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Comparison between statistical and fuzzy approaches for improving diagnostic decision making in patients with chronic nasal symptoms

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Abstract

This paper compares a fuzzy model, expressed in rule-form, with a well known statistical approach (i.e. logistic regression model) for diagnostic decision making in patients with chronic nasal symptoms. The analyses were carried out using a database obtained from a questionnaire administered to 1359 patients with nasal symptoms containing personal data, clinical data and skin prick test (SPT) results. Both the fuzzy model and the logistic regression model developed were validated using a data set obtained from another medical institution. The accuracy of the two models in identifying patients with positive or negative SPT was similar. This study is a preliminary step to the creation of a software that primary care doctors can use to make a diagnostic decision, when deciding whether patients with nasal symptoms need allergy testing or not.

Keywords: Logistic regression model; Fuzzy model; Fuzzy relations; Approximate reasoning; Fuzzy inference systems; Diagnostic decision making; Nasal symptoms; Skin prick test

1. Introduction

Chronic rhinitis is typically classified as allergic rhinitis (AR) if the symptoms and triggers correlate with a specific IgE-mediated response, or as non-allergic rhinitis (NAR) if symptoms are induced by irritant triggers in the absence of specific IgE-mediated responses [4]. AR is a common condition affecting 5–40% of the general population and there is evidence that its prevalence is increasing [3]. Rhinitis is an inflammation of the nasal membrane that causes periods of nasal discharge, sneezing, and congestion that persist for at least two hours per day [23]. Rhinitis is considered allergic when allergen-specific IgE initiates the immunologic reaction that causes symptoms, while it is non-allergic if allergen-specific IgE is negative [10].

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Diagnostic allergy tests attempt to detect specific IgE, which causes the nasal symptoms, binding common allergens, such as house dust mites, pollens, animal proteins, and mold spores [12]. However, primary care doctors are usually the first to encounter patients with chronic nasal symptoms, but they are often uncertain about how to differentiate between allergic and non-allergic forms of the disease. They normally require a consultation with an allergy specialist if nasal symptoms have been present for more than two years, and they occur cyclically [26].

The availability of a short questionnaire for the diagnostic decision, that correlates with the positive or negative allergy test, may serve to modify and rationalize the current approach taken by primary care doctors for evaluating patients with chronic nasal symptoms. In other words, we will try to answer the question: is it necessary for patients to undergo allergy testing? This decision will be made considering their demographic and clinical characteristics.

Due to its simplicity, high sensitivity, rapid interpretation, and a relatively low cost, SPT was until recently, often recommended by primary care doctors. But because of the current state of the economy and health care system problems, health care expenditure has fallen. In the Italian health care system, the total cost of an allergy test and *in vivo* testing is €44, considering the cost of the allergy extract and the allergist's charge (allergist's time for the medical history, clinical examination, and SPT [2]). This is paid by the patient, who possibly does not need an allergy test.

An important contribution to the rhinitis diagnostic decision can be provided by the examination of a database performed on a wide sample of patients with chronic nasal symptoms. The crucial point is how to examine the data obtained from the database in order to assemble a questionnaire that will facilitate the diagnostic decision of primary care doctors for new patients with chronic nasal symptoms.

The study analyses a database of 1359 patients with chronic nasal symptoms, performed with a logistic model and a fuzzy model, to evaluate the accuracy of the results of the SPT. The performances of the two models was validated through a data set obtained from another medical institution.

A considerable amount of scientific production is directed at the exploitation of databases or questionnaires in order to implement models and algorithms useful to the assessment, assistance in medical diagnosis, and treatment of allergic rhinitis and respiratory diseases. In their seminal work, Pantin and Merrett (1982) [21] applied a computer system to predict the IgE-mediated allergies by referring to a database compiled from previous patients' answers and their IgE antibody profiles. Chae et al. (1992) [6] improved the capability of the medical decision support system for diagnosing nasal allergy combining statistical and rule-based approach by a neural network. Shortly after, Chae et al. (1995) [5], through a covariance structure modeling, determined a structural relationship among patients characteristics, treatment and results of allergic rhinitis. Park et al. (1996) [22] developed a knowledge-based system to automate the diagnosis of allergic rhinitis by a combination of case-base and rule-based reasoning with a neural network. Recently, in the same clinical field, Zarandi et al. (2010) [27] developed a fuzzy rule-based expert system to diagnose asthma at initial stages. Zolnoori et al. (2012) [29] provided an intelligent fuzzy system for the problem of the underestimating of asthma control levels. In the same year Zolnoori et al. (2012) [28] developed a fuzzy expert system for evaluating the level of asthma exacerbation, and finally the same authors (2012) [30] furnished a solution of intelligence fuzzy system for the prescription of medicine for asthma in the primary stages based on asthma severity levels. Recently Tomita et al. (2013) [25] developed a scoring algorithm using clinical parameters to predict the presence of asthma in adult patients with respiratory symptoms. Padilla et al. (2013) [20] proposed a cross-sectional study aimed to assess the association between allergic rhinitis and asthma control in Peruvian school children. Weger et al. (2013) [8] used multiple regression analysis to develop two-step pollen and hay fever symptom prediction using actual and forecast weather parameters, grass pollen data and patient symptom diaries. Chatzimichail et al. (2013) [7] predicted asthma outcome using partial least square regression and artificial neural networks. The results of these applications are not applied in clinical practice.

Our paper, after the introduction, is presented in seven sections. We describe in Section 2 the Palermo database; in Section 3, we report the methods of statistical analysis and fuzzy analysis, used to examine the Palermo database; in Section 4, we report the results of the statistical analysis and of the fuzzy analysis, and the results of the logistic regression model and of the fuzzy model; in Section 5 we report the comparison between the logistic regression model and the fuzzy model of the Palermo database; in Section 6 we present the results of validation of the diagnostic decision, performed using a new database, with both logistic regression and fuzzy model; finally in Section 7 conclusions and future perspectives are described.