ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

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Determination of Preanesthetic High-Risk Using Fuzzy Risk Evaluation for Surgical Operations

Cerrahi Ameliyatlardaki Preanestezik Yüksek Riskin Bulanık Risk Değerlendirmesi ile Belirlenmesi

Barış SANDAL[a],
Yüksel HACIOĞLU[a],
Nurkan YAĞIZ[a],
Ece SALİHOĞLU[b]

[a]Department of Mechanical Engineering,
İstanbul University-Cerrahpaşa
Faculty of Engineering,
[b]Department of Pediatric Cardiovascular
Surgery,
İstanbul Bilim University,
Avrupa Florence Nightingale Hospital
Research and Application Center,
İstanbul, TURKEY

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Correspondence:
Yüksel HACIOĞLU
İstanbul University-Cerrahpaşa
Faculty of Engineering,
Department of Mechanical Engineering,
İstanbul,
TURKEY/TÜRKİYE
yukselh@istanbul.edu.tr

ABSTRACT Objective: Determination of preanesthetic high risk during surgical procedures using fuzzy risk evaluation. **Material and Methods:** In this study for the high risk patient classification, five major criteria comprising cardiac, pulmonary, renal or liver diseases and diabetes mellitus and three minor criteria comprising patients' age, body mass index and cigarette smoking were chosen to define the high-risk group. Since the fuzzy logic gives the ability to use linguistic expressions, that include the intuition of human operators or experts during the decision making process, it this study by using fuzzy logic modelling, rules for high risks were developed. To reach this aim a new fuzzy logic decision system is proposed that uses four input variables to calculate the risk as a percentage that is the output of the fuzzy system. **Results:** Using Fuzzy risk evaluation; By taking into account the number of inputs and number of their corresponding membership functions, it is deduced that 270 fuzzy rules will be enough. **Conclusion:** In this study, a risk classification model was developed by combining the risk criteria defined by previous medical studies and clinical experience with a fuzzy logic model in the preoperative period. This developed fuzzy logic model needs to be investigated by selecting specific groups of patients and specific operations.

Keywords: Anesthesia; high risk; pre anesthetic evaluation; fuzzy logic risk evaluation

ÖZET Amaç: Bu çalışmada bulanık mantık risk değerlendirmesi ile cerrahi girişim sırasında preanestezik yüksek riskin belirlenmesi amaçlanmıştır. **Gereç ve Yöntemler:** Bu çalışmada yüksek risk kriterli hastaların sınıflandırılmasında: Kalp, akciğer, böbrek, karaciğer hastaları ve diyabetus mellitus olan hastalar major risk kriterli olarak, hastanın yaşı, beden kitle indeksi ve sigara kullanımı ise hastalar için minör risk kriteri olarak belirlenmiştir. Bir minör ve bir major kriteri olan hastalar yüksek riskli olarak adlandırılmıştır. Ardından, bulanık mantık modelleme yöntemi kullanarak, yüksek riskler için kurallar geliştirilmiştir. Bulanık mantık, karar verme sürecinde operatör veya uzman insanların sezgilerini içeren dilsel ifadelerin kullanımına imkan verdiği için, bu çalışmada yüksek risk hesabı yapmak için bulanık mantık kullanılarak risk hesabında uygulanacak kurallar belirlenmiştir. Bu amaca ulaşabilmek maksadıyla çıkış olarak yüzdelik risk değerini hesaplamak için dört adet giriş değişkeni kullanan yeni bir bulanık mantıklı karar verme sistemi önerilmiştir. **Bulgular:** Bulanık mantık risk analizi ile belirlenen girişler ve bunlara karşılık gelen üyelik fonksiyonlarının sayısı dikkate alınarak, 270 adet bulanık mantık kuralı belirlenmiştir. **Sonuç:** Bu çalışma ile ameliyat öncesi dönemde önceki tıbbi çalışmalar ve klinik tecrübeler ile belirlenmiş risk kriterlerini bir bulanık mantık karar verme modeli ile birleştirerek bir risk sınıflandırması modeli geliştirilmiştir. Bu geliştirilen bulanık mantık modelinin belirli hasta grupları ve belirli ameliyatlar seçilerek araştırılmasına ihtiyaç vardır.

Anahtar Kelimeler: Anestezi; yüksek risk; preanestezik değerlendirme; bulanık mantık risk değerlendirmesi

The pre-operative risk classification of patients who will undergo anesthesia is a long-drawn interest and has been subject to many studies and classifications.

Many studies have been made especially on low-middle and high risk and many classifications have been made. These studies are usually done by evaluating clinical experiences and large patient series. The ideal classification system that medicine and engineering work together, based on a mathematical basis of clinical experience, is not yet defined.

Fuzzy set theory, that constitutes the basis for fuzzy logic decision making processes, was first introduced by Zadeh at 1965.[1] Fuzzy logic gives the ability to use linguistic expressions, that include the intuition of human operators or experts, during the decision making process. Thus, by using fuzzy logic, decision making is possible even with approximate information and uncertainty. This is why it has found wide application area in engineering, economics as well medical studies.[2-6]

The aim of this study is to predict "high-risk" patients during preoperative anesthetic evaluation using fuzzy inference system. To reach this aim a new fuzzy logic decision system is proposed that uses four input variables to calculate the risk as a percentage that is the output of the system.

MATERIAL AND METHODS

In our high risk patient classification, five major criteria comprise cardiac, pulmonary, renal or liver diseases and diabetes mellitus and three minor criteria comprise patients' age, body mass index (BMI) and cigarette smoking.[7-11]

FUZZY RİSK EVALUATİON

In the process of fuzzy logic decision making, the knowledge coming from experts are expressed by fuzzy rules. For a process with two inputs and single output those rules may be expressed as

$$1)\ \text{IF input } 1 : A_1 \text{ and input } 2 : A_2 \text{ THEN output} : U$$

Here, A_1, A_2 stand for input membership functions and U denotes the membership function for output variable. The fuzzy logic decision applications, generally include three steps during design namely, fuzzification, inference and defuzzification. With fuzzification, the membership functions along with corresponding ranges are determined for all input and output variables. By performing the inference, the output is calculated by fuzzy rules that depends on experts' information defined in advance. Since the output values are fuzzy variables they can not be used directly, thus in the final step that is called as defuzzification, the calculated output is transformed to a certain value.

In present work, a fuzzy decision process is designed for the evaluation of the risk of the patients that are going to have surgery. For this purpose, a fuzzy logic decision system is designed that has four inputs and single output. Figure 1 shows the general structure of the fuzzy logic decision model.

The input and output variables along with corresponding membership functions are depicted in Figure 2 and Figure 3, respectively. First input variable is the major risk that may include the cardiac, pulmonary, liver, renal and diabetes mellitus diseases. The membership functions M0, M1, M2, M3, M4 and M5 denote the number of the major risk. The remaining three input variables are the minor risks namely, age, obesity (body mass index, (BMI)) and smoking. The age of the patients are classified as Child, Young and Old. From the view point of weight, five membership functions namely, Underweight (UW), Normalweight (NW), Overweight (OW), Obese (Ob) and Morbid obese (M-Ob) are arranged for BMI by taking into account the classification of world health organization. Three membership functions are used for the smoking classification that is No, Moderate and High smoking. The output variable is the percentage of the Risk and five membership functions are used such as Very-Low-No-Risk (VLR), Low-Risk (LR), Moderate Risk (MR), High-Risk (HR) and Very-High-Risk (VHR).

During the construction of the rule base, the effect of the inputs are determined depending on the expertise in the field. The logic behind this rules is that the risk increases drastically with in-

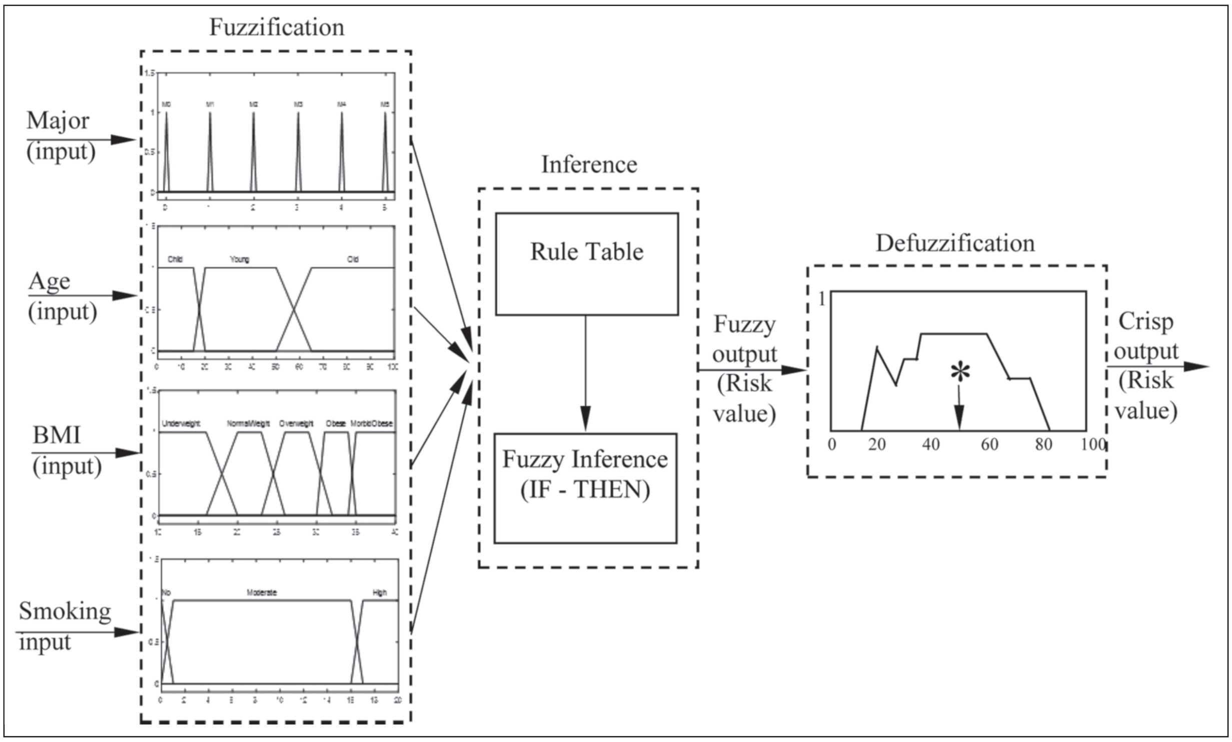

FIGURE 1: Diagram for the proposed fuzzy decision system.

creasing number of major diseases and similarly the risk increases slightly with increasing number of minor risks. By taking into account the number of inputs and number of their corresponding membership functions it is deduced that there will be 270 rules. Three rules for different cases will be explained here for better understanding. For the first case suppose that a non-smoking, young patient with normal weight and without any major disease is considered then the risk was assessed as very low. For the second case suppose that a non-smoking, child patient with normal weight and pulmonary disease is considered then the risk was assessed as moderate. For the third case suppose that a moderate smoking, old patient with normal weight and liver and cardiac diseases is considered then the risk was assessed as high. The fuzzy logic rules for those sample cases are presented below.

$$2)\ \text{IF} \begin{Bmatrix} \text{Number of Major Diseases} = \text{M0 and Age} = \text{Young} \\ \text{and BMI} = \text{NW and Smoking} = \text{No} \end{Bmatrix} \text{THEN Risk} = \text{VLR}$$

$$3)\ \text{IF} \begin{Bmatrix} \text{Number of Major Diseases} = \text{M1 and Age} = \text{Child} \\ \text{and BMI} = \text{NW and Smoking} = \text{No} \end{Bmatrix} \text{THEN Risk} = \text{MR}$$

$$4)\ \text{IF} \begin{Bmatrix} \text{Number of Major Diseases} = \text{M2 and Age} = \text{Old} \\ \text{and BMI} = \text{NW and Smoking} = \text{Moderate} \end{Bmatrix} \text{THEN Risk} = \text{HR}$$

During the inference of the decision the Mamdani type inference method is used and for the defuzzification the centroid method is preferred.

RESULTS

In this study, "Fuzzy decision rules for risk evaluation" was defined and a fuzzy logic model was developed for high-risk patients.

With clinical experience and clinical studies: we defined five major criteria including cardiac, pulmonary, renal or liver disease and diabetes mellitus and three minor criteria including patients' age, body mass index and cigarette smoking.

A basic fuzzy logic model has been developed for use in these patients and high risk group and since there is a huge number of rules, for brevity, the rules only for the case of one major risk is presented in (Table 1).

DISCUSSION

With technological and medical developments, surgery has been carried out for large number of

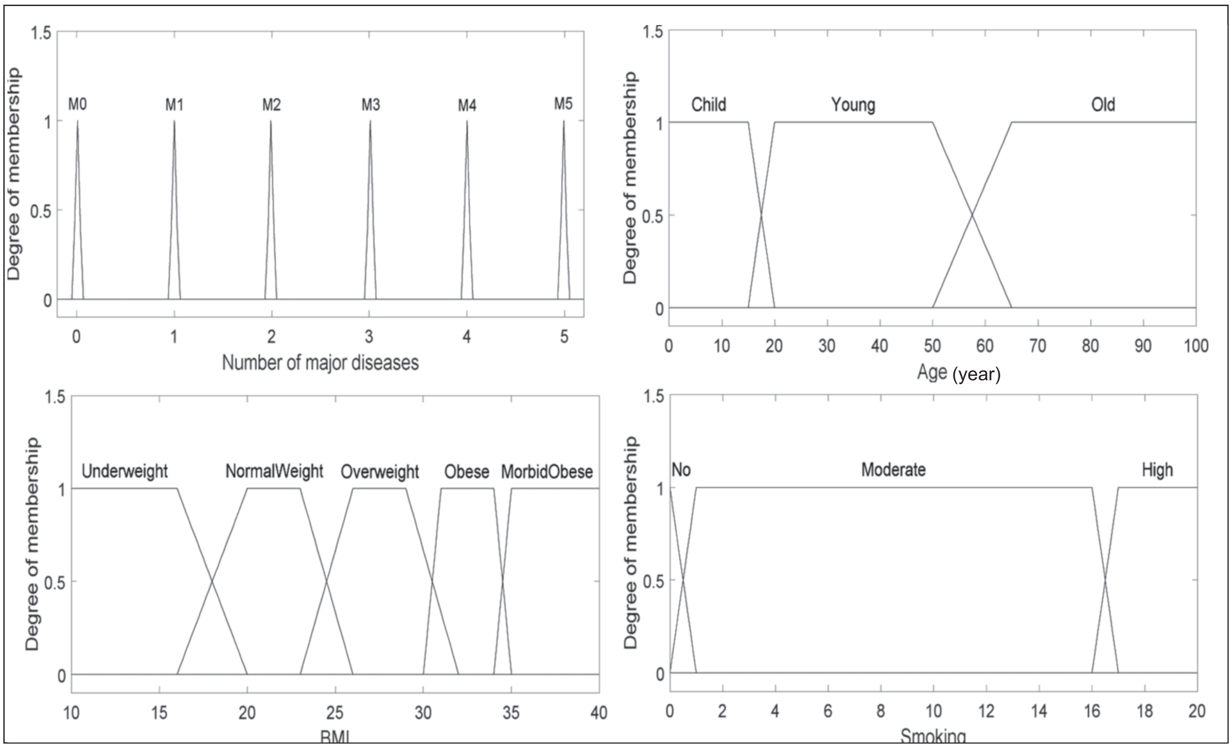

FIGURE 2: Membership functions for the input variables.

patients with high risks.[7] Though there are large number of records in the literature, the number of works for the high-risk patients are really low. Moreover, the is no agreement on the types and numbers of the risk factors.

In present work, we examined the prediction of "high-risk" patients during preoperative anesthetic evaluation using fuzzy inference system.

In various studies: the patients with cardiovascular, pulmonary, renal, liver diseases and diabetes mellitus accepted major high-risk potentially. Additionally, age, obesity and smokers were chosen as minor high-risk criteria.[9,11-13]

In a few works, the American Society of Anesthesiologists (ASA) Physical Status (PS) categorization was used as high-risk factor.[8,14] This one is the most widely used categorization by anesthetists for detection of patient's health status before operation. It is not a risk categorization instead it is an indicator of physical condition. For instance, if a case is categorized as ASA III, it indicates that the patient has a health problem such as diabetus mellitus, hypertension etc, but it does not indicate a high-risk patient. Thus a patient with a high ASA value may not be in the high-risk group. Therefore, we believe that utilizing a categorization, which consists of physical status, is not convenient for risk categorization.[15] Although there are some trials in which the POSSUM value procedure to determine high-risk patients was used, that procedure was not utilized by different works.[16,17]

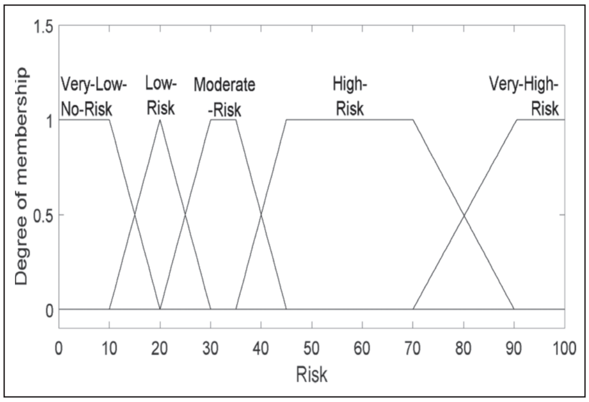

FIGURE 3: Membership functions for the output variable.

TABLE 1: Fuzzy decision rules for risk evaluation in case of one major risk.

Number of Major Diseases	Age	BMI	Smoking	Risk
M1	Child	UW	No	MR
M1	Child	NW	No	MR
M1	Child	OW	No	MR
M1	Child	Ob	No	MR
M1	Child	M-Ob	No	MR
M1	Young	UW	No	MR
M1	Young	NW	No	LR
M1	Young	OW	No	LR
M1	Young	Ob	No	MR
M1	Young	M-Ob	No	MR
M1	Old	UW	No	MR
M1	Old	NW	No	MR
M1	Old	OW	No	MR
M1	Old	Ob	No	MR
M1	Old	M-Ob	No	MR
M1	Child	UW	Moderate	HR
M1	Child	NW	Moderate	MR
M1	Child	OW	Moderate	MR
M1	Child	Ob	Moderate	HR
M1	Child	M-Ob	Moderate	HR
M1	Young	UW	Moderate	MR
M1	Young	NW	Moderate	MR
M1	Young	OW	Moderate	MR
M1	Young	Ob	Moderate	MR
M1	Young	M-Ob	Moderate	MR
M1	Old	UW	Moderate	HR
M1	Old	NW	Moderate	MR
M1	Old	OW	Moderate	MR
M1	Old	Ob	Moderate	HR
M1	Old	M-Ob	Moderate	HR
M1	Child	UW	High	HR
M1	Child	NW	High	HR
M1	Child	OW	High	HR
M1	Child	Ob	High	HR
M1	Child	M-Ob	High	HR
M1	Young	UW	High	HR
M1	Young	NW	High	MR
M1	Young	OW	High	MR
M1	Young	Ob	High	HR
M1	Young	M-Ob	High	HR
M1	Old	UW	High	HR
M1	Old	NW	High	HR
M1	Old	OW	High	HR
M1	Old	Ob	High	HR
M1	Old	M-Ob	High	HR

BMI: Body mass index, MR: Moderate risk, HR: High risk, LR: Low risk.

Kang et al. utilized similar factors to specify high-risk patients like defined in former Salihoglu study's criterion.[18-19] Salihoglu et al. examined the feasibility and safety of laparoscopic colorectal surgery to determine the high-risk patients.[19] They also examined the side effects on patients after the surgery. We chosen our criteria like Salihoglu's adviced criteria. Salihoglu determined five major criteria comprising cardiac, pulmonary, renal or liver disease, and diabetes mellitus and three minor criteria comprising age >70 years, body mass index >30 kg/m^2, and smoking.[19]

The minor criteria were identical in those two works, but Kang et al. did not define all cardiac health problems as a major risk; instead, they defined congestive heart failure, valvular heart disease, and anemia as distinct major risks. Nevertheless, determining all hematological health problems as a major risk in place of anemia alone might be more convenient.

Yucel et al. proposed a risk evaluation method for a hospital information system where the methodology includes analytic networks and fuzzy logic.[20] The algorithm was applied to a training and research hospital. The most important factor was found to be the user's previous hospital information system experience.

Yılmaz et al. proposed a neuro-fuzzy logic model to calculate the risk of getting lung cancer and then some suggestions were provided to eliminate the risk.[21] Dervishi investigated the monitored parameters such as heart rate, invasive blood pressure and oxygen saturation of 127 intensive care unit adult patients and evaluated their usefulness in risk assessment.[22] Monitored data were dimensionally reduced and used to train a support vector machine model, and then risk levels were determined using combination of fuzzy c-means clustering and random forest methods.

Khanmohammadi et al. introduced a new fuzzy method to predict the risk of mortality after cardiac operation and to determine the survival likelihood of patients.[23]

In this study, a risk classification model was developed by combining the risk criteria defined by previous medical studies and clinical experience with a fuzzy logic model in the preoperative period. In order to present the performance of the designed fuzzy logic risk evaluation process, a fictitious group of 10 patients along with their calculated risk values are presented in (Table 2). It is seen that the risk results conforms with the clinical experience.

This developed model needs to be investigated by selecting specific real groups of patients and specific operations. In this way, for example, special patient groups such as laparoscopic colon surgery or congenital heart surgery will have the chance to identify their specific risk classification.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

All authors contributed equally while this study preparing.

TABLE 2: Risk evaluation results.

Patient No	Number of Major Diseases	Age	BMI	Smoking	Risk (%)
1	2	43	19	0	47.6
2	0	70	22	10	20
3	0	30	27	0	7.5
4	5	62	29	10	88.9
5	1	39	30.5	0	27.5
6	2	21	26.5	20	60.3
7	3	55	17.5	15	72.5
8	4	50	36	0	89.5
9	3	60	18.5	0	66.1
10	1	73	23	12	32.5

BMI: Body mass index.

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