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Design of a Visual Interface for Comparing Antibiotics Using Rainbow Boxes

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Abstract. Non-optimal prescriptions of antibiotics have a negative impact on patients and population. Clinical practice guidelines are not always followed by doctors because the rationale of the recommendations is not always clear and can be difficult to understand. In this paper, we propose a new approach consisting in presenting the properties of antibiotics for allowing doctors to compare them and choose the most appropriate one. For that, we used and extended rainbow boxes, a new technique for overlapping set visualization. We tested our approach on 11 clinical situations related to urinary infections, and assessed the simplicity, the interest and utility with 11 doctors. 10 of them found that this approach was interesting and useful in clinical practice. Further studies are needed to confirm this preliminary work.

Keywords. Antibiotic prescription, Clinical Decision Support System, Visual analytics, Usability

1. Introduction

Non-optimal prescriptions of antibiotics have a negative impact on patients (risk of complications) and population (risk of bacteria resistance). To help general practitioners (GPs) to prescribe the right antibiotic, national health authorities elaborate Clinical Practice Guidelines (CPGs) which are evidence-based document written by a group of experts [1]. To facilitate their use, they are implemented in CDSSs (Clinical Decision Support Systems) which display, for each clinical situation, the antibiotics recommended in CPGs [2]. However, GPs are reluctant to use such systems because they don't always understand the rationale of the recommendation [3].

Rather than displaying the recommendation of CPGs (e.g. "prescribe this drug"), we propose a new approach consisting in presenting information for allowing the comparison of the various possible therapeutic options (e.g. "drug A has a low efficacy, drug B has a risk of serious adverse effects"), and letting GPs make their own choice. In a previous work [4,5], we identified the 6 properties of antibiotics that were necessary for choosing the antibiotic during prescription for urinary infections, and we ordered them according to their degree of importance. We hypothesize that this information could

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be used by GPs to choose one antibiotic among all those which are indicated for the clinical situation.

Few studies have focused on the presentation and the visual comparison of drug properties, and all of them used simple tables. Examples include a spreadsheet-like tool for reviewing and authoring drug properties, and tables for comparing the contraindications and the adverse effects of a new drug to a reference drug [6]. However, these tables are often very big and don't provide a global overview.

In a recent work, we designed a new technique for overlapping set visualization [7], *rainbow boxes* [8], and we applied it to the comparison of drug properties (contraindications and adverse effects). Rainbow boxes display the element to be compared (*e.g.* drugs) in columns, and the sets (*e.g.* drug properties) in labelled rectangular boxes that cover all the columns corresponding to the elements in the set. Larger boxes are placed at the bottom and two boxes can be side-by-side as long as they do not cover the same columns. A box can have holes, if the elements in the set are not displayed in consecutive columns. We designed a heuristic algorithm to find a near-optimal column order minimizing the number of holes, in a satisfying time.

The aim of the study was to design a visual interface displaying antibiotic properties and their importance, by using and adapting rainbow boxes. This interface could then be implemented in a CDSS for empiric antibiotic prescription [9]. In this paper, we will first describe the methods we followed for constituting a knowledge base containing the properties of antibiotics, for extending rainbow boxes and for evaluating the system. Then we will present the resulting interface and evaluation results and conclude.

2. Materials and Methods

2.1. Constitution of a Knowledge Base Containing the Properties of Each Antibiotic

By analyzing CPGs, we noticed that the reasoning for finding the appropriate antibiotic was based on the progressive exclusion of the antibiotics with the most important disadvantages. Therefore, we considered the 6 antibiotic properties as 6 potential disadvantages: (disadvantage #1) the antibiotic has a moderate clinical efficacy, (#2) the administration protocol is not convenient, (#3) it promotes the emergence of bacteria resistance, (#4) it is associated with a risk of serious or frequent adverse effects, (#5) it has a broad activity spectrum, (#6) it belongs to a precious class to keep for more serious indications. For each clinical situation, and for each antibiotic, a disadvantage is a Boolean value (true: the disadvantage is present, false: it is absent).

An algorithm developed in a previous work [4,5] was improved with the help of 6 medical experts to order the disadvantages of antibiotics according to their degree of importance. Disadvantage #1 (limited efficacy) was ranked as the most important, then #2, then #3, then #4-5-6 (same rank for the three). This order was transformed into a score computation, by associating a weight W_1 with each disadvantage #1 (from #1 to #6) (See details in results section). For a given clinical situation and antibiotic, the score is the sum of W_1 for each disadvantage #1 that is present. Thus, the antibiotic with the lowest score should be preferred.

From CPGs, we extracted all the clinical situations related to urinary infections. For each of them, we built a knowledge base containing the Boolean values for the 6 disadvantages of all the antibiotics that could be prescribed. The knowledge base was structured as an OWL formal ontology of the *ALIF* family of description logics.

2.2. Extending Rainbow Boxes to Display the Weight of Disadvantages

We extended the original rainbow boxes to take into account the weight associated with each disadvantage: we fixed the height of the box for disadvantage #1 to a value proportional to its weight W_1 . Consequently, the score can be visually computed by summing the height of all boxes present in a given column. We coloured the boxes in red. In addition, the saturation of the colour was also proportional to the weight (*i.e.* more important disadvantages have brighter red colours). We named the resulting visualization technique *weighted* rainbow boxes.

The OwlReady module for ontology-oriented programming [10] was used for accessing the knowledge base and generating rainbow boxes.

2.3. Evaluation Methods

Two sets of rainbow boxes were shown to 11 GPs: one with few antibiotics, and one with many antibiotics to compare. For each, we asked them 5 questions related to the simplicity, interest and utility of the interface (graduated with a Likert scale), and one question concerning the antibiotic they would prescribe. We also asked them if they would like to have such a system in clinical practice.

3. Results

3.1. Presentation of the Visual Interface for Comparing Antibiotics

11 clinical situations related to urinary infections were implemented in the form of rainbow boxes. The weights of the disadvantages were chosen to have a lexicographic order between disadvantages #1, #2, #3 and the conjunction of #4, #5 and #6; and an equal weight between #4, #5 and #6, *i.e.* $W_1 > W_2 + W_3 + W_4 + W_5 + W_6$; $W_2 > W_3 + W_4 + W_5 + W_6$; $W_3 > W_4 + W_5 + W_6$ and $W_4 = W_5 = W_6$. A lexicographic order means that disadvantage #1 is considered first, then #2 is considered in case of equality for #1, and so on. We arbitrarily chose the following values, which satisfy the previous formula: $W_{\#1} = 16.0$, $W_{\#2} = 7.9$, $W_{\#3} = 3.8$, and $W_{\#4} = W_{\#5} = W_{\#6} = 1.0$.

Figure 1 shows the resulting weighted rainbow boxes for two clinical situations, with 5 and 10 antibiotics. Antibiotics are displayed in columns, with their classes in headers, and the 6 disadvantages in the boxes. Only one hole is present (in the bottom, for ceftriaxone and the adverse effect disadvantages). The visualization allows to visually sum the weights of the various disadvantages for each antibiotic, *i.e.* to compute the score, easily, despite the presence of holes and gaps between some boxes. It is also very easy to find visually the antibiotics with the fewest and less important disadvantages (*e.g.* nitrofurantoin, for the second clinical situation in Figure 1). Moreover, they correspond to antibiotics recommended in rank 1 in CPGs.

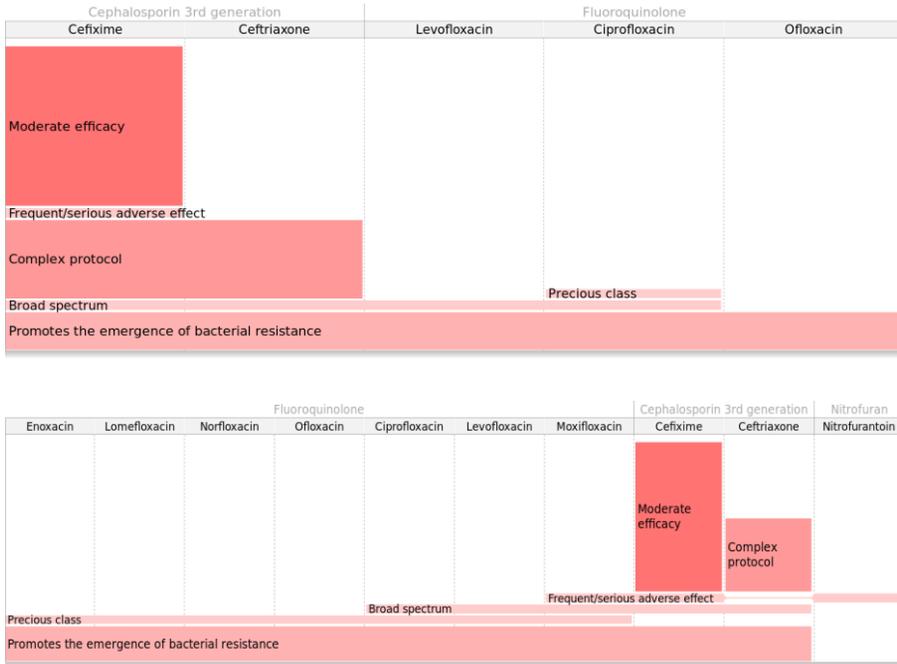


Figure 1. Weighted rainbow boxes showing the available antibiotics and their disadvantages in 2 clinical situations: pyelonephritis (top) and cystitis with risk of complication (bottom).

3.2. Evaluation Results

Rainbow boxes were perceived as easy for 64% of GPs in pyelonephritis, and 27.5% of GPs in cystitis. The reading of disadvantages looks easy for 73% of GPs in pyelonephritis and 64% of GPs in cystitis. About 90% of GPs found that the display of disadvantages of antibiotics could be interesting in clinical practice, and more than 91% of them found it could be useful in clinical practice. 5 GPs would like to have this system in clinical practice vs 3 who would not. In both clinical situations, 8 GPs prescribed the antibiotic with the fewest disadvantages displayed.

Table 1. Result of the evaluation. 11 GPs assessed two interfaces for cystitis and pyelonephritis

		Don't agree at all	Don't agree	Neutral	Agree	Fully agree
I find the interface easy	pyelonephritis	0	2	2	6	1
	cystitis	0	5	3	3	0
The disadvantages of each antibiotic are easy to read	pyelonephritis	0	2	1	6	2
	cystitis	0	2	2	6	1
I find interesting to visualize the disadvantages of antibiotics	pyelonephritis	0	0	1	4	6
	cystitis	0	0	1	5	5
It is useful to visualize the disadvantages of antibiotics in clinical practice	pyelonephritis	0	0	0	5	6
	cystitis	0	0	1	4	6
I would like to have this system in clinical practice		1	2	3	4	1

4. Discussion and Conclusion

Instead of displaying the recommendations of CPGs, we proposed a new approach consisting in comparing antibiotics according to their disadvantages, using rainbow boxes. Rainbow boxes were adapted to display the weight of each disadvantage. Although the rainbow boxes seemed to be more complex when the number of antibiotics is high, GPs still found the disadvantages easy to read. They also found that the comparison of antibiotics was interesting and useful.

Our approach allows GPs to choose the antibiotic to prescribe among all those able to treat the patient. It has several advantages. First, it allows GPs to adapt their prescription according to the patient profile [4] (*e.g.* if the most appropriate antibiotic cannot be given, then GP can choose a second one among those remaining). Second, the update of the system is facilitated, since the disadvantages could be updated from different resources (*e.g.* “protocol administration” from a drug database), instead of waiting many years for an updated version of the CPGs. Third, the use of weighted rainbow boxes allows GPs to see at a glance the antibiotic with the least disadvantages. Further studies are needed to confirm this preliminary work. Other types of infections (*e.g.* respiratory) should be tested. A broader evaluation with more GPs and with questions about the reasons why GPs would like to have a such system or not, needs to be conducted. The genericity of the approach to other domains beyond antibiotherapy, such as chronic disorders, needs also to be proven (other parameters (*e.g.* patient comorbidities) should probably be taken into account).

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