	8	2	5	10	100.0
5	17	121	5	5	1	1	6	20.0
6	17	62	3	3	0	0	3	0
7	9	288	5	10	2	7	12	140.0
8	2.8	287	5	14	2	11	16	220.0
9	8	294	6	11	2	7	13	116.7
Total			45	77	13	45	90	
Average	9.6	94	5.0	8.6	1.4	5.0	10.0	100

a very short time. In health care settings, RFID has been used to study the role of patient-health care worker networks and face-to-face contact frequency and duration in the disease transmission process[15] and to identify the most and least connected health care workers with patients.[16]

To date, no study has compared RTLS with the standard methodology of chart review for contact tracing. In this case study, we describe a relative effectiveness comparison of contact tracing between current state (chart review) and RTLS tracking for confirmed pertussis cases in an emergency department (ED).

MATERIALS AND METHODS

Equipment

Our RTLS system (Quake Global, Inc, San Diego, CA) utilizes 194 in-ceiling, passive RFID readers with 734 antennas, covering 212 locations in a 54,450 sq ft ED and radiology (supporting ED services) department space. The RTLS, driven by this RFID infrastructure, was in operation and reliable for 6 months before data collection. Core ED staff wore RFID-enabled employee identification tags. In addition to physicians and nurses, staff including respiratory therapists and registration personnel had RFID-enabled badges. However, some ancillary staff serving the ED (eg, medical students and radiology technicians) did not have RFID-enabled identification tags during the time of this study.

Study protocol

During an outbreak of pertussis in the Midwest region of the United States, a retrospective case study was conducted to identify possible contacts of 9 confirmed, successive pertussis cases between June 14 and August 31, 2016. Our study was performed in the ED of a large tertiary medical center with an annual volume of approximately 74,000 patient encounters. We used both traditional electronic medical record (EMR)-based contact identification and RTLS-generated data. All pertussis cases were diagnosed 1-2 days after the ED visit and reported to institutional infection control services. None of these 9 patients were admitted to the hospital.

Per existing contact tracing protocol, a list of possible exposures for each pertussis patient was generated after review of the EMR. Nurse leadership in coordination with hospital infection control, using current Centers for Disease Control and Prevention guidelines, conducted this review. Possible disease exposure included any health care worker whose role placed them in face-to-face contact with the index patient in the exam room or triage area. The EMR identified any health care workers who documented their interactions with patients.

Subsequently, a list of possible pertussis exposures was generated using a novel RTLS event mapping program that identified patients and staff, their colocations, and movements over time and space. It took <5 minutes to generate each of these RTLS data queries. Because pertussis is spread through droplet respiratory secretions, possible exposures were limited to colocation in ED exam rooms or triage areas where droplet exposures are most likely. Hallway and waiting room colocation were excluded from the analysis because they were not considered likely to result in face-to-face exposure. All possible exposures, identified through RTLS or EMR review, were offered standard pertussis exposure prophylaxis.

Analysis

We compared the number of possible exposures identified by EMR, the number of possible exposures identified by RTLS, and the roles of the health care staff that came in contact with confirmed pertussis cases. Descriptive statistics and paired *t* tests were used to compare the number of contacts and the role of those identified by EMR and RTLS, with $\alpha = 0.05$. In addition, a Pearson product-moment correlation between the length of stay (LOS) and the number of contacts identified by each methodology was performed.

RESULTS

Nine patients eventually diagnosed with pertussis presented to the ED during our identified time period, with patient ages ranging from 1.6-18 years (mean, 9.6 years). The average LOS was 94 minutes (range, 62 to 294 minutes; standard deviation = 96.6).

When combining all 9 cases, EMR review (alone) identified 45 potential contacts (Table 1 and Fig 1). Thirteen health care workers were identified in the EMR but not identified by RTLS, including 2 physicians, 6 triage nurses, 1 discharge nurse, 1 scribe, 1 urology technician, 1 radiology technician, and 1 medical student. RTLS alone identified 77 contacts, of whom 45 were additional new contacts not identified from the EMR. Table 2 shows the roles of the health care staff identified by RTLS but not by EMR review. RTLS identified twice as many possible contact cases as those identified by EMR review ($P < .01$) increasing the number of potential contacts above those identified by the EMR from an average of 5 contacts per case to an average of 10 contacts per case (Fig 1 and Table 1).

DISCUSSION

In this study, RTLS doubled the number of potential pertussis exposures identified beyond the conventional methods of EMR-based contact identification, suggesting that RTLS may be more effective than traditional EMR review alone. RTLS-generated data