# A Mobile Application System for Diagnosis and Management of Community-Acquired Pneumonia

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***Abstract*—The Community-Acquired Pneumonia (CAP) is a disease frequently detected in hospitals demanding suitable treatment. From a medical perspective, handling high amount of variables needed for CAP's diagnosis process is a problem due to the significant number of patients in nowadays hospitals and the difficulty of a physician to apply the knowledge in real-time for each patient what leads to delays and imprecisions in diagnosis. Thus, quick and precise diagnosis, besides medical penetration in hospital environment are important factors to deal with the CAP's diagnosis process problem. This paper presents a mobile application system for diagnosis and management of community-acquired pneumonia so as to solve the CAP's diagnosis process problem. As proof of concept, our system was deployed on a high circulation public hospital. Experimentation qualitative results reveal that it increases the speediness and precision in diagnosis, besides the applications' penetration in hospital environment.**

***Keywords*—Community-Acquired Pneumonia, Diagnosis, Treatment, Mobile Application, iOS.**

## I. Introduction

Despite advances in medicine and technology, there are still common infectious disease syndromes of high morbidity and mortality worldwide [1] [2]. The Community-Acquired Pneumonia (CAP) is the leading cause of death from infectious disease in the U.S. It is estimated that more than 900,000 cases of community-acquired pneumonia occur each year in people over 65 age in the U.S. with 600,000 hospitalizations [3] [4] [5] [6]. Moreover, the economic burden for treating patients with CAP is on the order of $ 4.8 billion per year [7]. On the other hand, in Brazil, it was the fourth leading cause of overall death in 2005 with 24,756 deaths, and in 2007 there were 47,661 hospitalizations only in the state of Rio Grande do Sul [1].

In clinical practice, the physicians specify internal guidelines to manage the CAP in their hospitals [8]. These guidelines are complex documents that specify rules that are used to stratify patients and then get the diagnosis and treatment for CAP. Generally, these guidelines present algorithm decisions at different levels, tables containing therapy for specific pathogens, treatment recommendations, tables quantifying the index of severity of pneumonia, tables of demographic factors, findings on physical examination of the patient and many others. Therefore, managing all information required for the diagnosis and treatment of CAP—quickly and accurately—is a challenge for physicians, specially for beginner physicians.

In this paper, we present a mobile application system for diagnosis and management of CAP. Our specialist system supports experienced and beginner physicians to deal with a high amount of variables and take a quick and precise diagnosis based on rules described by the internal guidelines previously established by hospital physicians. Our system was implemented and deployed on the *Hospital Nossa Senhora da Conceição* (HNSC), placed in Porto Alegre city, Brazil. Experimentation results indicate the system increases the speediness and precision in diagnosis task, as well as the applications' penetration in such hospital.

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To the best of our knowledge, the system presented in this work is pioneer to contribute to CAP diagnosis quickly and precisely using a mobile technology. Neither specialized scientific literature nor health care industry present similar system.

The rest of this paper is organized as follows. The materials and methods are described in details in Section II. Section III describes and discusses the experimental results achieved. Finally, in Section IV, the conclusions of this work are presented.

## II. Materials and Methods

So as to facilitate the understanding, this section will be separated into two stages. In the first stage, we discuss the rules specified by the HNSC internal guideline for the CAP management. In the second stage, the mobile application developed will be presented. This application aims at automating the internal control guidelines of CAP previously presented, and all its technology will be discussed.

### A. Stage A: Rules for the management of CAP

Firstly, in order to stratify the severity of CAP, the sum of the severity indexes presented in Table I is calculated [1]. Table I assesses 20 variables related to different patient characteristics such as demographic variables, comorbidities, physical examination findings and laboratory and radiological findings variables. Thus, when a particular patient's condition is equal to a variable specified in the Table I, the weight of that variable (column 2 of Table I) is added to the sum.

With the value of the sum from the use of Table I, it is possible to categorize patients into five risk groups as described in Table II. The first category refers to patients who achieved a maximum of 69 points. In this category the risk of death is 0.4% and the suggested treatment is outpatient. In category II the risk of death is 0.7%, the treatment is outpatient and refers to patients who have reached 70 points. In category III, patients who achieved between 71 and 90 points are allocated. This category contains 2.8% risk of death and the suggested treatment is the brief hospitalization. In Category IV treatment is hospitalization and the risk of death is 8.5%. In addition, this category belongs to the patients who achieved between 91 and 130 points. Finally, the category V belongs to the patients who reached more than 130 points. The treatment of patients in this category is hospitalization and the risk of death is 31.1%.

TABLE I. Community-acquired pneumonia severity index [1]

| Feature | Points |
|---|---|
| **Demographic factors** | |
| Age in years (for men) | age |
| Age in years (for women) | age - 10 |
| Nursing home resident | +10 |
| **Comorbid conditions** | |
| Neoplasia | +30 |
| Chronic liver disease | +20 |
| Congestive Heart Failure | +10 |
| Cerebrovascular disease | +10 |
| Renal desease | +10 |
| **Physical examination** | |
| Altered mental status | +20 |
| Respiratory rate $\geq$ 30 mpm | +20 |
| Blood pressure $<$ 90 mmHg | +20 |
| Temperature $<$ 35 °C or $>$ 40 °C | +15 |
| Pulse $\geq$ 125 bpm | +10 |
| **Laboratory and radiographic findings** | |
| Arterial pH $<$ 7,35 | +30 |
| Urea $>$ 10,7mmol/L | +20 |
| Sodium $<$ 130 mmol/L | +20 |
| Glucose $\geq$ 250 mg/dl | +10 |
| Hematocrit $<$ 30 % | +10 |
| $PaO_2$ $<$ 60 mmHg | +10 |
| Pleural effusion | +10 |

TABLE II. The five risk groups for patients with Community-Acquired Pneumonia [1]

| Risk Group | Sum of the total points | Fatality rate | Suggested Treatment |
|---|---|---|---|
| I | - | 0,4% | Outpatient treatment |
| II | =70 | 0,7% | Outpatient treatment |
| III | 71-90 | 2,8% | Brief hospitalization |
| IV | 91-130 | 8,5% | Hospitalization |
| V | >130 | 31,1% | Hospitalization |

If the suggested treatment requires some type of hospitalization or not, the treatment algorithm shown in Fig. 1 should be followed. This algorithm has five levels and briefly describes the antibiotic therapy according to the different situations of the patient. This algorithm was developed by an internal team of the HNSC and it is sufficiently clear. For example, if the patient does not require hospital

treatment and presents no risk to specific germs, would be indicated as primary therapy Ampicillin or amoxicillin $+/-$ macrolide. On the other hand, if the patient requires hospital treatment will be necessary to determine if there is still the need for treatment in the intensive care unit before concluding about the therapy to be applied.

As shown in Algorithm illustrated by Fig. 1, several decisions depend on knowledge regarding the pathogen of risk. In this context, Table III shows the etiology used for the treatment of CAP. In this Table, the pathogen of risk and the risk factors are clearly presented. It should be observed in Table III that the antibiotic therapy was omitted but is clearly presented to health professionals through the mobile application only.

TABLE III. TREATMENT OF COMMUNITY-ACQUIRED PNEUMONIA ACCORDING TO THE ETIOLOGY [1].

| Pathogen of Risk | Risk Factors |
|---|---|
| Pneumococcus | pathogen number 1, without the need for specific risk factors. |
| Penicillin-resistant pneumococci | use of $\beta$-lactam antibiotics in the last three months, immunosuppressive disease, corticosteroid use and age over 65 years in some studies. |
| Hemophilus influenzae | extreme ages, disease that causes changes to the structure of the lung parenchyma. |
| Hemophilus influenzae (ampicillin resistant) | Previous use of $\beta$-lactam antibiotics in the last three months. |
| Enterobacteria | individuals living in institutions, cardio-pulmonary disease, multiple medical comorbidities, alcoholism, recent use of antibiotics. |
| Pseudomonas aeruginosa | structural Lung Disease, prolonged corticosteroid therapy, malnutrition, use of broad-spectrum antibiotic. |
| Anaerobes | septic teeth, neurological disease, altered consciousness, alcoholism, swallowing disorders, neoplasia causing airway obstruction. |
| Staphylococcus aureus | drug addiction, structural Lung Disease. |
| Legionella pneumophila | contaminated water. |
| Chlamydia psittacci | contact with birds. |
| Mycoplasma pneumoniae | associated with microepidemics, mostly, family affecting more children, adolescents and young adults. |
| Virus | history of contact. |

### *B. Stage B: The proposed mobile application system*

Currently, this paper describes the first version of the proposed mobile application system which was written in the Objective-C language using a development approach called Model View Controller (MVC). The application was implemented to run on the iOS platform, more specifically under iPhone type devices. In addition, we used the Xcode 5.0.2 programming environment for the overall development of the application. As shown in Fig. 2, six graphical user interfaces were designed. Among these graphical interfaces, three of these correspond to access menus and other three correspond respectively to the core functionality of the application, namely: 1) a graphical user interface for the risk stratification of pneumonia, 2) a graphical interface for the algorithm treatment; 3) a graphical interface to the treatment according to etiology. In addition, the arrows represent the transitions between the different graphical user interfaces, i.e., navigability between the graphical interfaces that the user can do while using the mobile application.

We will focus on the three main interfaces of the mobile application. For example, Fig. 3 shows the results obtained for the risk stratification of CAP in a hypothetical patient who displays only the items glucose and pleural effusion enabled. In this simple example, the total score was equal to twenty points and therefore lethality resulted in only 0.4%. As a result, the suggestion was only outpatient treatment. It is important to note that the graphical user interface of the application was developed using the Portuguese language only.

Fig. 4 illustrates a graphical user interface that implements the algorithm for the treatment of pneumonia. This Figure illustrates the situation of a hypothetical patient who presents the following conditions: 1) requires hospital treatment, 2) does not require intensive care unit, 3) presents risk for specific germs. As a result, the mobile application automatically displays on the screen that treatment occurs as the pathogen of risk.

Finally, Fig. 5 illustrates a graphical user interface used to aid in the treatment according to etiology. In this interface, all pathogens are displayed as a list. When the user presses a finger on one of these

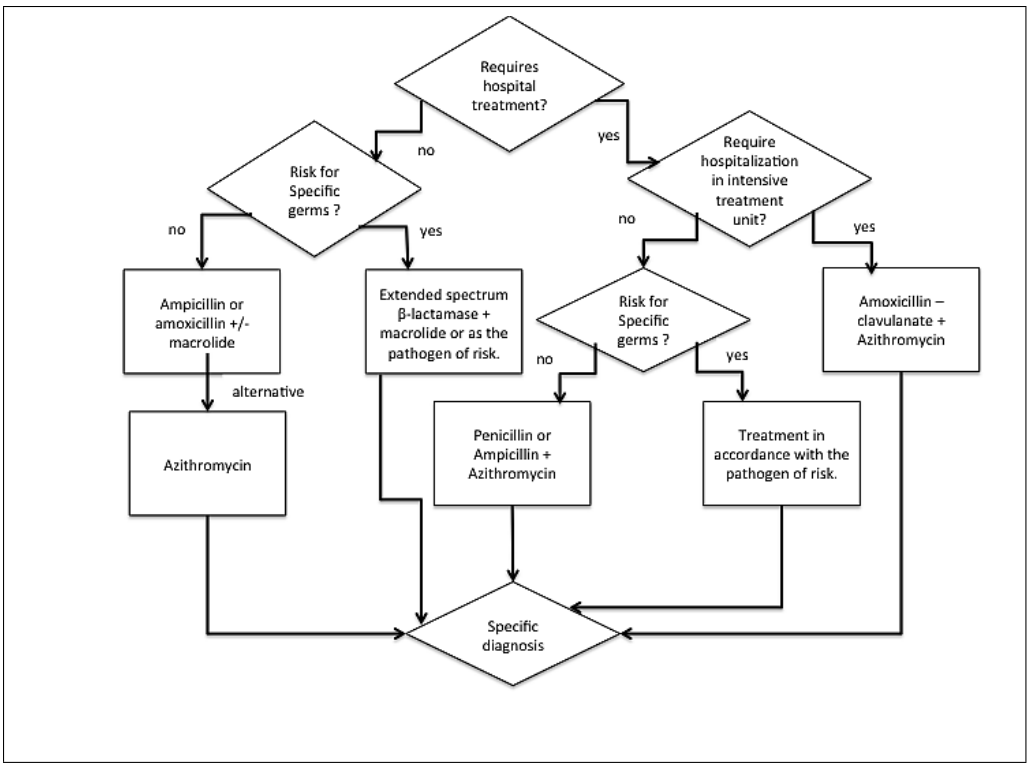


Fig. 1. Summarized algorithm for the treatment of CAP [1].

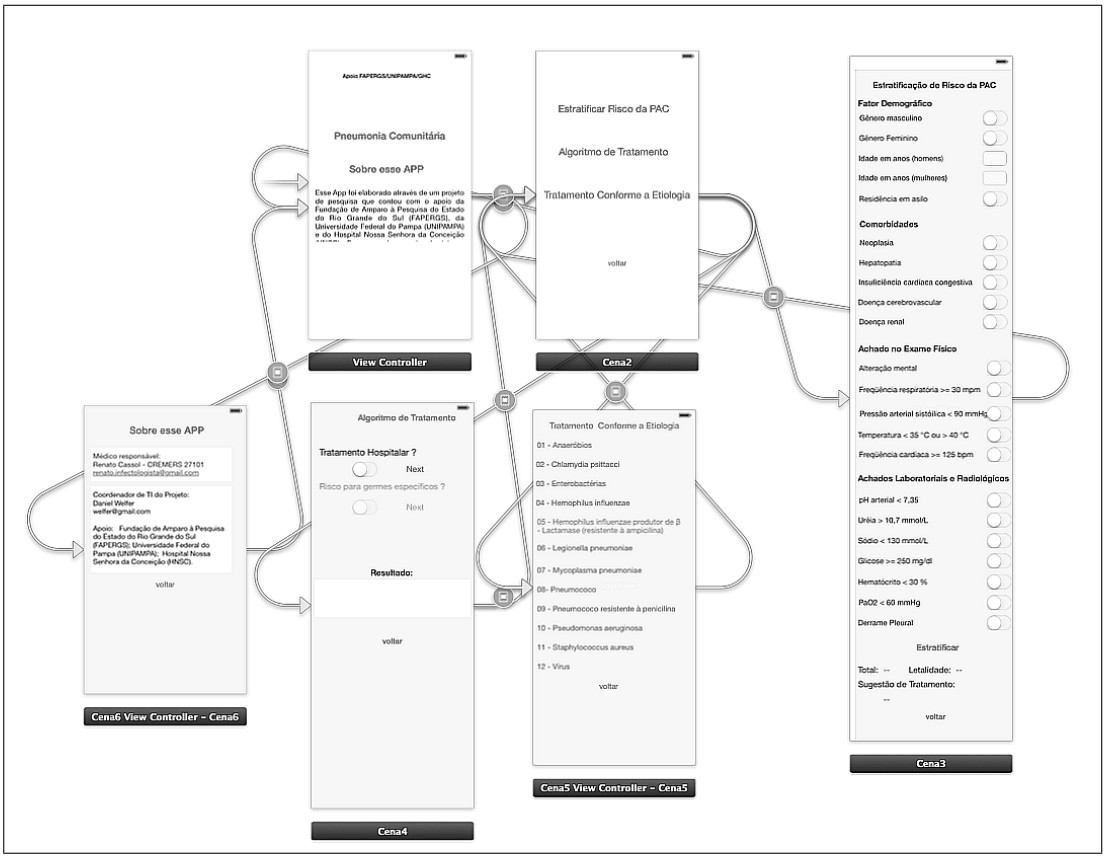


Fig. 2. All graphic user interfaces that were developed for the proposed mobile application.

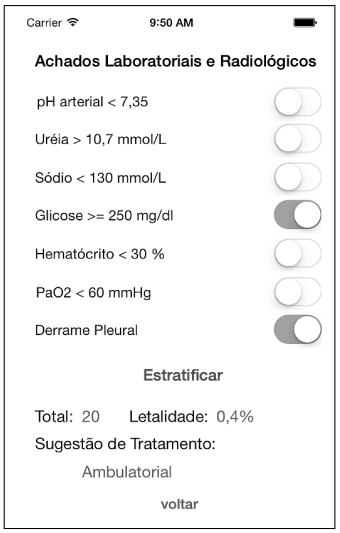


Fig. 3. Graphical user interface showing the stratification of the risk of CAP.


Fig. 4. Graphical user interface showing the algorithm for the treatment of CAP.

pathogens from the list, a new window opens where the risk factors and treatment are clearly presented.

## III. Experimental Results

Our results are preliminary, qualitative and were obtained using as a parameter the physician responsible for the hospital infection control at the HNSC in Porto Alegre city. To better understand the impact of using the mobile application, a methodology based on questions/answers was adopted, as follows.

**Question 01:** Using the mobile application would speed up the treatment of patients with infectious syndromes?

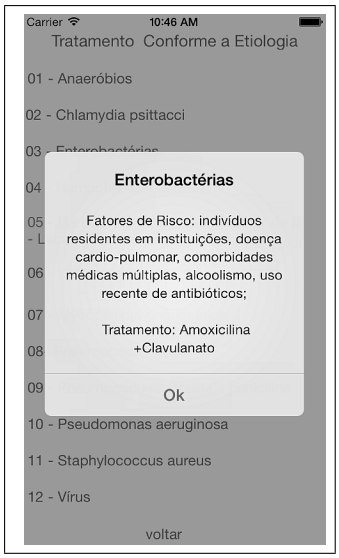


Fig. 5. Graphical user interface showing the treatment according to etiology.

*"Yes, the mobile application speeds up and mostly adjusts the antibiotic therapy with the internal protocols of the HNSC."*

**Question 02:** The use of the mobile application can avoid errors when prescribing a treatment or medicine?

*"The mobile application avoids prescribing a drug that has no activity against the causative agent decreasing hospital mortality and adding quality medical care in HNSC. One patient correctly treated for an infection has improved outcome and early hospital discharge."*

**Question 03:** The use of the mobile application can help in controlling the hospital infection?

*"The mobile application helps the hospital infection control since antimicrobials are those recommended by the Center for Infection Control and those that induce fewer and resistance mechanisms of bacterial resistance."*

**Question 04:** The developed application can be used for training of health professionals who have not yet mastered the treatment protocols for various infectious diseases. Thus, the developed software can be viewed as a mechanism for educational purposes. Is that correct?

*"The mobile app is a great educational mechanism. As is easy to use and free to reach large*

*amounts of physicians in training it is of great value. Currently many residents Hospital has used the mobile application for prescribing antimicrobials for community-acquired pneumonia. The new residents will arrive in 2014 will be instructed to use the mobile application. This mobile app, as far as can be ascertained, is the first to be used in this way for a hospital 100% SUS."*

**Question 05:** The mobile application is much more useful in the hospital environment than a traditional software installed, for example, in a desktop or notebook computer?

*"For being the application on mobile platform it has the agility and penetration needed for medical care. The fact that he is "in the palm of the hand" gives the user a much better adherence and does not require a physical computer platform that is not always available at the hospital bedside."*

In the context of this preliminary assessment, it is possible to see that the proposed mobile application generates benefits. On the side of the patient, the proposed mobile application can provide rapid diagnosis, accurate identification of the treatment to be applied, and therefore can improve the health of the patient more quickly. For health professionals, the system can prevent diagnosis mistakes, providing friendly use, speediness and knowledge for the purpose of inexperienced professional training.

It is important to highlight the main purpose of the application is to guide the initial treatment—at the screening stage—when the diagnosis is not obvious [1]. Therefore, the risk arising from the use of the application is limited. In addition, the need for image diagnosis is not necessary at this stage.

## IV. Conclusions and Future Work

This paper presents a novel mobile application system for diagnosis and management of CAP. In this first version, such application is able to aid the diagnosis and to implement an algorithm for the treatment of pneumonia according to etiology.

Through the use of the mobile application by a infectious diseases specialist, we claim that our system brings important contributions for improving clinical practices, as (i) speed up the processing of high variables amount, (ii) precision improving in diagnosis by a specification of knowledge that can support medical decisions, avoiding errors and advising beginner physicians, and (iii) penetration needed for medical care through a mobile application. For future works, we plan to study how the application can establish a secure communication with the hospital electronic health record management system in order to recover medical records and past diagnosis of patients. In addition, we intend to carry out a further analyze the use of the application by a team of several physicians.

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## References

[1] A. Auler, A. P. Alves, P. Behar, L. C. Dias, B. R. D. Santos, and P. Vanny, "Tratamento de Pneumonia Adquirida na Comunidade (PAC)," Controle de Infecção Hospitalar (CIH) - Hospital Nossa Senhora da Conceição (HNSC), Tech. Rep., 2010.

[2] P. Drummond, J. Clark, J. Wheeler, A. Galloway, R. Freeman, and A. Cant, "Community acquired pneumonia–a prospective uk study." *Arch Dis Child*, vol. 83, no. 5, pp. 408–412, Nov 2000.

[3] S. Butt and E. Swiatlo, "Treatment of community-acquired pneumonia in an ambulatory setting." *Am J Med*, vol. 124, no. 4, pp. 297–300, Apr 2011. [Online]. Available: http://dx.doi.org/10.1016/j.amjmed.2010.06.027

[4] S. R. Majumdar, F. A. McAlister, D. T. Eurich, R. S. Padwal, and T. J. Marrie, "Statins and outcomes in patients admitted to hospital with community acquired pneumonia: population based prospective cohort study." *BMJ*, vol. 333, no. 7576, p. 999, Nov 2006. [Online]. Available: http://dx.doi.org/10.1136/bmj.38992.565972.7C

[5] M. E. Burman and W. L. Wright, "Diagnosis and management of community-acquired pneumonia: Evidence-based practice," *The Journal for Nurse Practitioners*, vol. 3, no. 9, pp. 633–649, October 2007, DOI: 10.1016/j.nurpra.2007.07.019.

[6] M. L. Jackson, K. M. Neuzil, W. W. Thompson, D. K. Shay, O. Yu, C. A. Hanson, and L. A. Jackson, "The burden of community-acquired pneumonia in seniors: results of a population-based study." *Clin Infect Dis*, vol. 39, no. 11, pp. 1642–1650, Dec 2004. [Online]. Available: http://dx.doi.org/10.1086/425615

[7] T. M. File, Jr, "Streptococcus pneumoniae and community-acquired pneumonia: a cause for concern." *Am J Med*, vol. 117 Suppl 3A, pp. 39S–50S, Aug 2004.

[8] H. M. Lode, "Managing community-acquired pneumonia: a european perspective." *Respir Med*, vol. 101, no. 9, pp. 1864–1873, Sep 2007. [Online]. Available: http://dx.doi.org/10.1016/j.rmed.2007.04.008