Spread of Staph Infections in Hospitals

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Overview

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What is MRSA

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- It is spread by contact.
- It is carried by about 2% of the population (or 2 in 100 people), although most of them aren't infected.

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- When it occurs in these settings, it's known as health care-associated MRSA (HA-MRSA).
- HA-MRSA infections typically are associated with invasive procedures or devices, such as surgeries, intravenous tubing or artificial joints.

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- At-risk populations include groups such as high school wrestlers, child care workers and people who live in crowded conditions.

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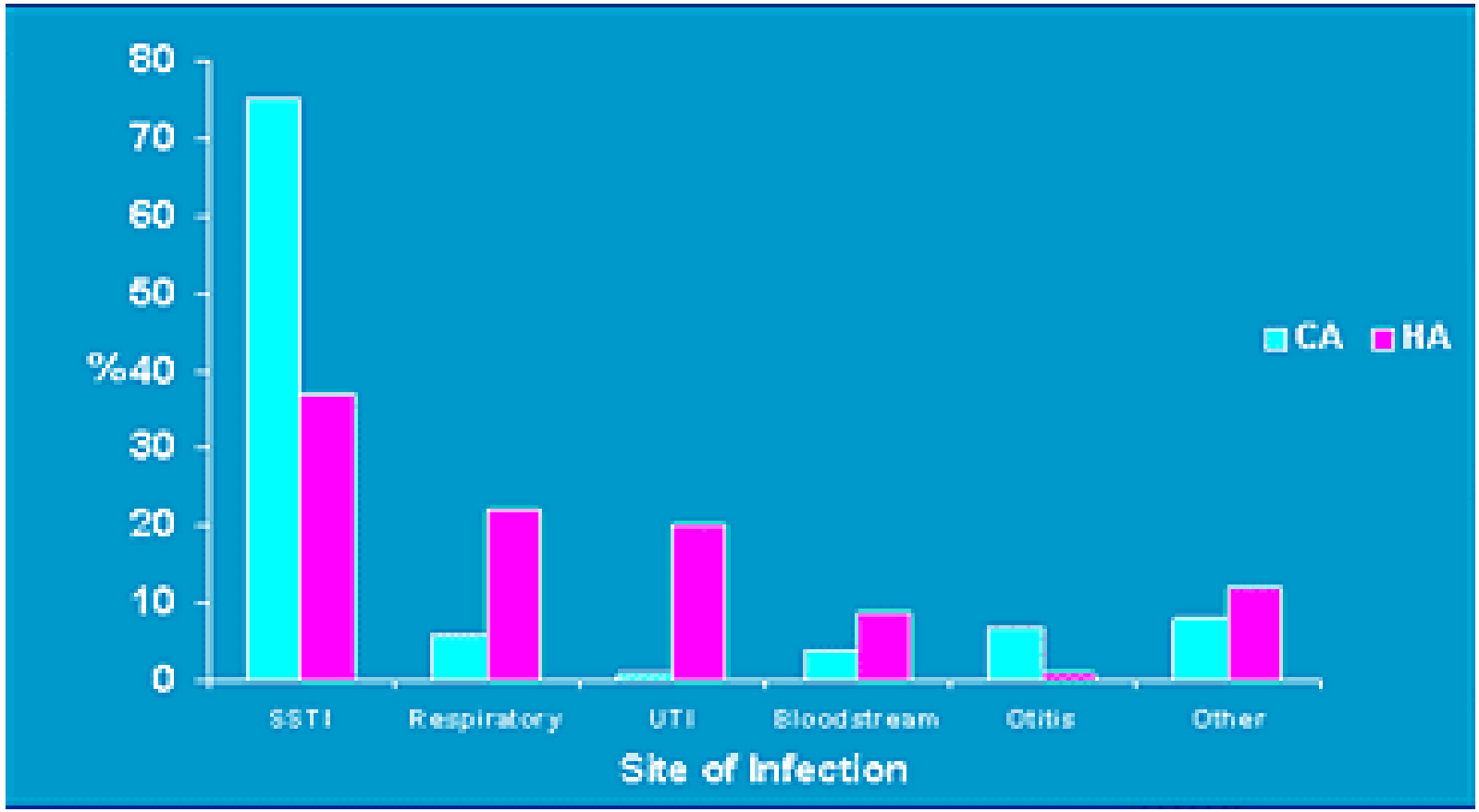

Figure: Site of

Overview

Building our model

Patient groups

$$K(t) \quad C(t) \quad S(t)$$

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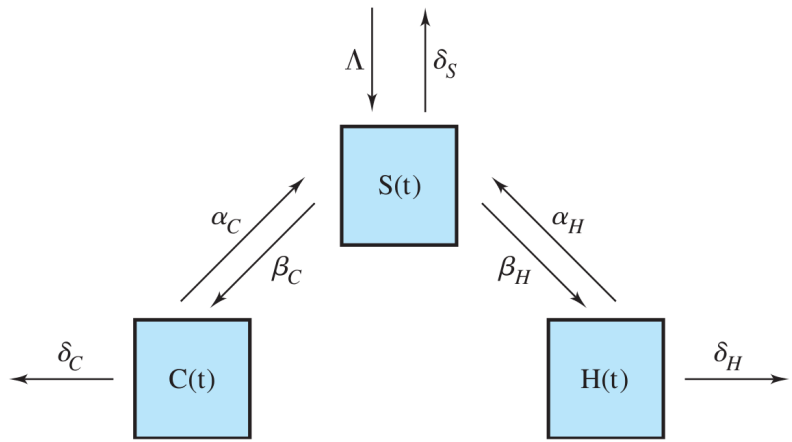

Figure: A diagram of how patients transit between the compartments

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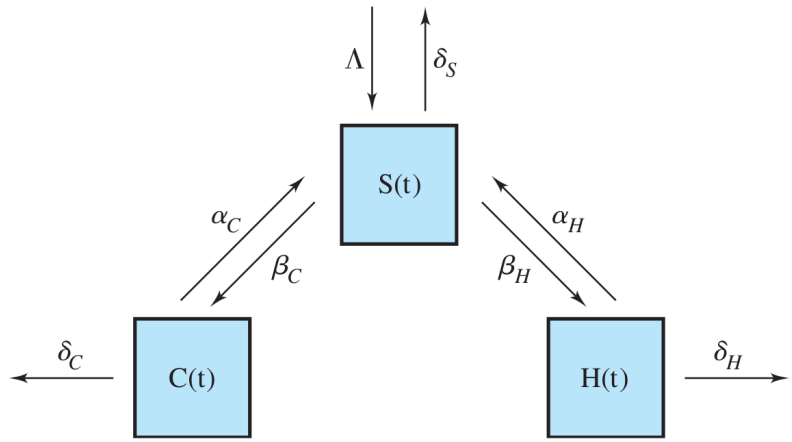

Figure: A diagram of how patients transit between the compartments

SIS (susceptible-infected-susceptible). Patients with no immunity.

Overview

Transition between states

$$\frac{dS}{dt} = \underbrace{\Lambda}_{\text{entrance rate}} - \underbrace{\frac{\beta_H S(t) H(t)}{N}}_{\text{acquire HA-MRSA}} - \underbrace{\frac{\beta_H S(t) C(t)}{N}}_{\text{acquire CA-MRSA}} +$$

$$\underbrace{\alpha_H H(t)}_{\text{HA-MRSA decolonized}} + \underbrace{\alpha_C C(t)}_{\text{CA-MRSA decolonized}} - \underbrace{\delta_S S(t)}_{\text{exit hospital}} \qquad (1)$$

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Transition between states

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Simplyfing our model

If we assume that the hospital is always full, we can conserve the system by letting $\Lambda = \delta_S S(t) + \delta_H h(t) + \delta_C C(t)$

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In this case $S(t) + C(t) + H(t) = N$ for all t (assuming you stat with population of size N)

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Overview

Explore

Parameter	Symbol	Baseline Value
Total nutients	N	400
Length of stay		
Susceptible	$1/\beta_S$	5 days
Colonized CA-MRSA	$1/\beta_C$	7 days
Colonized HA-MRSA	$1/\beta_H$	5 days
Transmission rate per susceptible patient to		
Colonized CA-MRSA per colonized CA-MRSA	β_C	0.45 per day
Colonized HA-MRSA per colonized HA-MRSA	β_H	0.4 per day
Decolonization rate per colonized patient per day per length of stay		
CA-MRSA	α_C	0.1 per day
HA-MRSA	α_H	0.1 per day

Table: Parameter values obtained from the Beth Israel Deaconess Medical Center

Critical Points

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$$\begin{cases} \frac{0.4H(400-H-C)}{400} - (\frac{1}{5} + 0.1)H = 0 \\ \frac{0.45y(400-H-C)}{400} - (\frac{1}{7} + 0.1)C = 0 \end{cases}$$

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$$\begin{cases} H = 0 & \mathrm{C} = 0 \\ H = 100 & \mathrm{C} = 0 \\ H = 0 & \mathrm{C} = 184.127 \end{cases}$$

Interpreting results

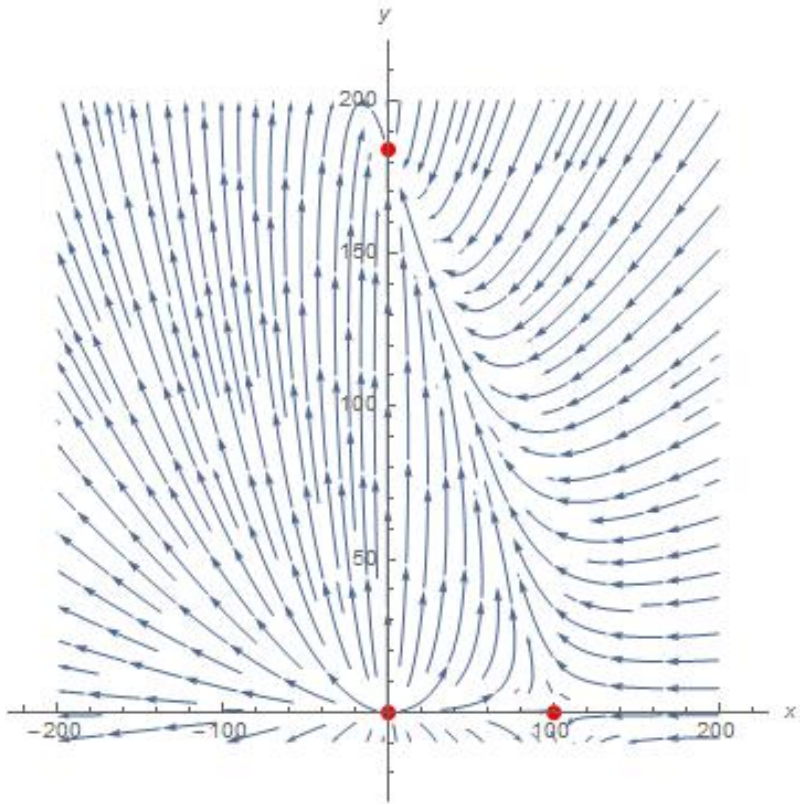

Figure: Direction field for the equation system

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We can see that we have an asymptotically stable point $\{H = 0, C = 184.127\}$. Based on the direction field, we can observe that this node it's also a spiral on.

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The other two nodes, $\{H = 0, C = 0\}$ and $\{H = 100, C = 0\}$ seems to be unstable points since all the arrows are getting away from them.

Given enough time, any point from this plane will converge to $\{H = 0, C = 184.127\}$, meaning that, using this model, CA-MRSA will overtake HA-MRSA.

Bibliograpy I


R.K. Nagle, E.B. Snaff, A.D. Sieder
Fundamentals of Differential Equations and Boundary Value Problems.
Addison-Wesley, 2012.


S. Balint, L. Braescu, E. Kaslik
Ordinary and Partial Differential Equations Lecture Notes
West University of Timisoara, 2006. 2000.