Game-theoretic surveillance approaches for hospital-associated infections

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Objective

To analyze optimal disease screening in strategic multiunit settings and determine how the level of unit autonomy may effect screening decisions.

Introduction

Disease screening facilitates the reduction of disease prevalence in two ways: (1) by preventing transmission and (2) allowing for treatment of infected individuals. Hospitals choosing an optimal screening level must weigh the benefits of decreased prevalence against the costs of screening and subsequent treatment. If screening decisions are made by multiple decision units (DU; e.g., hospital wards), then they must consider the disease prevalence among admissions to their unit. Thus, the screening decisions made by one DU directly affect the disease prevalence of the other units when patients are shared.

Because of this interdependent relationship, one DU may have an incentive to "free-ride" off the screening decisions of others as the disease prevalence declines. On the other hand, DUs may find it futile to invest in screening if they admit a large number of infected patients from neighbors who fail to screen properly. This problem is important in determining the optimal level of unit autonomy, since increasing a unit's level of autonomy in screening effectively increases the total number of DUs.

Methods

We develop a theoretical model that incorporates the two channels through which screening may reduce prevalence. The model is based on a hospital composed of N treatment units (e.g., ICU and ER) divided into n DUs, that transfer patients between one another and an outside population. Disease prevalence in each DU is determined by an SIS model based on the multi-institutional framework of Smith, et al. (1,2). A DU's prevalence is a function of its own screening level (s) and that of their neighbors (š).

We develop a cost structure similar to Armbruster and Brandeau that incorporates the various costs to screen for and treat a disease. (3) Given these costs, a single DU chooses the screening level that minimizes its net present value of discounted future costs. We solve for the symmetric, pure-strategy Nash equilibrium.

Results

As the rate of recovery following treatment (τ) increases relative to screening and treatment costs, the DU's best response curve transitions from an inverted-U pattern to one that is monotonically decreasing (Fig. 1). Additionally, the equilibrium screening value is monotonically decreasing in the number of DUs (Fig. 2). Here the best response curves intersect the line of equal screening values.

Conclusions

When treatment is less effective, free-riding is less severe and a DU's optimal screening may actually increase with its opponents level. However, as treatment becomes more effective, optimal

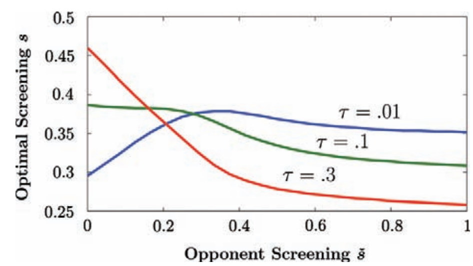

Fig. 1. Best Responce Function.

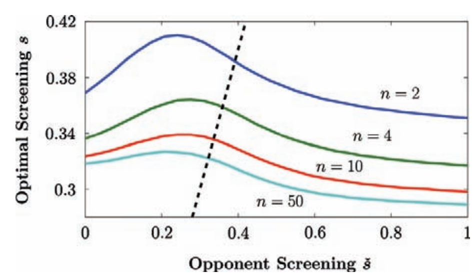

Fig. 2. Equilibrium Values.

screening levels are strictly decreasing in the other DU's allocation: free-riding takes full effect. As the number of DUs increases, so does the opportunity to free-ride. This means optimal screening will decrease and disease prevalence will increase as the number of DUs increases. Therefore, in a purely symmetric environment increasing unit autonomy may adversely affect disease prevalence: authority for screening should be centralized.

Keywords

Game theory; screening; infectious disease

References

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  Citation: Emerging Health Threats Journal 2011, **4**: 11021 - DOI: 10.3402/ehtj.v4i0.11021