AntibioHelp®, an innovative clinical decision support system for improving antibiotic prescriptions in primary care

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Most antibiotic prescriptions occur in primary care settings[1] where prescribing can be difficult for several reasons. Firstly, prescriptions are often empirical, without identification of the causal agent. Physicians are also guided by bacterial resistance rates but they are continually changing and physicians may not be aware of these changes[2]. Finally, external factors, such as the physician's working conditions, patient expectations and financial pressures within the healthcare system, may also influence antibiotic prescription practices[3].

Physicians can use clinical practice guidelines (CPGs) to facilitate prescription[4]. CPGs are textual documents containing recommendations from a group of experts based on scientific evidence[5]. However, they are difficult to use in clinical practice because of their complexity (large amounts of ambiguous and heterogeneous text)[6]. Clinical decision support systems (CDSS) have been developed to make CPG use easier[7]. These systems implement CPGs in the form of "if/then" rules, *e.g. if (otitis) then (amoxicillin)*. However, their rates of adoption by physicians are low because[8]: (i) they provide recommendations for only a limited number of well-defined patient profiles, and physicians may find it difficult to extrapolate the recommendations to their own patients; (ii) they display only the conclusion of CPGs, not the underlying rationale, and this can undermine physician confidence in these systems; (iii) they are often difficult to use / navigate.

We designed a CDSS for primary care, AntibioHelp®, to overcome these shortcomings[9,10]. Navigation is based on usability principles[11] and the decision process used to treat patients with infectious diseases:

On page 1, the physician selects the disease and patient profile.

On page 2 (Figure 1), the physician can visualise the entire decision process in an "at-a-glance" interface. This interface, built according to a "space-filling approach" is divided into five areas[9]:

- The Treemap representation (top, left), presents the possible alternatives with recommended action(s) in intuitive colours. Red boxes lead to a display of the antibiotics, and their level of recommendation.
- The two areas below the main area are optional (they simply explain the decision variables used in the main area).
- Hospitalisation criteria (top, right) are shown with a graphical summary, Mister VCM[12] (e.g. a highlighted eye means that the patient should be hospitalised in case of ophthalmological problems). Detailed criteria can also be visualised.
- The area at the bottom right displays situations for which the recommendation cannot be applied.

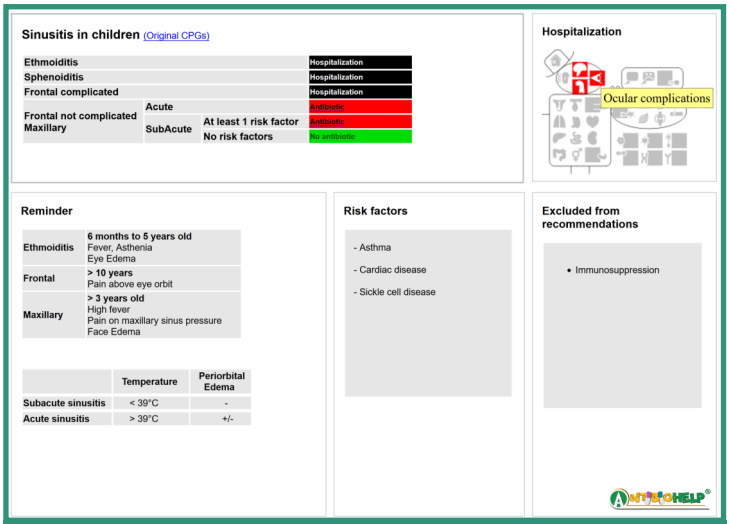

Figure 1: The at-a-glance interface. All clinical practice guidelines are implemented in this "at-a-glance" interface. For more details, see [9].

Page 3 (Figure 2) is displayed only if the recommended action chosen on page 2 is "antibiotic prescription". It displays both the recommended and non-recommended antibiotics, together with their properties, weighted by degree of importance[10]. The properties displayed are those used by the experts writing CPGs to determine which antibiotic to recommend[13]. This interface uses the "rainbow boxes" technique[14,15]. Antibiotics are displayed in columns, and properties in coloured rectangular boxes. Antibiotics are separated into two groups[10]:

- The antibiotics on the right (dark grey) should not be prescribed - they do not have the necessary properties in terms of efficacy or are contraindicated.
- The antibiotics on the left (light grey) can be prescribed. AntibioHelp® helps physicians choose the best one(s) by rating them and displaying their

properties. Advantageous properties are displayed in a green box (e.g. narrow spectrum). Disadvantageous properties are in an orange box (e.g. serious side effects). No box is displayed if the properties are unknown. Box height is proportional to the weight attributed by the experts in the CPGs as determined via artificial intelligence techniques[16]: a preference model was learnt with a metaheuristic algorithm[17] and applied to a knowledge base built from CPGs and the knowledge of antibiotic experts.

AntibioHelp® was assessed by physicians in two crossover studies[9,10]. Visualisation of weighted antibiotic properties helped physicians to extrapolate recommendations to patients for whom CPGs provided no explicit recommendations (41% decrease in error rate, *p*-value=$6x10^{-13}$). It also increased physician confidence in their prescriptions for these patients (+8%, *p*-value=0.02). The usability of AntibioHelp® was found to be excellent (System Usability Score = 81). Physicians particularly appreciated the rapidity of the response (< 3 interfaces displayed), the consistency of interfaces for all diseases, and the overview of the decision process in an "at-a-glance" interface.

AntibioHelp® could help to improve antibiotic prescriptions in primary care[18], by helping physicians to extrapolate recommendations for situations for which no recommendations exist in CPGs, through the visualisation of weighted antibiotic properties. It also increases GP confidence in the system, by displaying the entire decision process in an "at-a-glance" interface, together with the rationale underlying recommendations, and it can be easily and rapidly used by physicians.

In the future, AntibioHelp® will be connected to electronic health records and updated automatically through external resources, such as microbiological observatories, and drug databases. This automatic updating will inform physicians of advances in medical knowledge in real time (e.g. physicians could be alerted, in real time, of changes in bacterial resistance, by a red box for the property "bacterial resistance"). A randomised controlled trial[19] will also be conducted, to assess the impact of AntibioHelp® on antibiotic prescription quality and bacterial resistance.

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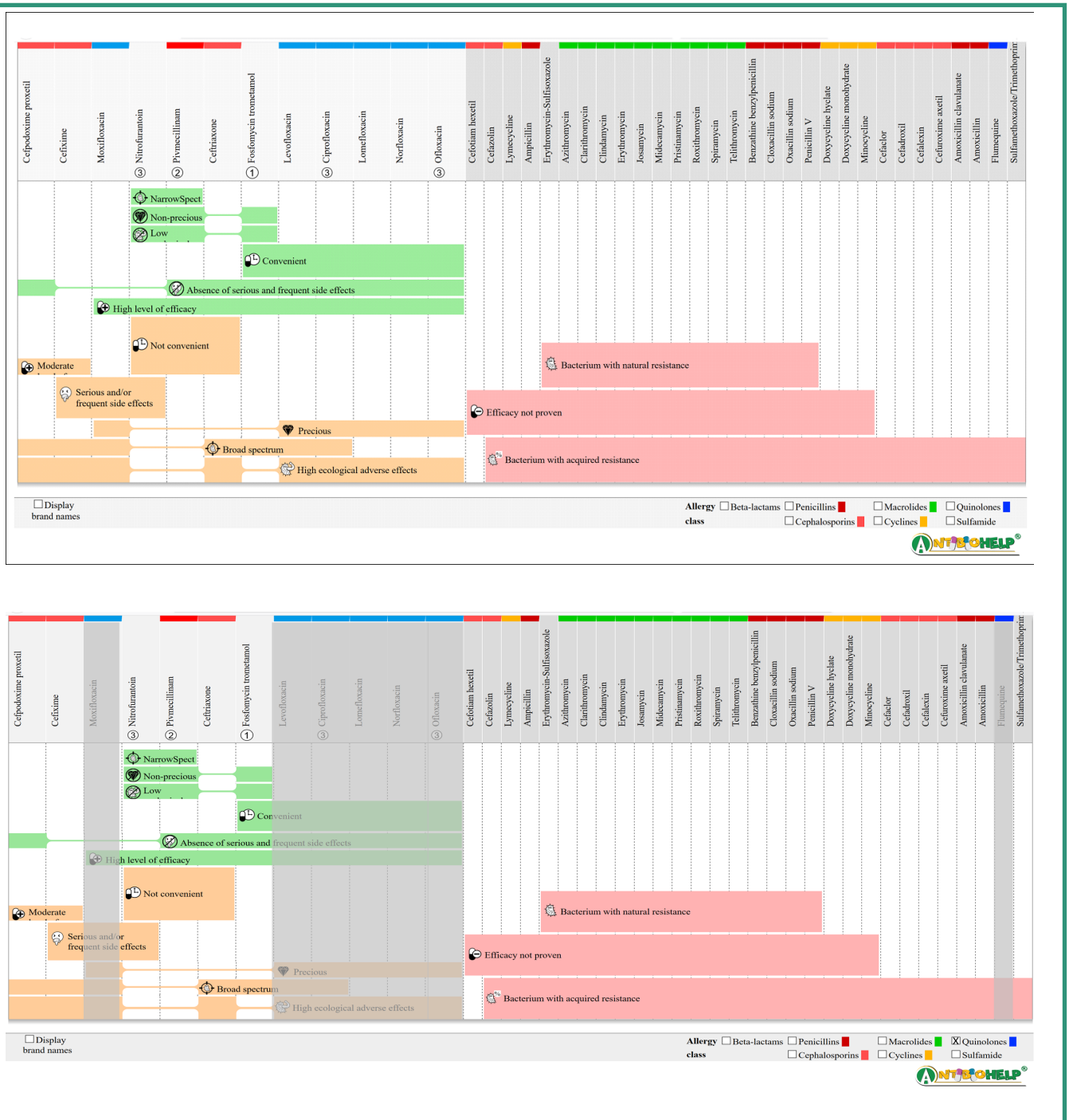

Figure 2: Example of uncomplicated cystitis in a woman. In this case, the 12 antibiotics located on the left (light grey) can be prescribed. At a glance, we can see that one of them, fosfomycin trometamol, has the greatest total height of green boxes and the smallest total height of orange boxes. This antibiotic is therefore the most appropriate in this case. In the column header, we can see that this is the antibiotic recommended in rank 1 in the clinical practice guidelines.
This interface can also be used for extrapolating recommendations to patients for whom CPG recommendations do not apply, *e.g. for women with uncomplicated cystitis and a recent history of fluoroquinolone treatment*. In such cases, the physician can tick the checkboxes at the bottom of the screen to grey out the antibiotics from classes that cannot be prescribed (in this case, quinolones). The physician can then see, at a glance, that there are six antibiotics with the necessary properties, including fosfomycin trometamol, which remains the most appropriate. See [10] for more details.