Stopping Hospital Acquired Infections Using Complex Systems Science

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Each year in United States, about 100,000 people die at hospitals not from the illness that brought them there, but at least in part from an infection they acquired during their treatment. These healthcare-associated infections (HAIs) affect an estimated 1.7 million Americans a year and add between $30 and 45$ billion to the costs of healthcare [1]. The pathogens responsible are unique to hospitals but can spread outwards to communities. Making matters more difficult, HAIs are frequently resistant to multiple antibiotics.

The current approach to reducing the transmission of HAIs focuses on the points of contact between patients and health care providers and their immediate surroundings [2, 3]. For doctors, this means washing hands before and after administering care to each patient. Medical instruments are also sterilized to prevent specific infections, such as UTIs from catheters. Patients who are diagnosed with particularly infectious or serious infections like MRSA are more fully isolated. The most effective of these interventions take up a lot of health care providers time and making them routine may not be straightforward??given everything else that has to be done, it is hard to wash hands every time it is recommended [4–6]. In any case, their effectiveness is far from complete.

Part of the reason these patient-centric methods fail is that pathogens are actually located everywhere in a hospital setting [7]. Doctors hands may be clean, but their clothing also comes into contact with patients or patients bedding. Equipment may be sterilized, but the tray containing them may be set on contaminated services. Cell phones and PDAs are also vectors for transmission, along with surfaces like light switches and bed railings which are likely to be touched by patients [8, 9].

The fundamental problem with standard approaches to reducing HAIs is that they are high-effort but low-leverage. They focus only on single patients, while our analysis [10] shows that the overall structure of the system is a key part of the problem.

Hospitals involve a lot of physical contact between people moving from room to room. NECSI co-faculty Dr. Luci Leykum tracked the number and variety of people moving around in a typical hospital setting [7]. In addition to patients, physicians and nurses, there are also ward clerks, social workers, food service workers, housekeeping, phlebotomists, X-ray technicians and visitors. Any of these individuals may come into contact with infected patients or surfaces but not all follow the same preventative techniques. So pathogens are able to move throughout the hospital environment.

Our research into network dynamics shows that the easy movement of pathogens is responsible for the high impact of HAIs. The more connections there are in the hospital systems, among people and between people and surfaces, the more aggressive pathogens can become [11]. This network is essential to pathogen breeding and mutuation that leads to drug resistance.

Trying to stop transmission at all the nodes in the hospital system is what makes present techniques ineffective. They are high-effort and low-impact. A higher leverage approach is needed.

Instead of focusing on nodes, we need to cut the links that connect the system together. The entire network should be partitioned to disrupt pathogen transmission. Hospitals can be broken down into units such as wards or floors, with travel between areas partially restricted. Disinfection gateways need to be designed for this purpose [12].

Located at the entrances to wards, disinfection gateways would involve a more thorough decontamination process than simple hand washing (see mockup in Figure 1). Clothing and personal electronics could also be sanitized. The gateways function like airlocks, sanitizing individuals exiting and entering the ward to keep pathogens from spreading or being introduced.

Because many healthcare providers move inside of wards more often than between them, these gateways could be kept efficient and not take up too much time. Visitors and patients would not necessarily need to use the gateways, because as individuals they have far fewer contacts and chances for transmission than care providers. In the event of a time-sensitive emergency, gateways can be bypassed. These exceptions would also represent only a small proportion of contacts.

FIG. 1: A mockup of a disinfection gateway for use in inhibiting the spread of infections.

The same idea applies in many different contexts. Partitioning a hospital to disrupt the transmission of disease can be directly compared to our research into containing epidemics [13]. During outbreaks, monitoring travelers for symptoms, and partitioning countries or cities into neighborhoods with screening or limited travel between these domains can be an effective way to contain an outbreak. While the costs of travel limitations are often debated, stopping an epidemic early prevents larger human, social and economic costs. Just as in the hospital, the purpose of these partitions is not to abandon infected individuals to their fates, but to allow for targeted care while reducing the likelihood of spreading disease into other neighborhoods, cities, or countries. Disrupting networks of pathogen transmission can reduce the impacts of HAIs as well as the odds of widespread epidemics.

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