Modelling the Contact Propagation of Nosocomial Infection in Emergency Departments

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Abstract*-The nosocomial infection is a special kind of infection that is caused by microorganisms acquired inside a hospital. In the daily care process of an emergency department, the interactions between patients and sanitary staff create the environment for the transmission of such microorganisms. Rates of morbility and mortality due to nosocomial infections areimportant indicators of the quality of hospital work. In this research, we use Agent Based Modeling and Simulation techniques to build a model of Methicillin-resistant Staphylococcus Aureus propagation based on an Emergency Department Simulator which has been tested and validated previously. The model obtained will allow us to build a contact propagation simulator that enables the construction of virtual environments with theaim of analyzing how the prevention policies affect the rate of propagation of nosocomial infection*

INTRODUCTION

The nosocomial infection is a kind of infection that is caused by microorganisms acquired inside a health care environment [1]. It is the most common type of complication affecting hospitalized patients. Inside a health care environment we can find several microorganism that can be causative of a nosocomial infection, but our work has focused in the propagation of the Methicillin-resistant Staphylococcus Aureus (MRSA), one of the most common and dangerous microorganisms in this environment. The presence of these bacteria could mean serious health problems for a patient. It is a common cause of skin, wound and blood stream infections as it may be responsible for a greater hospital length of stay, expensive treatments and an increased mortality [2]. These bacteria live in the skin of some patients and could be transmitted to another patient by physical contact through the interaction between patients, healthcare staff and environment. The most common transmission vias are: healthcare staff's hands, contaminated medical equipment and objects in the hospital room environment. We use Agent Based Modeling and Simulation techniques to build the model and the simulator of Methicillin-resistant Staphylococcus Aureus contact propagation in emergency departments. The simulator allows us to build virtual scenarios to understand the phenomenon of the propagation and the potential impact of the implementation of prevention policies on propagation

Conceptual Model of MRSA Transmission

The model proposed in our research has the advantage of being developed based on a previous emergency department model and previous emergency simulator, both of which have been developed as part of previous research works [3][13] carried out with the collaboration of healthcare staff at the Emergency Department of Hospital Universitari Parc Taulí. This previous model used ABMS techniques to define the full attention process of an emergency department. In our research, we make use of an Agent Based Model and Simulation (ABMS) to create a contact transmission model of MRSA inside an emergency department. For this purpose, we defined all actors involved in the emergency department process and their specific function and behavior. Every person who has a role in the emergency department is defined as an active agent in our model. The environment objects and equipment are representing as passive agents.

Transmission Forms: There are two forms of contact transmission, direct transmission and indirect transmission.

1) Direct transmission: When MRSA bacteria are transmitted from an active agent (transmission vector) to another active agent (susceptible agent). For instance, when an infected/contaminated patient is touched by a member of healthcare staff without a physical barrier.

2) Indirect transmission: When an active agent (transmission vector) touches medical equipment or objects in the hospital environment and MRSA bacteria is transmitted to the object, later, a susceptible agent (patient or healthcare staff) has contact with the same object and acquires the microorganism.

TABLE I
POSSIBLE WAYS OF TRANSMISSION

Agent 1	Agent 2
Carrier healthcare staff	Susceptible patient
Carrier healthcare staff	Passive agent
Infected/colonized patient	Passive agent
Infected/colonized patient	Healthcare staff
Passive agent	Passive agent
Passive agent	Healthcare staff
Passive agent	Susceptible patient

Agents and Behaviors: In our research, we make use of an Agent Based Model and Simulation (ABMS) to create a contact propagation model of MRSA inside an emergency department. For this purpose, we defined all actors involved in the emergency department process and their specific function and behavior.

1) *Active Agents:* Every person who has a role in the emergency department is defined as an active agent in our model: patients, doctors, nurses, admission staff, laboratory technicians, auxiliary personnel and cleaning staff (Fig. 1). For the purpose of our propagation model we divided active agents in two sets: Patient and Healthcare Staff. It is necessary to make this classification because each group can take a different infectious status. We classified patients, according their infectious status in non-colonized, colonized or infected. All non-colonized patients are susceptible to acquiring MRSA, but some of them could be more susceptible than others, such as patients with open wounds, external devices among other reasons. Colonized patients have MRSA bacteria but they do not show symptoms, and infected patients have MRSA bacteria and show symptoms. Healthcare Staff has three possible infect status: non-carrier, carrier and colonized. The carrier status is a temporary colonized.

In an attempt to control MRSA transmission rate, some concrete actions are performed in ED such as hand washing, hand disinfection and the use of isolation material, all of which are called Prevention Policies. Only the Healthcare Staff agents can be perform these prevention policies.

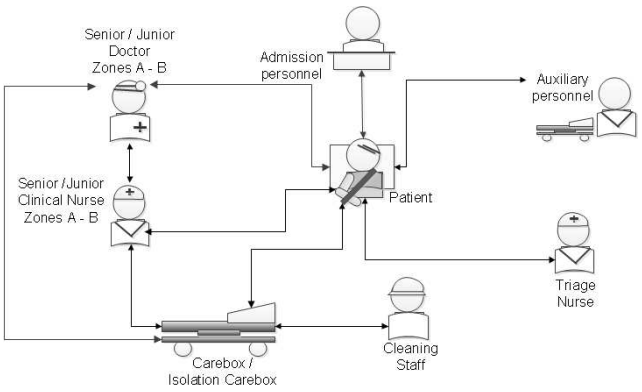

Fig. 1. General Diagram of Physical Contact.

2) *Passive Agents:* It is very important to take into account the environmental objects that healthcare staff use in the process of attention patient because the MRSA bacteria can be transmitted when an active agent touch a contaminated surface. For our purpose, we created the passive agent "Carebox" in order to represent all the environmental objects and equipment that can be in contact with the active agents. We use the infected variable to reflect whether a carebox is contaminated with MRSA or not. The possible value for infected variable are: non-contaminated or contaminated. When an MRSA patient is assigned to a carebox, the infected variable takes the value contaminated, and it will remain at such a value until a disinfection process has been carried out by cleaning staff.

TRANSMISSION MODEL

Frequent interaction between patients and healthcare staff is the principal way to MRSA transmission. Whenever an interaction between agents is given, we consider an MRSA transmission is likely. However, there is a wide variety of factors that will determine if the transmission has a direct impact on the infectious status of the susceptible agent and change it from non-carrier or non-colonized, to carrier, colonized, infected or whether in contrast, the bacteria are removed and the infectious status of the susceptible agent will not change. Our model considers in each interaction the susceptibility of the agent who is at risk of acquiring MRSA. If the agent at risk is a patient, the analysis is based on the health state of the patient (predisposition, infected status), but if the agent at risk is a member of the healthcare staff, the analysis takes in account other values such as accomplishment and effectiveness of prevention policies (hands wash, disinfection hands, etc.). The model takes into account the parts of the overall attention process in which the agents interact with each other, because the contact propagation can take place in these moments. Whenever the healthcare agent finishes an attention task, they may or may not apply the prevention policies: hand washing, hand disinfection or using isolated material. The action that is executed can be effective or not.

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