Improving Infection Control at Massachusetts General Hospital

Design Team
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Abstract
The number of recorded Healthcare-Associated Infection (HAI) cases has increased by 36% over the past 20 years, costing the healthcare industry in the United States an additional $5 billion per year. These HAI-related costs include lost wages and unnecessary procedures, as well as additional medicine, medical supplies and equipment, which typically result from increased lengths of stay and hospital readmissions. The capstone group has been collaborating closely with a practicing clinician in the Massachusetts General hospital to develop generalizable, yet usable knowledge to address the problem of HAIs in the outpatient clinic. Using Arena as an analysis tool, the group has developed a set of recommendations that are adaptable to different outpatient settings. The specific focus of this project is on the effect of improved hand sanitization compliance and compartmentalization on infection transmission in the outpatient setting.

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The Need for Project

Healthcare associated infections (HAI), also known as nosocomial infections, refer to infections acquired in the hospital or healthcare setting. These types of infections have become increasingly common with 1.7 million recorded cases every year – 99,000 of which result in unnecessary deaths [1]. Furthermore, HAI-related costs burden the medical industry with an additional annual expense of $5 billion [1]. While healthcare professionals have attempted to control the spread of HAIs, the number of recorded cases has increased by 36% in the last 20 years and continues to grow every year [1]. Most HAI prevention initiatives have been conducted in the inpatient settings (e.g. ICU, emergency wards), but only few have actually focused on HAIs in the outpatient setting [2,3]. Nevertheless, the risk of transmitting HAIs is ever present in outpatient clinics, requiring a more complete understanding of this multidimensional problem and actionable recommendations to address it.

The Design Project Objectives and Requirements

**Design Objectives**

The goal of the project is to investigate ways to reduce the spread of infection in outpatient clinics. In addition to testing specific situations, the group aims to develop more generalizable knowledge on this topic. The project aims to test potential methods for reducing infection transmission including compartmentalization and hand sanitization in terms of system-wide exposure, performance, and feasibility.

**Design Requirements:**

The boundaries surrounding this design process mainly consist of parameterizing the trade-offs between qualities and efficiency without violating feasibility constraints such as staff, behavioral limits, and patients’ profiles. The urgent care clinic staff at MGH consists of two nurses, four doctors, a lab technician, a receptionist, and a referral clerk. In regards to facility, the resources available are two nurse stations, two triage rooms, five exam rooms, and a lab. As our primary objective is to decrease overall patient exposure to infections, the team is specifically looking to reduce the infection rate at least 20% from the baseline level.
Design Concepts Considered

We developed four candidate design concepts of which we found that the compartmentalization model is the most feasible.

The team considered multiple methods for achieving the objective. Initially, the team focused on integrating real-time location systems in clinical procedures as a means to measure and enforce hand hygiene compliance among clinical staff. The team was planning to investigate ways to improve hand-hygiene though installing radio-identification devices (RFID) on the hand sanitizers to measure the compliance of health-care. However, due to significant delays in the deployment of this technology; the solution became infeasible. The team also considered simulating the risk of transmission by using either an agent-based model or a system dynamics model to investigate how changes in the system would affect the spread of infection. The proposed model in agent-based model focused on simulating the behavior of the agents in the clinic. The system dynamics model would simulate the risk of transmission. However, the team decided to discard these solutions due to the complexity of model parameterization and the lack of accessible data.

The team also considered an optimization model for hand hygiene intervention that would find the optimal set of interventions to maximize the hand sanitization level over time subject to improvement decay and available resources. The team was not able to proceed with this solution due to the importance of validation and the high variability of intervention results data in the literature.

Finally, the group decided to simulate the workflow of the outpatient clinic using Arena to investigate the effects of implementing policy changes on hand hygiene and compartmentalization. The team has proceeded with this model because it is feasible to implement and parameterize and it is uniquely capable to meet our objective of investigating how operational dynamics affect the system-wide transmission of infections. 891 scenarios were simulated, represented all reasonable combinations of compartmentalization and hand sanitization improvements that the clinic may choose to take on. Of these, 73 scenarios were identified as pareto optimal.
**Recommended Design Concept**

Various levels of compartmentalization were studied and compared to alternative interventions to find a desirable balance of lower exposure and minimum waiting times. Primarily, our model investigates how compartmentalizing the clinic will affect infection transmission and clinic productivity. Compartmentalization mainly refers to the grouping of certain resources, process, and/or personnel to limit and control movement throughout the clinic. If a compartmentalized process is implemented, a patient will only be exposed to a subset of resources once he or she starts a certain flow path within the clinic. Limited and controlled flow would potentially provide better opportunities for isolation and containment of certain infections circulating throughout the clinic, and allow for better identification of their source(s). An example of implementing compartmentalization is to segregate the patient population in the waiting room according to their risk of carry infection. From the waiting room, a patient moves to one of the nursing stations, again based on their estimated risk. The patient can then only move to an exam room in the same subset as their nursing station. Compartmentalization reduces the system-wide probability of cross-contamination, and the associated infections.

The model suggests that compartmentalization may reduce net exposure of patients to infections by up to 44%. As the level of compartmentalization decreases, smaller savings are seen, ranging from 10% to 23%. However, such intermediate policies can minimize the additional delays introduced as a result of compartmentalization, and are also significantly more feasible to implement.

**Financial Issues**

The impact of improved policy setting in this area is measured by its impact on the triple aim: cost, quality, and population health. The finances of potential recommendations are difficult to quantify, and would vary greatly between clinics considering these kinds of policies. In general, the benefits of the policy as measured by the triple aim would be improved health, lower medical costs of treating infections, and minimized waiting time. The costs would be measured as the fixed cost of dividing the clinic, the price of any additional staff required, and potentially lost revenue resulting from lower throughput. For the MGH urgent care clinic, we estimate that up to 5540 patient exposures may be avoided per year, which could save the hospital up to $443,000 per year in additional medical costs treating 55 patients who require inpatient care for their HAIs.
Recommended Improvements

The best balanced policy appears to be a compartmentalization of the processes from patient arrival through triage on a risk basis, with additional improvements to hand sanitization. In terms of limiting exposure, a maximally compartmentalized clinic is the most effective. However, this option is particularly infeasible. Only dividing part of the clinic (e.g. the triage and exam processes) will achieve a significant, albeit smaller level of improvement to exposure, while being significantly easier to implement. Patient wait times under compartmentalization in the MGH urgent care clinic in particular appear to be driven by queues for the exam rooms. Therefore, dividing exam rooms has the highest efficiency cost for the safety improvement. As a result, the scenarios which appear to best balance these two objectives while still remaining feasible appear to be those that do not include exam room compartmentalization as well as no new staff. In particular, splitting the waiting rooms, administrative staff, and triage processes into two sets is simultaneously satisfies the competing objectives. This policy results in approximately a 14% decrease in newly exposed patients, a 16% reduction in the overall staff exposure probability, while only increasing waiting times by 6 minutes on average.

Importantly, this compartmentalization approach involves risk-based sorting of patients upon arrival to the clinic. This sorting mechanism cannot be entirely accurate; however, within the bounds of feasible sorting, sorting parameters were selected that would be both feasible and efficient: 80% of high risk patients are correctly classified (sensitivity), and 70% of low risk patients are correctly sorted (specificity). Additionally, improvements to hand sanitization and environmental cleaning could be added for further reductions in infection transmission. These multi-improvement scenarios are represented in the three-objective scatter plot on the previous page, and were evaluated to find the pareto optimal set (in green). In general, compartmentalization was found to be most effective when it did not apply to the exam rooms, and moderate sanitization improvement can be effectively combined with this level of compartmentalization.

