Determining Vaccine Dosage with Fuzzy Logic in Allergen Immunotherapy for Allergic Asthma

Mervenur ÇETİN*, Murat BEKEN**‡

*Department of Computer Engineer, Engineering Faculty, Bolu Abant İzzet Baysal University, 14030, Bolu,Turkey

**Department of Computer Engineer, Engineering Faculty, Bolu Abant İzzet Baysal University, 14030, Bolu,Turkey

(mervenurc288@gmail.com, murat.beken@ibu.edu.tr)

‡Corresponding Author; Computer Engineer, Engineering Faculty, Bolu Abant İzzet Baysal University, 14030, Bolu, Turkey
Tel: +0374 254 10 00/584,

Fax: +0374 254 10 00, mervenurc288@gmail.com,

Received: 13.10.2023 Accepted:29.11.2023

Abstract- Asthma is a chronic respiratory disease characterized by restricted airflow as a result of inflammation and narrowing of the airways.Inflammation and airway narrowing are the hallmarks of the chronic respiratory disease asthma. When environmental allergens cause this narrowing of the airways, allergic asthma develops. Symptoms include coughing, wheezing, and chest tightness. For severe cases of asthma, simple controller medications and bronchodilators are not enough. In such cases, allergen immunotherapy, commonly known as vaccination therapy, is one of the treatment alternatives. Allergen immunotherapy is a type of medicine that reduces a person's immune response to allergens. However, patients may experience local, systemic or anaphylactic reactions following vaccination. For patients with systemic and anaphylactic reactions, dosage determination is critical. The physician will use his or her expertise and knowledge to reduce or increase the dosage if changes are needed based on the patient's response. It is an important and stressful responsibility that doctors have taken on. The optimal dosage can be determined by conducting a fuzzy study based on the patient's pulmonary function test and post-vaccination reactions. With more precise data, the process can be taken further and the stress level of doctors should be reduced as a result of this study. The main objective is to reduce the number of post-vaccination side effects experienced by patients in order to complete the treatment successfully and to minimise any adverse effects on the patient's life that may result from the vaccine.
Keywords Fuzzy, Asthma, Allergen immunotherapy, Determining vaccine dosage.

1. Introduction

Individuals with allergic asthma may experience symptoms such as itching, coughing, shortness of breath, and chest tightness when exposed to environmental triggers called allergens. Allergic asthma is a type of asthma that causes inflammation and narrowing of the airways. While it is not life-threatening, it reduces the quality of life, affecting success in school and work and restricting physical activity. In addition, it is a predisposing factor for the development of other allergic diseases. [1].

Asthma is defined by reversible obstruction of the airway, inflammation of the airway, and increased bronchial responsiveness. While it may also be observed in adults, it is a prevalent chronic illness during childhood [2]. Patients diagnosed with allergic rhinitis (AR) have a threefold increased likelihood of also developing asthma when compared to patients without AR. The treatment of AR is known to reduce acute exacerbations, decrease hospitalizations and augment quality of life for patients afflicted with asthma [3].

Fig. 1. Asthma medications.

AR and asthma are diseases that share similar mechanisms. The initiation mechanism for both is an immunoglobulin (Ig) related systemic inflammatory response, which leads to inflammation of the nasal and bronchial mucosa [4,5]. While it is believed that genetic background plays a role, environmental factors also have an effect [6].

There are three main methods for the treatment of allergic diseases, primarily including AR, which are allergen avoidance, pharmacotherapy, and immunotherapy. Due to their ability to suppress symptoms and provide rapid relief, medical treatment methods are often preferred in practice [7].

For patients with severe asthma, medications aimed at controlling and bronchodilators alone might not suffice. In such cases, doctor-regulated allergen immunotherapy (vaccine treatment) is a viable treatment option.

Currently, the primary objective of treating asthma and allergic rhinitis (AR) is to manage symptoms and enhance the patients' quality of life. The control of asthma and AR symptoms is dependent on a range of physiological, environmental, and behavioural factors [11, 12]. Currently, the primary objective of treating asthma and allergic rhinitis (AR) is to manage symptoms and enhance the patients' quality of life. Moreover, numerous studies have revealed that allergic symptoms have an adverse effect on the well-being of an individual [13].

The purpose of this study was to investigate the respiratory function tests (SFT), symptom follow-up, supportive medication, and quality of life of a patient with asthma and AR who started allergen immunotherapy treatment on December 31, 2010 (age: 10, gender: female), whose treatment was stopped on November 3, 2015, and whose treatment follow-up continued until May 30, 2017, and who was followed up at the Paediatric Allergy Outpatient Clinic of Dr. Sami Ulus Obstetrics, Gynecology, Child Health and Diseases Training and Research Hospital. The patient file belongs to Mervenur ÇETİN, one of the authors of the article. Due to the confidentiality of patient information and the storage and not sharing of personal data, this stage of the study was carried out by analyzing the treatment process of a single patient.

For this and similar treatments, there is still no method or procedure for personalised treatment, and no study using artificial intelligence. Studies have looked at changes in patients' quality of life before and after allergen immunotherapy treatment. Depending on the patient's constitution and reactions, procedures such as reducing or increasing doses are carried out during the treatment process.

This process is the result of the doctor's decisions based on experience and knowledge. This is a situation that can cause difficulties in the patient's quality of life during the treatment period, as well as a situation that can cause no response or a late response to treatment. In addition, this responsibility is an important and stressful situation for doctors.

The aim of this project is to determine the next dose of vaccine based on the patient's previous reactions, to minimise the patient's reactions after vaccination and to minimise the negative impact of vaccination on the patient's life, thus making the treatment process more efficient.

The objective of this study, using fuzzy logic, is to find and put into practice elements that improve the quality of life and reduce the incidence of allergic diseases. It also seeks to improve the quality of life of this group of patients so that they can actively participate in all aspects of life. The study also aims to compile patients who have responded quickly and favorably to therapy.

2. Materials and Methods

2.1. What is Asthma?

2.1.1. Diagnosis of Asthma and Allergic Asthma

A chronic inflammatory illness of the airways, asthma affects a variety of cells and cellular components. A variety of respiratory symptoms, including wheezing, shortness of breath, chest tightness, and cough, as well as varied expiratory airflow limitation characterize this diverse condition. Chronic inflammation is linked to airway hyperreactivity, which causes symptoms to come back again. Reversible airway blockage in the lungs, which is common but variable and typically linked to self-limiting or curable diseases, is a common cause of these attacks. Later airflow restriction may become irreversible [14].

Although asthma can develop in adults, it is more common in children [11]. Around 30% of patients start showing symptoms around age 1, and 80–90% start showing symptoms around age 4–5. Typically, asthma that starts at these times does not last into adulthood. While symptoms typically get better during adolescence, in some people with severe asthma, they may persist until old age [15], [16].

2.2. Immunotherapy Treatment for Allergies

2.2.1. What is Vaccination Therapy?

For more than a century, vaccine therapy has been employed as a form of therapy to deal with the underlying causes of allergic disorders. It entails giving the patient goods made from allergens at regular intervals and in gradually increasing doses. In reality, the compounds administered to the patient during vaccine therapy are allergens that the person commonly comes into contact with in their daily lives. These allergy medications that are given to the patient don't include any drugs or corticosteroids. Vaccine therapy is frequently given using a tiny needle inserted beneath the skin or, less frequently, orally, in a fashion that is painless for the patient. The objective is to find a dose that is appropriate and causes no problems for the patient, finally desensitizing the person to the allergen.

Allergen immunotherapy is one of the treatment methods that aim to reduce the immune system's response to allergens, which is the etiology of allergic diseases. This treatment aims to decrease the immune system's reaction by exposing the

patient to small amounts of the allergen at specific intervals and gradually increasing the dose. It is a well-known treatment method aiming to develop tolerance to the allergen to which the patient is sensitive [8]. Allergy vaccines consist solely of the standardized allergen that the patient is sensitive to and attached to it are some carrier substances, known as adjuvants, that enhance the vaccine's efficacy. Except for adjuvants, there are no other medications, such as cortisone, included in the vaccine.

Immunotherapy was first used for the treatment of AR in 1911 by Noon and Freeman [9]. The initial phase of the therapy typically lasts between 3 to 6 months. In the maintenance phase, which begins after 6 months, a designated dose is administered monthly for a period of 3 to 5 years.

The only therapy that can completely heal allergic disorders is allergen immunotherapy. It follows medication and allergen avoidance in the management of allergic disorders. Use of the allergens responsible for the clinical picture and proof of sensitivity by skin prick tests or specific IgE positivity should be required for immunotherapy. The procedure needs to be carried out under the direction of allergy experts. According to studies, immunotherapy significantly reduces asthmatic symptoms, patients take fewer medications, those with rhinitis don't develop asthma, and there are fewer new sensitizations [10].

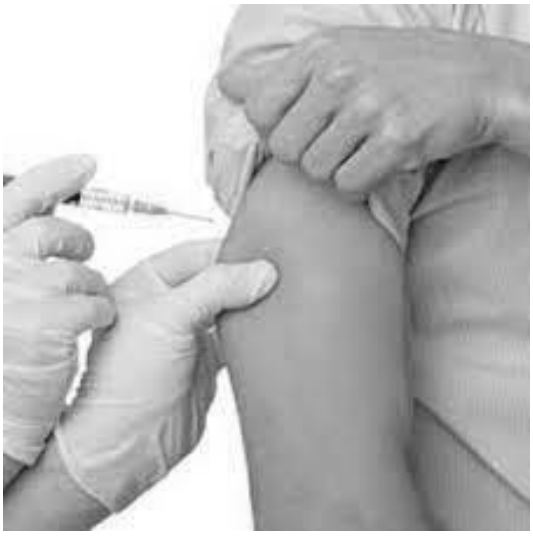

Fig. 2. Vaccination Therapy.

To ensure the safety and success of the treatment, the decision to undergo vaccine therapy and the treatment plan must be made by immunology and allergy specialists.

In addition to reducing sensitivity to allergens, vaccine therapy also reduces disease symptoms and the need for medication. It also has a protective effect in preventing new allergies and asthma development.

A double-blind placebo-controlled clinical trial was completed that tested immunotherapy with a mixture of multiple allergen extracts in 121 perennial asthmatic children. This was the first test of treatment with allergen mixtures. The trial showed that over 30% of children underwent a complete or partial remission during the 2.5 years of therapy, but the changes were almost identical in both treatment and placebo control groups [18].

2.2.2. What Is the Vaccine Therapy Process Like?

Vaccine therapy consists of two stages. In the first stage, the dose is increased until the maintenance dose, which is an appropriate dose that does not cause problems, is reached. Injections are usually administered weekly. The second stage of vaccine therapy, after reaching the maintenance dose, involves injections every 2 weeks, then every 3 weeks, and later every 4 weeks. Maintenance treatment is administered every 4-6 weeks. The average duration of vaccine therapy is 3-5 years, but this duration can vary for each patient. Improvement in symptoms is slower compared to medication therapy and may occur months later. Even if the symptoms completely disappear, the treatment should continue. In cases where the expected benefit is not seen 12-18 months after vaccine therapy, the treatment should be discontinued [17].

2.2.3. What Are the Side Effects of Vaccination Treatment?

a. Local or general side effects may occur after vaccination. The effect of the drug given to the patient in the area where it is applied is called the local effect.

b. It is normal to have coin-sized redness, itching and swelling at the injection site. If the reaction is 5cm or more in diameter, the patient will be kept under observation for a while and given local ice and antihistamine medication.

Antihistamines are substances that block the action of histamine. Histamine is an important chemical produced when a person is exposed to a substance to which they are allergic.

c. Although much rarer compared to local side effects, side effects affecting the entire body can occur within the first 24 hours. It may include itchy hives, swelling of the tongue or lips, shortness of breath, hoarseness, chest tightness, runny nose, low blood pressure, and loss of consciousness. In such cases, the patient should seek the nearest healthcare center or consult their allergist.

d. Due to the possibility of severe reactions, vaccination treatment should be administered under the supervision of an allergy specialist and in a hospital setting. Patients should wait for 30 minutes after the injection and should not leave the hospital without showing the injection site to the doctor.

e. Unlike medications, the vaccine does not have harmful side effects on internal organs. It does not contain drugs or corticosteroids, and it does not cause weight gain [17].

f. After vaccination, hot baths, saunas, long showers and strenuous physical activity should be avoided [17].

g. Vaccinations should be given regularly on the scheduled days. If vaccination is interrupted, treatment will be inadequate or unsuccessful [17].

In conclusion, vaccination treatment in patients with allergic rhinitis and coexisting mild to moderate asthma is an effective method to manage the disease and halt its progression with persistent implementation.

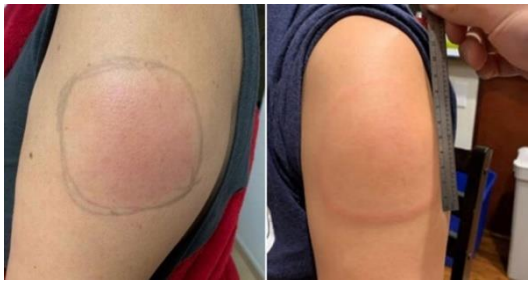

Fig. 3. Swelling And Redness Occurring In The Vaccination Area Is A Common Side Effect.

2.3. Fuzzy Logic

2.3.1. What is Fuzzy Logic?

Fuzzy Logic is a type of logic that works with "inexact" or "fuzzy" concepts, rather than strict true or false values. While traditional logic assumes that a statement is either true (1) or false (0), fuzzy logic assigns a value between integers to a statement.

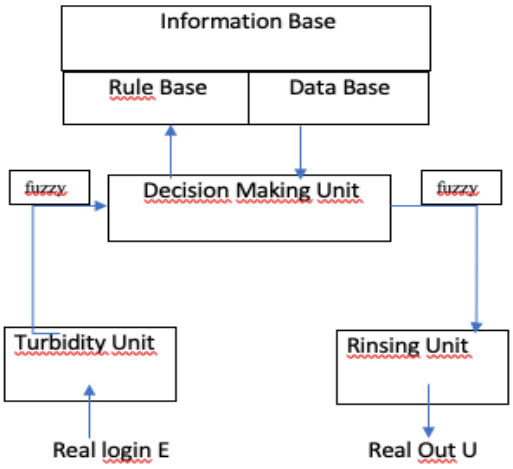

Fig. 4. Basic Structure of Fuzzy Logic Controller.

This is useful for dealing with uncertainty and modeling complex real-world problems more effectively.

When dealing with complex and uncertain data, fuzzy logic can help obtain more precise and flexible results. Fuzzy logic does not perform learning but can build a control mechanism based on learned data. In fact, the reason for using fuzzy logic in this study is exactly this.

By providing control based on the patient's data, we can predict the next step more accurately and minimize any adverse effects in the treatment process.

2.3.2. Fuzzy Mamdani Model

The study falls under the category of Fuzzy problems, specifically in the 'Mamdani category.' The 'Fuzzy Mamdani Model,' or simply the 'Mamdani Model,' is an example of an approach used to model and design decision-making and control systems using fuzzy logic.

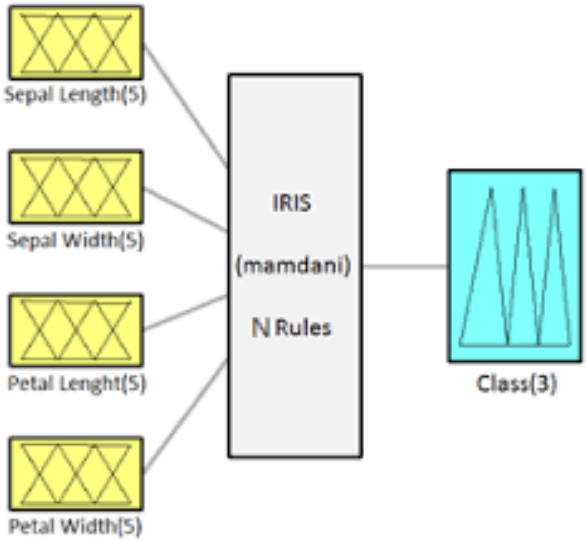

Fig. 5. Fuzzy Inference System.

This model was developed in the 1970s by British engineer Ahmed Mamdani and has been used in the management and control of complex systems.

The Mamdani Model consists of the following key components:

1. Fuzzy Rules: These express fuzzy logic rules used to control the system or make decisions. Each rule calculates an output variable based on one or more input variables. These rules are typically expressed in natural language using the "if... then" format. For example, a fuzzy logic rule could be something like "If the temperature is high and the humidity is low, then turn on the air conditioning."

2. Fuzzy Logic Sets: This section defines the appropriate fuzzy sets for the input variables of each rule. It helps convert vague or fuzzy concepts into numerical values. For example, fuzzy sets might be created for input variables like "high temperature" and "low humidity."

3. Fuzzy Operation Rules: Each rule specifies a particular fuzzy operation for the output variable. This involves the process of calculating the output variable using the input variable's fuzzy set membership functions and logical operations (e.g., union, intersection).

4. Fuzzy Output Variables: This section defines the fuzzy set for the output variable and how it is transformed into an actual output.

5. Weighting and Aggregation: In this step, each rule's output is weighted according to its relevance within the output variable's fuzzy set, and aggregation is performed.

6. Defuzzification: All rule outputs are combined to produce a final result. This represents the output variable as either a precise numerical value or an uncertain numerical value.

The Mamdani Model is used for solving problems that involve uncertainty and are expressed in natural language. This model finds applications in automation systems, climate control, traffic management, household appliances, artificial intelligence applications, and many other fields. Fuzzy logic is preferred in such applications because it can better handle the complexity and uncertainty of the system.

In this study, respiratory test results, vaccine dosage, dosages of certain drugs, and, most importantly, post-vaccination patient reactions are considered as fuzzy values.

3.Methods

3.1. Inputs and Membership Functions

Different membership functions have been used for each input. Within the scope of our values, three different functions have been defined:

low, middle, and high.

One factor to consider in the study is the season, as the patient in question has undergone treatment with seasonal allergen triggers.

The list of inputs is as follows:

1. Season
a. Winter
b. Summer
c. Spring
d. Autumn
2. Respiratory Test (PET)
a. PET-Respiration-fvc
b. PET -Respiration-fev1
c. PET -Respiration-fev1/fvc
d. PET -Respiration-pef
e. PET -Respiration-mef25-75
f. PET -Respiration-fef25-75

3. Vaccination
a. Administered Vaccine Vial
b. Administered Dose (ml sc)

4. Complaints
a. Shortness of Breath
b. Nighttime Cough
c. Cough with Exertion
d. Mouth Breathing during Sleep
e. Sneezing
f. Itchy Nose
g. Nasal Congestion
h. Itchy Eyes

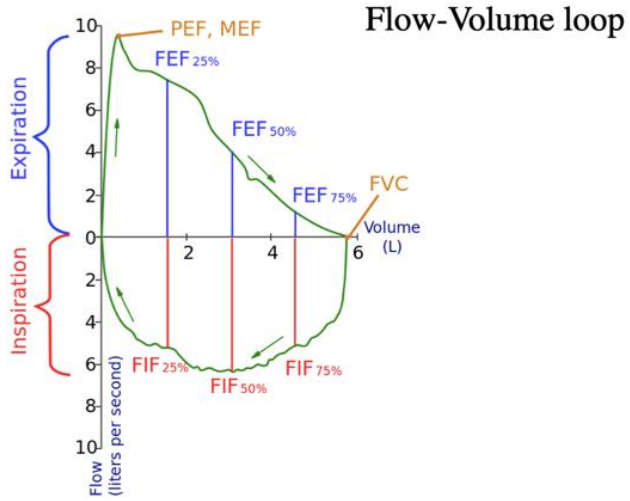

Fig. 6. Respiratory Test (Lung volüme and capacity)

Fig. 7. A spirometry device is an instrument used in pulmonary function testing.

Table 1. Patient Data Used As Inputs

DATE	2.a	2.b	2.c	2.d	2.e	2.f	3.a	3.b	4.a	4.b	4.c	4.d	4.e	4.f	4.g	4.h
23.12.2010	75	87	109	83	116				0	0	1	1	1	1	0	0
06.01.2011	69	78	108	81	96		0(Grey)	0.1	0	0	1	1	1	1	0	0
13.01.2011	66-68(4)	76-79(5)	109-110	64-83(28)	100-134(34)		0(Grey)	0.2	0	0	0	0	0	0	0	0
20.01.2011							0(Grey)	0.4	0	0	1	0	0	0	0	0
27.01.2011	70	82	111	85	118		0(Grey)	0.8	0	0	0	0	0	0	0	0
05.05.2011	72	82	107	79			4(Blue)	0.8	0	0	0	0	0	0	0	0
18.05.2011	72	78	91	59	87		4(Blue)	0.6	0	0	1	0	0	1	0	0
01.06.2011	75-76	85-88(3)	108-109	73-75		103-118(15)	4(Blue)	0.6	1	1	0	0	0	0	0	0
07.06.2011	80	88	104			117		Control								
23.06.2011	76	85	106	92		115	4(Blue)	0.6	0	0	0	0	0	0	0	0
07.07.2011	76	85	106	88		108	4(Blue)	0.8	0	0	0	0	0	0	0	0
13.10.2011	81	86	104	85		103	4(Blue)	0.8	0	0	0	0	0	0	0	0
06.01.2012	80	83	103			94	4(Blue)	0.8	0	0	0	0	0	0	0	0
01.03.2012	79	81	90.5	99		91	4(Blue)	0.8	0	0	0	0	0	0	0	0
22.06.2012	75	83	97.5	122		103	4(Blue)	0.8	0	0	0	0	1	1	0	1
03.01.2013	78	84	95.4	123		95	4(Blue)	0.8	0	0	0	0	0	0	0	0
24.05.2013	82	85	92.3	103		89	4(Blue)	0.8	0	0	0	0	1	1	0	1
06.12.2013		84	126			106	4(Blue)	0.8	0	0	0	0	0	0	1	0
).01.2014	83	93	98.4	123		115	4(Blue)	0.8	0	0	0	0	0	0	0	0
28.02.2014		91-97(7)	107			97-122(29)	4(Blue)	0.8	0	1	0	0	0	0	1	0
22.05.2014	97	102			123		4(Blue)	0.8	0	0	0	0	1	0	1	1
18.07.2014		97	113			118	4(Blue)	0.8	0	0	0	0	1	0	1	1
09.12.2014	82	94	98	95	105		4(Blue)	0.8	0	0	0	0	1	0	0	0
06.02.2015	79-74-7	93-87-7	100-100	89-86-3	113-116+3		4(Blue)	0.8	0	1	0	0	0	0	1	0
24.03.2015	82	94	96	82	99		4(Blue)	0.6 (Since arriving 15 days late)	0	0	0	0	0	0	1	0
14.07.2015	80	92	98	97	103		4(Blue)	0.8	0	0	0	0	1	0	0	0
03.11.2015	84	99	99	89	115		4(Blue)	0.8	0	0	0	0	0	0	0	0

3.2. Membership Function Preference

Understanding what a value represents within which ranges is crucial when selecting membership functions. For example, when selecting membership functions for drugs, functions with sharper values of 2 or 1 are created, whereas for values such as itch, redness and PET, membership functions of the type trimf with at least 3 functions and maximum and minimum points are preferred.

3.3. Outputs and Membership Functions

One of the most important outputs for us is the swelling and redness at the site where the vaccine is administered. This reaction is, in a sense, the body's warning signal in response to the vaccine. The severity of the redness and swelling can have a direct impact on the patient's SFT values, shortness of breath and associated conditions such as fatigue and arm pain. It is therefore important to select the points that are more

indicative of warning when determining the intervals for the functions in post-vaccination reactions. Side effects should be closely monitored during the treatment process. Since we have historical data in this project, we can derive the most accurate results based on local side effects, namely redness and swelling.

1. Local Side Effects

a. Redness (cm)

b. Swelling (cm)

c. Itching

Table 2. An example output table is available with the obtained data.

DATE	1.c	1.a	1.b (first 30 sec)	1.b (1. day)	1.b (2.day)
23.12.2010					
06.01.2011	1	0			
13.01.2011	1	0			
20.01.2011	1	0			
27.01.2011	1	0		5	9
05.05.2011	1	6-8	3-4		

As seen in Table-2, the dose that was previously 0.4 on August 27, 2011, was increased to 0.8. Following the reactions exhibited by the patient, the subsequent 3 doses were reduced to 0.6 ml. This process is the maintenance dose determination process. Our goal in this process is to provide the patient with the most effective treatment while minimizing local side effects.

After the vaccination application, local ice application and antihistamine medication were used to keep the patient's local side effects under control.

3.4. Fuzzy Logic Rules Used

Separate rules have been created for different situations, such as the reaction status when taking certain doses and changes in vaccine dosage, in relation to SFT values. These rules can be further refined based on the detailed observational data obtained from the patient.

Table 3. Rulers-1

1.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is low) and (Swelling is low) and (Itching is low)
2.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is middle) and (Swelling is middle) and (Itching is middle)
3.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is low) and (Swelling is middle) and (Itching is low)
4.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is low) and (Swelling is low) and (Itching is middle)
5.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is low) and (Swelling is middle) and (Itching is middle)
6.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is summer) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is low) and (Swelling is low) and (Itching is low)
7.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is summer) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is middle) and (Swelling is middle) and (Itching is middle)
8.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is summer) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is low) and (Swelling is middle) and (Itching is low)
9.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is summer) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is low) and (Swelling is low) and (Itching is middle)
10.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is summer) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is low) and (Swelling is middle) and (Itching is middle)
11.	If(FEV is middle) and (FVC is middle) and (FEV1/FVC is high) and (S is winter) and (FEF25-75 is high) and (PEF is middle) and (AD is middle) then (Redness is low) and (Swelling is low) and (Itching is low)
12.	If(FEV is middle) and (FVC is middle) and (FEV1/FVC is high) and (S is winter) and (FEF25-75 is high) and (PEF is middle) and (AD is middle) then (Redness is low) and (Swelling is high) and (Itching is low)
13.	If(FEV is middle) and (FVC is middle) and (FEV1/FVC is high) and (S is winter) and (FEF25-75 is high) and (PEF is middle) and (AD is middle) then (Redness is low) and (Swelling is low) and (Itching is high)

14.	If(FEV is middle) and (FVC is middle) and (FEV1/FVC is high) and (S is winter) and (FEF25-75 is high) and (PEF is middle) and (AD is middle) then (Redness is high) and (Swelling is low) and (Itching is low)
15.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is high) and (Swelling is low) and (Itching is low)
16.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is high) and (Swelling is high) and (Itching is low)
17.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is middle) and (Swelling is high) and (Itching is low)
18.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is middle) and (Swelling is high) and (Itching is low)
19.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is middle) and (Swelling is high) and (Itching is high)
20.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is middle) and (Swelling is middle) and (Itching is low)

Table 4. Rulers-2

21.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is middle) and (Swelling is middle) and (Itching is middle)
22.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is middle) and (Swelling is middle) and (Itching is high)
23.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is middle) and (Swelling is high) and (Itching is low)
24.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is high) and (Swelling is middle) and (Itching is middle)
25.	If(FEV is normal) and (FVC is normal) and (FEV1/FVC is normal) and (S is winter) and (FEF25-75 is normal) and (PEF is normal) and (AD is low) then (Redness is low) and (Swelling is low) and (Itching is low)
26.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is summer) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is high) and (Swelling is high) and (Itching is high)
27.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is winter) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is high) and (Swelling is high) and (Itching is high)
28.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is spring) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is high) and (Swelling is high) and (Itching is high)
29.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is autumn) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is high) and (Swelling is high) and (Itching is high)
30.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is autumn) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is high) and (Swelling is high) and (Itching is middle)
31.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is spring) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is high) and (Swelling is high) and (Itching is middle)
32.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is spring) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is middle) and (Swelling is high) and (Itching is middle)
33.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is spring) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is high) and (Swelling is middle) and (Itching is middle)
34.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is spring) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is middle) and (Swelling is middle) and (Itching is middle)
35.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is autumn) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is high) and (Swelling is high) and (Itching is middle)
36.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is autumn) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is middle) and (Swelling is high) and (Itching is middle)
37.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is autumn) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is high) and (Swelling is middle) and (Itching is middle)

38.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is autumn) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is middle) and (Swelling is middle) and (Itching is middle)
39.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is autumn) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is middle) and (Swelling is middle) and (Itching is high)
40.	If(FEV is high) and (FVC is high) and (FEV1/FVC is high) and (S is autumn) and (FEF25-75 is high) and (PEF is high) and (AD is high) then (Redness is high) and (Swelling is low) and (Itching is middle)

4. Discussion and Conclusion

1. A review of respiratory tests (SFTs), symptom monitoring, supportive medications, and the quality of life of a patient with asthma and AR (allergenic rhinitis) who was started on allergen immunotherapy was performed.

31 December 2010 (age: 10 years, gender: female), treatment was discontinued on November 3, 2015, and follow-up continued until May 30, 2017.

2. The study findings indicate that targeted allergen injection immunotherapy results in a marked decrease in symptom scores and medication requirements in suitably chosen patients suffering from seasonal allergic rhinitis.

3. Injection immunotherapy carries a recognised and relatively low risk of significant adverse effects.

4. Taking antihistamines after vaccination can reduce local side effects at the site of injection.

5. It has been noted that individuals with sensitivity to seasonal allergens exhibit increased reactions during the summer and spring vaccination periods. Patients with seasonal allergies should take into consideration the season when determining the appropriate vaccine dosage.

6. Based on the patient's history, this project shows that specialized treatment methods are available for the patient.

7. Based on patient data, the administered vaccine doses enhance patients' quality of life throughout their treatment process.

8. Owing to data protection and privacy regulations, we analysed the treatment procedure of a single patient in this stage of the study. The examination of a larger patient group will strengthen the conclusion of this project, which is currently only based on a single case.

9. The obtained findings provide guidance for forthcoming research. The prospect of enhancing distinct allergic conditions and implementing personalized treatment is promising.

10. There is significant potential to advance the comprehension of personalized medicine when treating allergic asthma with the use of fuzzy logic.

Acknowledgements

I would like to express my gratitude to the administration of Dr Sami Ulus Women's Health, Child Health and Diseases Training and Research Hospital and the esteemed faculty at the Paediatric Allergy Clinic for their unwavering support and attention during my treatment process, as well as for sharing their knowledge and experience.

I would like to express my sincere gratitude to my family, who have always been by my side, never wavering in their support, believing in me and providing me with both financial and moral support throughout my treatment journey.

With the hope of practising my profession in the light of knowledge, ethics and secularism

References

[1] M. Blaiss Current concepts and therapeutic strategies for allergic rhinitis in school-age children. Clin Ther 2004;26(11):1876-1889.

[2] L. Tamer, M. Calikoğlu, NA. Ates, et al. Glutathione-S-transferase gene polymorphisms (GSTT1, GSTM1, GSTP1) as increased risk factors for asthma. Respirology 2004;9(4):493-8.

[3] R. Pawankar, Allergic rhinitis and asthma: are they manifestations of one syndrome?. Clin Exp Allergy 2006;36(1):1-4.

[4] L. Söderström, A. Kober, S. Ahlstedt, et al. A further evaluation of the clinical use of specific IgE antibody testing in allergic diseases. Allergy. 2003;58(9):921-8.

[5] J. W. Yunginger, S Ahlstedt, PA Eggleston, et al. Quantitative IgE antibody assays in allergic diseases. J Allergy Clin Immunol 2000;105(6):1077-84.

[6] S. T. Holgate, Genetic and environmental interaction in allergy and asthma. J Allergy Clin Immunol 1999;104(6):1139-46.

[7] N. Mygind, R. Dahl, S. Pedersen, K. Thestruhp-Pedersen (eds). Allergy hand book Translate: Şirin A (edt). 1. Turgut 1988. 36-59.

[8] H. S. Nelson, Immunotherapy for inhalant allergens. In: Adkinson Jr NF, Bochner BS, Busse WW (eds). Middleton's Allergy Principles and Practice. 7th edition. Philadelphia: Mosby Elsevier; 2009. 1657-77.

[9] L. Noon Prophylactic inoculation against hay fever. Lancet 1911;1:1572- 3.

[10] Ş. Çekiç, N. Sapan, Allergen Specific Immunotherapy. J Curr Pediatr 2015;13:46-55.

[11] Global Initiative For Asthma. Global Strategy for Asthma Management and Prevention. 2016.

[12] Ö. Abadoğlu, Asthma control assessment questionnaires. Asthma Allergy Immunol 2008;6:99-104.

[13] E. G. Oh. The relationship between disease control, Symptom distress, functioning, and quality of life in adults with asthma. J Asthma 2008;45:882-6.

[14] H. K. Reddel, LB. Bacharier, ED. Bateman et al. Global Initiative for Asthma Strategy 2021. Executive Summary and Rationale for Key Changes. Archivos De Bronconeumologia 2022;58(1):35-51.

[15] F. D. Martinez, Development of wheezing disorders and asthma in preschool children. Pediatrics 2002;109(2)362-7.

[16] R. C. Strunk, Defining asthma in the preschool-aged child. Pediatrics 2002;109(2):357-61.

[17] A. Selçuk, O. Şener. part 16, Vaccine (Immunotherapy) Treatment in Allergy https://solunum.org.tr/TusadData/Book/327/1252015145833-17_Bolum_16_Asi.pdf

[18] A. Eggleston, M. D. Peyton, Allergen-specific immunotherapy in childhood asthma. Current Opinion in Pediatrics 9(6):s 582-584, Aralık 1997.