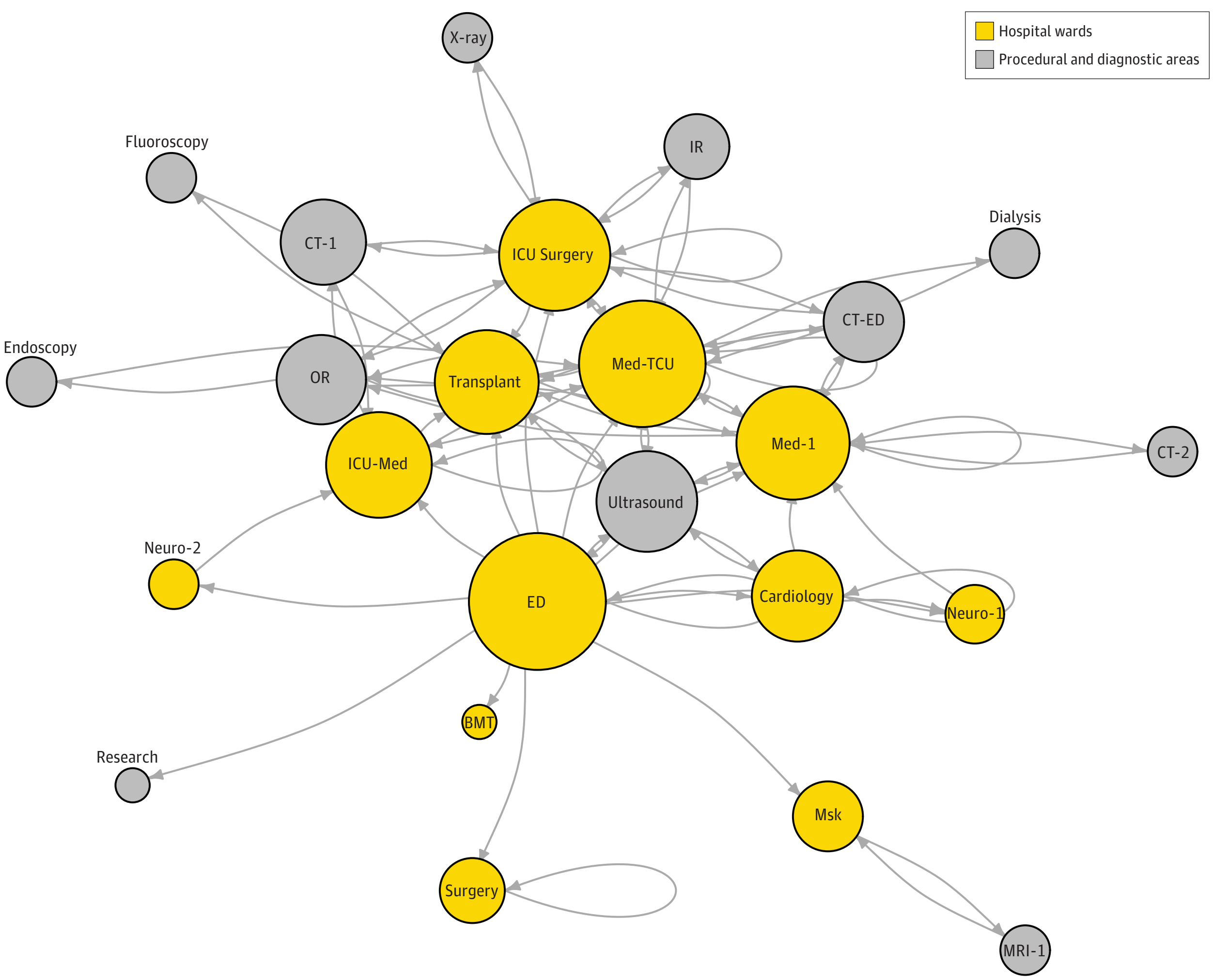
Using Spatial and Temporal Mapping to Identify Nosocomial Disease Transmission of *Clostridium difficile*

Hospital-acquired *Clostridium difficile* infection (CDI) is associated with significant morbidity and mortality.[1] While risk factors like antibiotic exposure modulate susceptibility, infection control efforts aimed at reducing contact with infectious spores are critical to prevent nosocomial transmission.[2-5] During hospitalization, patients visit many procedural and diagnostic common areas, presenting opportunities for contact with contaminated surfaces. However, these potential exposures are not typically captured in analyses evaluating disease transmission.[6] Electronic health record (EHR) data allow us to track patients in time and space, but these data are not typically leveraged for infection control quality improvement efforts. We evaluated whether using a room within 24 hours of a patient with CDI was associated with increased risk of CDI in specific areas across our hospital.

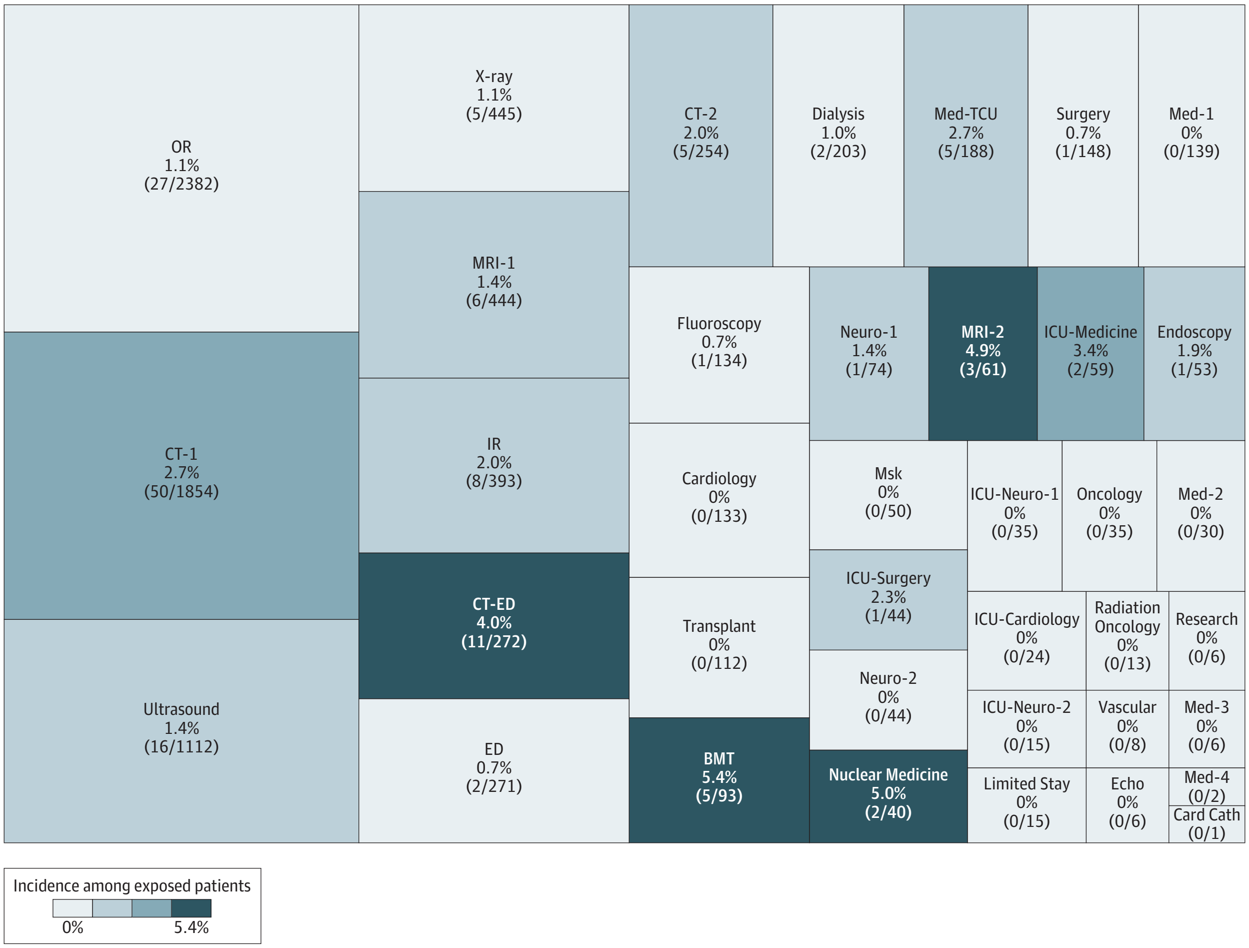
Methods | We analyzed EHR data from all adult hospitalizations in a large university hospital between January 2013 and December 2015. Patients with CDI were considered *C difficile* positive from the time the positive test was ordered until hospital discharge. Spaces were considered potentially contaminated for 24 hours after a patient with CDI visited them. All hospitalized patients who had not yet tested positive for CDI and passed through a space while it was potentially contaminated were considered exposed to *C difficile,* while patients who

Figure 1. Movement of Patients With *Clostridium difficile* Infection From the Emergency Department (ED) Throughout the Hospital



Network graph displaying the hospital ward, procedural, and diagnostic areas in the hospital visited by a subset of patients with *C difficile* infection who were diagnosed in the ED during a single year. The size of each circle represents the number of *C difficile*–positive patients who passed through that location. Yellow denotes bed census areas (eg, nursing units), and gray denotes procedural and diagnostic common areas. Patients with *C difficile* infection visited a mean (SD) of 4.2 (4.0) locations while hospitalized, including procedural and diagnostic common areas, representing multiple sites of potential contamination of surfaces and disease transmission. BMT indicates bone-marrow transplant unit; CT-1 and -2, computed tomographic scanner suites 1 and 2; CT-ED, CT scanner suite in the emergency department; ICU, intensive care unit; IR, interventional radiology; Med, medical nursing unit; MRI-1, magnetic resonance imaging suite 1; Msk, musculoskeletal unit; Neuro-1 and -2, neurology units 1 and 2; OR, operating room; and TCU, transitional care unit.

Figure 2. *Clostridium difficile* Exposure Across the Hospital and the Risk of *C difficile* Infection (CDI)



The number of exposures in a given area of the hospital is represented by the size of each box. The risk of developing CDI if exposed is indicated by (1) the color of each box; (2) the percentage reported; and (3) explicitly as the fraction of CDI occurrences among exposed patients for each location. While room-level data were collected, outcomes for individual patient rooms were analyzed at the level of the nursing unit. Analyses for each area exclude individuals who were exposed elsewhere in the hospital. Compared with the hospitalwide overall CDI incidence of 1.3%, shaded locations had increased risk of disease among exposed patients. Only the emergency department (ED) computed tomographic (CT) scanner (CT-ED) met statistical significance in adjusted analyses (incidence, 4%; OR, 2.5; 95% CI, 1.2-5.2). BMT indicates bone-marrow transplant area; Card cath, cardiac catheterization suite; CT-1 and CT-2, CT scanner suites; Echo, echocardiogram area; ICU, intensive care unit; IR, interventional radiology; Med, any of multiple specified medicine units; MRI-1 and MRI-2, magnetic resonance imaging suites; Msk, musculoskeletal unit; Neuro-1 and Neuro-2, neurology units; OR, operating rooms; TCU, transitional care unit.

occupied the same space at any other time served as the unexposed control group. Patients were followed for 60 days from the time they passed through a given space for development of CDI, after allowing a 24-hour incubation period during which time the occurrence of CDI was deemed unrelated to exposure. *Clostridium difficile* infection was defined as a positive laboratory test for *C difficile* (toxin immunoassay or glutamate dehydrogenase antigen plus confirmatory polymerase chain reaction), obtained when the patient was either an inpatient or outpatient in our system.

Logistic regression with clustering by patient was used to calculate odds ratios (ORs) for developing CDI of exposed vs unexposed individuals who passed through the same space. Patients with CDI during the prior year were excluded. Covariates included age, sex, antibiotic use, number of location changes, length of stay, proton pump inhibitor use, inflammatory bowel disease, and prior hospitalization (within 90 days). This study was approved by the University of California institutional review board, waiving written informed consent.

Results | There were 86 648 adult hospitalizations and 434 745 patient location changes within the hospital during the study period. There were 1152 cases of laboratory-documented CDI (overall incidence, 1.3%). The CDI-positive patients moved through a mean (SD) 4.2 (4.0) hospital locations, potentially contaminating those spaces (**Figure 1**).

Exposure and risk of subsequent CDI varied across locations (**Figure 2**). Being exposed to CDI in the computed tomography scanner in the emergency department (CT-ED) was significantly associated with the development of CDI (incidence, 4%; OR, 2.5; 95% CI, 1.2-5.2). This effect remained significant (OR, 2.7; 95% CI, 1.3-5.7) after adjustment for covariates and in sensitivity analyses extending the incubation period to 72 hours (OR, 2.8; 95% CI, 1.2-6.3). Trends in other areas did not reach statistical significance, and the effect was not significant in an adjusted hospitalwide analysis. Subsequent investigation revealed that cleaning practices for the scanner table of the CT-ED had not yet been updated to match the standardized methods applied in other radiology suites.

Discussion | In a large university hospital, passing through the CT-ED within 24 hours after a patient with *C difficile* had been there was associated with increased risk of developing CDI. Our novel analytic methods identified a previously undiscovered opportunity for real-world practice change. We continue to monitor the success of improved cleaning practices implemented as a result of this study. Leveraging EHR data for spatial and temporal analytics may be a widely applicable strategy for infection control and quality improvement at other institutions and for other infectious diseases.

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FIREARM VIOLENCE

Use of Firearms in Terrorist Attacks: Differences Between the United States, Canada, Europe, Australia, and New Zealand

Although firearms are used in only a small proportion of terrorist attacks, these highly publicized events shed light on access to weapons and mass shootings. The sociopolitical and cultural context surrounding firearms, including the proportion of individuals owning guns, varies between countries.[1] The United States has a higher rate of firearms deaths than other high-income countries.[2,3] We compared the proportion of terrorist attacks committed with firearms in the United States with the proportion in other high-income countries. We also compared the lethality of attacks with firearms to those by other means.

Methods | We queried The Global Terrorism Database from 2002 to 2016.[4] Maintained by the National Consortium for the Study of Terrorism and Responses to Terrorism at the University of Maryland, this database incorporates a methodology that includes both machine learning and manual review to abstract high-quality information from more than 1 million daily media reports published worldwide in over 80 languages. The database defines a terrorist attack as the "use of illegal force and violence by a non-state actor to attain a political, economic, religious, or social goal through fear, coercion, or intimidation."[4] For each attack, the location, type, and number of fatalities are collected. The database categorizes weapons as biological, chemical, explosive, fake weapons, firearms, incendiary (eg, arson), melee, sabotage equipment, vehicle (nonexplosive), other, and unknown.

To avoid calculating proportions in countries with few data points, we calculated the proportion of attacks involving firearms among countries in the top 75th percentile (10 attacks or more) over the study period. The number of fatalities per attack was calculated by weapon type. Of the 23 countries with at least