A Collaborative Visualization Tool to Support Doctors' Shared Decision-Making on Antibiotic Prescription

Weina Jin, M.D.
School of Interactive Arts and Technology
Simon Fraser University
Surrey, BC, Canada
weinaj@sfu.ca

Diane Gromala, Ph.D.
School of Interactive Arts and Technology
Simon Fraser University
Surrey, BC, Canada
gromala@sfu.ca

Carman Neustaedter, Ph.D.
School of Interactive Arts and Technology
Simon Fraser University
Surrey, BC, Canada
carman@sfu.ca

Xin Tong, M.Sc.
School of Interactive Arts and Technology
Simon Fraser University
Surrey, BC, Canada
xintongt@sfu.ca

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Abstract

The inappropriate prescription of antibiotics may cause severe medical outcomes such as antibiotic resistance. To prevent such situations and facilitate appropriate antibiotic prescribing, we designed and developed an asynchronous collaborative visual analytics tool. It visualizes the antibiotics' coverage spectrum that allows users choose the most appropriate antibiotics. The asynchronous collaboration around visualization mimics the actual collaboration scenarios in clinical settings, and provides supportive information during physician's decision-making process. Our work contributes to the CSCW community by providing a design prototype to support asynchronous collaboration among healthcare professionals, which is crucial but lacks in many of the present clinical decision support systems.

Author Keywords

Information Visualization; Asynchronous Collaboration; Clinical Decision Support.

ACM Classification Keywords

H.5.2 [Information Interfaces and Presentation]: User Interfaces; H.5.3 [Information interfaces and presentation]: Group and Organization Interfaces

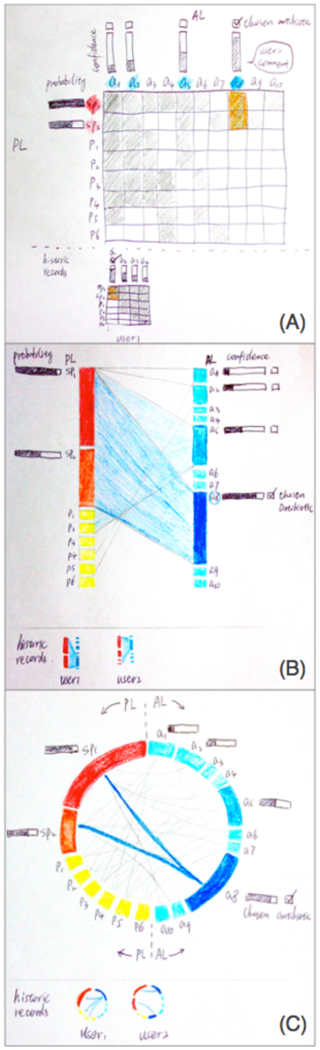

Figure 1: Three visualization models: **(A)** Matrix; **(B)** Bipartite; **(C)** Circular Connection.

Introduction

Antibiotics are some of the most commonly, yet injudiciously prescribed medications worldwide. Inappropriate use of antibiotics can result in unnecessary medication of patients, adverse drug events, increase in healthcare cost and the development of antibiotic resistance [1]. Therefore, the prescription of antibiotics needs to be optimized.

This research aims at designing an intuitive user interface to provide information during physicians' antibiotic decision-making process. While designing such system, visual presentation is considered as a valuable tool for quick access to comprehensive information [2]. Moreover, the clinical hypothesis formation and decision-making are collaborative processes and seldom carried out by a single person. Based on these considerations, we focus on designing a visual analytics tool that supports doctors' asynchronous, distributed collaboration on antibiotic choices. It could visualize the spectrum of antibiotic for target pathogens, and the knowledge generated from the system is shared among users.

Related Work

Several researches engaged in designing clinical decision support system (CDSS) on antibiotic choices. Forsman et al. [2] designed an interactive CDSS which contained a holistic overview that summarizes the crucial information for antibiotic choices. Another system called "ADVISE" focused on antibiotic usage in Intensive Care Unit [6]. The user selected actual or potential pathogens and compared these to one or many potential antibiotics, so that an overall antibacterial coverage pattern could be visualized. Despite these related work, few systems incorporated the collaborative functionality. Moreover, since the above-mentioned systems were built upon hospital information system, it is complicated to achieve knowledge accumulation and shared decision-making for a larger group of doctors outside the particular hospital where the system was implanted.

Design Rationale

Before designing the prototype, we examined the traditional sensemaking process of physicians during their choices of antibiotics. For a patient with suspected infection, doctors often come up with several suspect pathogens after gathering enough information from the patient. Then doctors select antibiotics based on the suspect pathogens and the patient's personalized information. To achieve the optimal selection of antibiotics, doctors usually refer to previous experience, search pharmaceutical databases, or discuss with colleagues. Such search process may not be comprehensive, and physicians may miss the optimal drug. In addition, doctors may not have a clear idea about the antibiotic coverage spectrum, which may lead to overprescribing that pose a risk to antibiotic resistance [4]. Such problem is more prominent when determining the combination antibiotic therapy which involves two or more antibiotics for complex infection.

To solve the clinical gap, we designed the system which is similar to a visualized drug manual. It visualizes the coverage spectrum of each candidate antibiotic. The spectrum of an antibiotic is defined as the pathogens covered in its indication. The collaborative function allows users to refer to other physicians' knowledge and experience. It shows the previous decision patterns of other users who shared their decisions on treating the same suspect pathogens.

The System Design

Visualization of Antibiotic Coverage Spectrum

We iterated the design firstly by drawing several possible visualization models based on the data relationship. Since both the pathogen and antibiotics variables have one-to-

Figure 2: The implementation of matrix model.

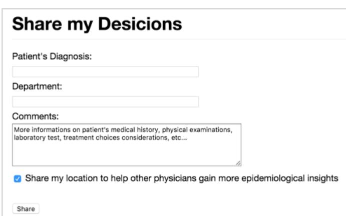

Figure 3: The present user can choose to share his/her treatment decision with other doctors to facilitate future collaboration.

many relationship, we focused on three candidate visualization models: matrix (Figure 1A), bipartite (Figure 1B), and circular connection graph (Figure 1C). After sketching and analyzing each model, the matrix model was chosen as the fittest one for the problem, since it provides more information on the spectrum as well as enables multiple antibiotics comparison.

A web application prototype was developed based on the matrix model. After the user searched or selected the *suspect pathogens* (SP), the system will create three data files from the database. The database is mined from FDA label database [5] and cleaned with Python 3.5 in advance. The system then generates a matrix visualization based on the curated data files. The rows repent *antibiotic list* (AL), which contains all the possible antibiotics that include one or more suspect pathogens in its indication. The columns represent *pathogen list* (PL), which includes all the pathogens that are covered in the indication of each antibiotic in *antibiotic list*. Each grid is filled with color if its corresponding pathogen is included in the indication of the corresponding antibiotic (Figure 2).

Asynchronous Collaboration

To enable shared decision-making, users can mark on the visualization and leave comments. The users make personal marks on the main visualization indicating how likely they will choose a particular antibiotic. This is achieved by adjusting the slider of each antibiotic in the row. The corresponding row that shows the pathogen coverage spectrum will be highlighted accordingly by increasing the opacity of the filled color. The antibiotics with the highest likelihood are the user's final decision.

The present user can share his/her decision-making thoughts to facilitate future collaboration for other users (Figure 3). In the "Share my Decisions" part, which locates in the bottom of the page, the user can fill in additional information related to the treatment decision s/he made for this case. The additional text comments will be shared along with the user's present visualization state. The view sharing is fundamental when collaborating with visualization, since users need to see the same visual environment in order to ground each others' actions and comments [3].

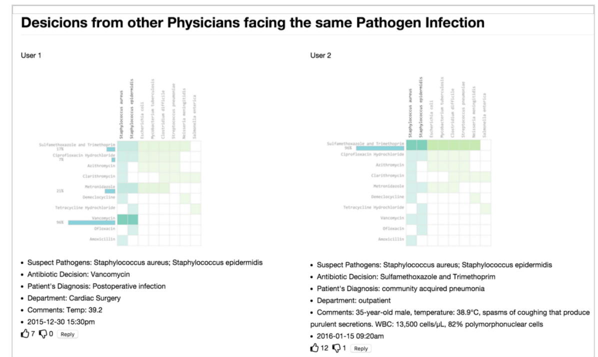

Figure 4: The view sharing from previous users who dealt with the same pathogen infection case. The asynchronous collaboration shows the visualization state and their comments.

During the decision-making process, the tool provides awareness of previous users' decision, which allows the present user refers to previous user's choices who faced similar cases. Below the main visualization, users can find the visualized decision patterns from previous cases which had one or more the same *suspect pathogens* with the present case. This asynchronous collaboration mimics the knowledge and experience consultant process during the clinical decision-making. Clinicians usually refer to other physicians' knowledge and experience when they are unsure about the choices. The collaborative function

Usage Scenario

Dr. Adam is a family doctor. He is treating a 32-year-old man with skin infection, whose body temperature is 38.5°C. He suspects that the infection is probably caused by *Staphylococcus aureus*. However, the patient is allergic to penicillin, the most commonly used antibiotic for such infection.

Therefore, Dr. Adam uses the system to check if there is any other antibiotic that fits this case. The system visualized 15 antibiotics that can target the suspect bacteria. Dr. Adam notices below the main visualization, in the collaboration part, a previous user dealt with the similar case before, and it chose cefazolin.

Inspired by that, Dr. Adam finally makes his treatment decision, and shares his opinion within the community. Dr. Adam also clicks the "thumb up" button, as he adopts the decision opinion from this user.

is achieved by allowing the present user refer back to what antibiotics the previous physicians chose when they were dealing with similar cases. Previous users may leave additional information for further users to refer to, such as patient's diagnosis, crucial data of physical examinations and laboratory tests, treatment considerations, etc. (Figure 4).

The decision sharing is a start for further discussion. The present user can click the "reply" button below each users' visualization pattern, to start a discussion, or ask for further information. The system will send an email notification to the previous user about the new reply. This function also services as the support of awareness in collaboration. Another function to facilitate asynchronous collaboration with visualization is the "vote" button. The present user can vote for or against the treatment opinion from previous users by clicking the "thumb up/down" button.

Conclusion

In this paper, we presented a system that facilitates physicians' sensemaking process while they are selecting antibiotics for patients with infection. This system visualizes the antibiotics' coverage spectrum that allows users choose the most proper antibiotics. The asynchronous collaboration around visualization mimics the actual collaboration scenarios in clinical settings, and provides supportive information during the shared decision-making process. Our work contributes to the CSCW community by providing a design prototype to support asynchronous collaboration among healthcare professionals, which feature is crucial for decision-making process but lacks in the majority of present clinical decision support systems. Our system aims to avoid antibiotic misuse, and to prevent antibiotic resistance. Our further work includes strengthening the prototype to promote user engagement and collaboration among the professional community, and implementing strategies to protect user-generated information that may contain patients' medical information. A usability study with clinicians will also be conducted, to evaluate its potential as a clinical application.

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