Comparison of screening for methicillin-resistant *Staphylococcus aureus* (MRSA) at hospital admission and discharge

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Introduction

- Methicillin-resistant *Staphylococcus aureus*: bacterium that colonizes the skin of human beings and proximate environment.
- Antibiotic resistance has made eradication much more difficult.
- Approximately 90,000 Americans infected every year. 22% dies.
- General symptoms: swollen pus-filled red bumps, ulcers. High risk groups: patients who suffer from diabetes, ulcers, chronic renal disease, or skin lesions; patients who've had previous antibiotic exposure or frequent hospital stays.

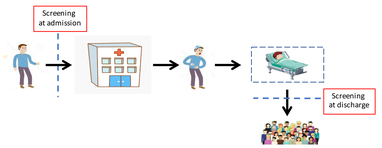

Figure 1: *Depiction of control strategies*

Methodology

We develop a system of nonlinear differential equations to model MRSA transmission and control strategies in a hospital. Our baseline model considers contaminated (H_C) and uncontaminated (H) health care workers (HCWs); and uncolonized (U), colonized (C), and infected (I) patients. Our screening at admission model additionally includes isolated (Z) patients. Finally, our screening at discharge model adds flagged (F) and unflagged (F_U) patients in the community.

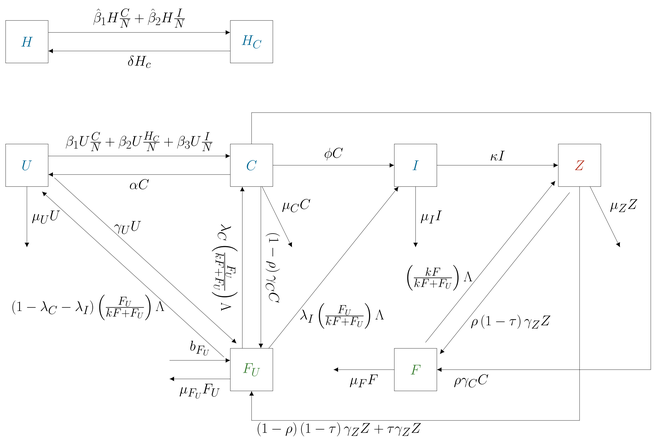

Figure 2: *Flowchart for screening at discharge model*

β_1	Transmission rate b/w colonized and uncolonized	γ_A	Discharge/treatment rate of compartment A
β_2	Transmission rate b/w cont. HCWs and uncolonized	μ_A	Death rate of compartment A
β_3	Transmission rate b/w infected and uncolonized	τ	Probability of successful treatment
$\hat{\beta}_1$	Transmission rate b/w colonized and HCWs	ρ	Screening probability
$\hat{\beta}_2$	Transmission rate b/w infected and HCWs	λ_C	Probability admitted patient is colonized
δ	Decontamination rate of HCWs	λ_I	Probability admitted patient is infected
α	Decolonization rate of patients	b_{F_U}	Birth rate of community
ϕ	Rate of progression from colonized to infected	κ	Rate of progression from infected to isolated

Analysis

There does not exist a disease-free equilibrium for our system as we are assuming patients carrying the bacteria are always entering the system according to the probabilities λ_C and λ_I. We assume that no new infected or colonized patients are admitted ($\lambda_C = \lambda_I = 0$) so, the hospital community is completely susceptible. The (adjusted) reproduction number R_0 was calculated using the next generation matrix method and takes the following form:

$$R_0 = \frac{1}{2}\left(R_P + \sqrt{R_P^2 + 4 \cdot R_H^2}\right)$$

R_P and R_H denote the colonization/infection potential of patients and HCWs, respectively.

$$R_P = N_P^*\left(\frac{\beta_1}{\alpha+\mu_C+\gamma_C+\phi} + \frac{\phi}{\alpha+\mu_C+\gamma_C+\phi}\cdot\frac{\beta_3}{\kappa+\mu_I}\right)$$

$$R_H = \sqrt{N_H^*\left(\frac{\hat{\beta}_1}{\alpha+\mu_C+\gamma_C+\phi} + \frac{\phi}{\alpha+\mu_C+\gamma_C+\phi}\cdot\frac{\hat{\beta}_2}{\kappa+\mu_I}\right)\frac{N_P^*\beta_2}{\delta}}$$

N_H^* and N_P^* denote the proportion of HCWs and patients with respect to total hospital population, respectively. When $R_0 > 1$, the presence of a new infected or colonized patient will produce an outbreak in the hospital.

Sensitivity analysis was performed on R_0. The results are summarized in Figure 3.

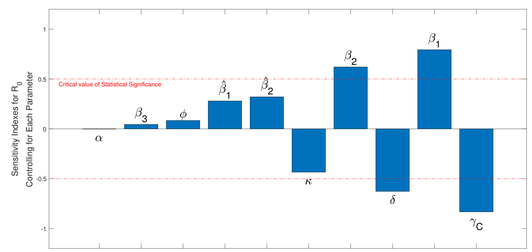

Figure 3: *Sensitivity of R_0 to changes in various parameters.*

Increasing the rate of discharge of colonized patients (γ_C) and decreasing the transmission rate between colonized and uncolonized patients (β_1) can significantly reduce the potential of a MRSA outbreak. Thus, more aggressive identification and eradication methods for colonized patients as well as stricter adherence to decontamination protocols in the hospital are the most important steps to reduce MRSA proliferation.

Furthermore, variation in the transmission rate between uncolonized and infected patients (β_2) as well as the decontamination rate of contaminated HCWs (δ) can also be used to reduce outbreak potential.

We also found that the adjusted reproduction number of any model is greater than 1 for the literature parameter values used and our estimate of δ, which means that increasing the decontamination rate can decrease the value of the reproduction number but it is not enough to avoid outbreak.

Results

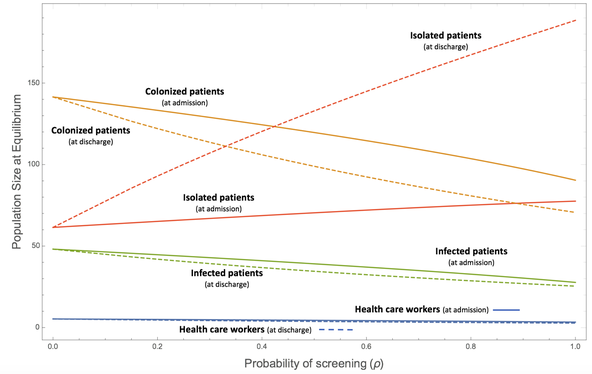

Figure 4: *Compartment population sizes at the endemic equilibrium as ρ varies.*

- Infected patient population and contaminated HCW population at equilibrium do not change significantly between control strategies as ρ varies.
- Screening at discharge is more effective at lowering colonized patient population at equilibrium, as compared to admission screening.
- Screening at discharge sends significantly many more patients to isolation than screening at admission.

Discussion and conclusion

The original models do not allow for a disease-free equilibrium. However, under the assumption of $\lambda_I = \lambda_C = 0$, we can obtain an expression for an adjusted reproduction number, denoted R_0. We calculated that $R_0 > 1$ for the parameters found in the literature, suggesting a strong infection potential of MRSA bacteria. Hence, an outbreak will always occur with the admission of an infected or colonized patient.

As shown in Figure 4, screening at discharge is a more effective strategy for reducing MRSA colonized patients in hospitals. However, isolated patient population grows significantly faster as compared to the alternative, suggesting that screening at discharge is not practical in terms of infrastructure limitations or cost considerations.

Further research is required to determine practicality considering both cost and a finite capacity isolation unit. Also, there is need for a broader spatial analysis.

Acknowledgments

We would like to give special thanks to Dr. Carlos Castillo-Chavez, Dr. Anuj Mubayi, Ms. Rebecca Perlin and Ms. Sabrina Avila. This research was conducted as part of 2018 MTBI at the Simon A. Levin Mathematical, Computational and Modeling Sciences Center (MCMSC) at Arizona State University (ASU), partially supported by grants from the National Science Foundation (Grants MPS-DMS-1263374 and DMS-1757968), the National Security Agency (Grant H98230-J8-1-0005), the Alfred P. Sloan Foundation, the Office of the President of ASU, and the Office of the Provost of ASU.