ARAŞTIRMA RESEARCH

DOI: 10.5336/mdethic.2021-85397

A Fair Computer Aided Approach in Intensive Care Unit Patient Admission: A Method Research

Yoğun Bakım Ünitesi Hasta Kabulünde Bilgisayar Destekli Adil Bir Yaklaşım: Bir Yöntem Araştırması

Sevim YAĞIZ[a], Barış SANDAL[b], Derya KARABULUT[b], Ziya SALİHOĞLU[c]

[a]Department of Medical History and Ethics, İstanbul University İstanbul Faculty of Medicine, İstanbul, Türkiye
[b]Department of Mechanical Engineering, İstanbul University-Cerrahpaşa Faculty of Engineering, İstanbul, Türkiye
[c]Department of Anesthesiology and Reanimation, İstanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine, İstanbul, Türkiye

ABSTRACT In this study, a novel fuzzy logic approach for intensive care unit (ICU) admission has been aimed to be developed which make use of the principles of medical ethics to help the medical staff's decision and reach a fair priority ranking of patients under coronavirus disease-2019 (COVID-19) pandemics. Determination of the priority rank of candidate patients in justice is very important since the main aim of ICU is to save the patients' lives as many as possible without any ethical accusations. Several medical risk factors have been reported in the literature that affects ICU admission. Age, SaO2 level and additional diseases, which medical experts considered important risk factors during the COVID-19 pandemic, were taken as medical criteria. Medical Ethics Principles of autonomy, beneficence and non-maleficence are taken into consideration together with utilitarian ethical strategy of maximizing number of lives and years saved to reach a fair admittance ranking in fuzzy logic software. The output score of ICU admission was conformed to patients' conditions and expert's decisions. The software developed has been verified to imitate the decision results of ICU experts who obey the ethical principles of autonomy, beneficence, non-maleficence, maximizing the number of lives and years saved for severe pandemic conditions. However, the final judgment must be left to the responsible doctor. The improved approach can simply be extended to various numbers and types of inputs, ethical viewpoints, and pandemic situations.

Keywords: Fair decision; intensive care unit; medical risk factors; medical ethics; fuzzy logic

ÖZET Bu çalışmada koronavirüs hastalığı-2019 [coronavirus disease-2019 (COVID-19)] pandemisi sürecinde yoğun bakım ünitelerine (YBÜ) hasta kabulünde tıp personelinin karar vermesine yardımcı olunması ve adil bir öncelik sıralamasına ulaşılması için tıbbi etik prensiplerini de dikkate alan yepyeni bir bulanık mantıklı yaklaşımın geliştirilmesi amaçlanmaktadır. YBÜ'nün temel amacı mümkün olduğunca çok sayıda hastanın hayatını kurtarmak olduğu için kabul sürecinde aday hastaların öncelik sıralamasının herhangi bir etik suçlama olmaksızın adil bir şekilde tespit edilmesi çok önemlidir. Literatürde, yoğun bakım ünitesine kabulü etkileyen birçok tıbbi risk faktörü vardır. COVID-19 pandemisi sırasında tıp uzmanlarının önemli risk faktörleri olarak değerlendirdiği yaş, SaO2 seviyesi ve kişinin mevcut hastalıkları tıbbi kriterler olarak dikkate alınmıştır. Bulanık mantık yazılımında, otonomi, yararlı olma ve zarar vermeme gibi medikal etik prensipleri kurtarılan hayat sayısını ve yaşanacak yıl toplamını maksimize etme gibi faydacı (utiliterian) ilkelerle beraber dikkate alındı. Yoğun bakım ünitesine yatış karar puanlaması, hastaların durumuna ve uzman kararlarına uyumlu hale getirildi. Geliştirilen yazılımın otonomi, yararlı olma ve zarar vermeme, kurtarılacak hayat sayısını ve yaşanacak yıl toplamını şiddetli pandemi koşulları için maksimize etme gibi etik prensiplere uygun kararlar veren YBÜ uzmanlarının kararlarını yansıttığı doğrulandı. Yine de son kararın sorumlu doktora bırakılması gerekir. Geliştirilen yöntem çeşitli veri girişleri ve tipleri, etik bakış açıları ve pandemik koşullar için kolaylıkla uyarlanabilir.

Anahtar Kelimeler: Adil karar; yoğun bakım ünitesi; tıbbi risk faktörleri; medikal etik; bulanık mantık

The intensive care unit (ICU) is a vital and expensive location when the medical equipment and their maintenance are taken into account.[1] It has gained more importance nowadays. Under normal clinical conditions, all patients have been reached life-supporting care with their free will after being informed or with their pre-submitted testament, unless they refuse the medical support.[2,3] An ultimate goal of

Correspondence: Barış SANDAL
Department of Mechanical Engineering, İstanbul University-Cerrahpaşa Faculty of Engineering, İstanbul, Türkiye
E-mail: bsandal@iuc.edu.tr

Peer review under responsibility of Turkiye Klinikleri Journal of Medical Ethics, Law and History.

Received: 22 Jul 2022 ***Received in revised form:*** 06 May 2022 ***Accepted:*** 15 Jun 2022 ***Available online:*** 21 Jun 2022

2146-8982 / Copyright © 2022 by Türkiye Klinikleri. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

ICU is to save the patients' lives and then recover them since all patients admitted to the ICU have serious health risks. Therefore, choosing a patient for admission to the ICU in justice is essential.[1]

Lots of ethical problems might arise in triage locations. ICU admission for patients is always a crucial and time-consuming decision. The transfer time to the ICU is a significant parameter of the patients' consequences.

Several researches have revealed that delayed determination of clinical deterioration, causing retarded admission to the ICU and, hence, delayed medical therapy, leads to increased mortality.[4,5] However, the intensive and increasing demand for ICUs has been resulted in serious trouble all over the world. Since choosing the right patient for ICU admission is an important decision, healthcare administrators need to develop formulas to cope with the admission of patients who should not be overlooked because of high number of candidates.

Identifying patients who are likely to benefit from ICU admission is challenging. A satisfying and objective decision-making process can be performed depending on the knowledge of the patient's medical record history and having accurate current clinical information.[6] Several risk factors have the potential to affect the determination of the patients for the ICU triage.[7] In literature, the most confounder factors such as chronic comorbidities as major ones of cardiac, pulmonary, renal, liver, and diabetes mellitus and minor ones body mass index (BMI) (≥30 kg/m^2), smoking and others, the patient's age, ICU occupancy, arterial blood oxygen saturation (SaO_2 level), respiratory rate, life-threatening conditions and heart rate have been reported.[7-15] Bates and Young had developed a fuzzy logic algorithm in support of decision-making in the ICU, their proposed model was insufficient for any pandemic case since they considered only arterial blood pressure and urine output.[6] Fernandes et al. used a machine learning approach to determine emergency department patients with a high level of ICU admission.[14] They included the risk parameters that were routinely recorded at triage, such as body temperature, oxygen saturation, heart rate, respiratory rate. The varying characteristics of the diseases depending on the patients make it difficult to determine the patient for admission to the ICU. Moreover, when coronavirus disease-2019 (COVID-19) pandemic conditions were widespread, ICU or ventilatory equipment insufficiency has happened in certain countries such as Italy and the USA.[16] The main criterion in ICU admission is the substantial need of the patient for intense medical care.

The admission process must be totally convincing from ethical point of view. It has been reported in many studies, ICU admission decision has been affected by many non-medical factors such as social position of patient, the affection of personnel towards patients caring infants or elderly parents, the pressure applied by patient companions resulting in violation of important ethical considerations of beneficence of patients, justice in admission, effective life saving performance of the ICU.[17,18]

The search for a method to reach fair non-discriminative decisions in the delivery of life-supporting care medical service under insufficient conditions is the main motivation of this study. From ethical point of view "Four-principle Medical ethics approach of Beauchamp and Childress" has been used together with utilitarian approach whenever ICU insufficiency happens.[18,19]

Fuzzy logic was introduced by Zadeh and was well approved as a decision making method.[20] Since fuzzy logic allows users to model the intuitive and logical informations and experts' experiences, it has been applied in several areas, including medicine.[21,22] Bates and Young applied fuzzy logic using arterial blood pressure and urine output in support of decision-making in the ICU.[6]

Although in most cases the expert decides by taking the experiences and intuitions into account, there is no validated approach for the making decision process. In this study, a fair computer-aided method for the patient admission to the ICU using a fuzzy logic algorithm was aimed to be proposed to perform a fair and elegant priority ranking among disparate patients. To reach this aim, major important medical patient data of SaO_2, age and the comorbidities are taken into consideration in ICU admission having fuzzy logic algorithm imitating the very eminent related experts' decision logic.

MATERIAL AND METHODS

Among the various admission parameters to ICU in general, medical people primarily have advised 3 significant medical risk factors, which were age, SaO_2 level and comorbidities to COVID-19 among others.[7,9-11,13] On the other hand, when they have revised their decision process in case of ICU insufficiency of COVID-19 and they have used additional criteria such as recovery possibility, minimizing the ICU bed occupancy time before recovery, maximizing the year of lives saved and saving most lives using the medical risk factors. It is obvious that ICU people have used utilitarian approach in case of ICU insufficiency thinking that "the greatest good for the greatest number".[18] In this study, the medical data for patients such as age, SaO2 and disease are produced for hypothetical ICU candidates to verify the success of the software improved. The study has been carried out convenient to Principles of Declaration of Helsinki.

MEDICAL ETHICS

In this study, using the novel fuzzy logic approach improved has been offered in decision process of selecting and priority ranking of patients who confirm the medical care under normal or difficult pandemic circumstances for ICU staff. To reach correct decisions from ethical point of view, Biomedical Ethics Principles of Beauchamp and Childress have been used together with utilitarian approach whenever the ICU insufficiency arises.[19]

Four principles method enables one to reach a compromising, easily applicable result and has been preferred in clinical daily life. The first principle for respect of autonomy enables the patient as an autonomous person in reaching medical care to protect his/her right to make decisions about his own life. Therefore, patients' approval will be the start of the algorithm improved. The second and third ones are the principle of beneficence which emphasizes the helpfulness for the patient and the principle of non-maleficence which aims to prevent damage or to get rid of the results of the damage. These principles will be taken into care in outputs of the software. The aid of medical care must be more than the damage it causes or at least there must be a balance in between. Therefore, arterial blood oxygen saturation, the accompanying major and minor diseases and the age of ICU candidates have been considered as fuzzy logic inputs by keeping in mind the goal to reach a life supporting benefit for the patients. They result in a guarantee for patients not to be exposed the discrimination because of future disability or poor life quality expectancy for them, social or other reasons as an egalitarian approach in justice. In fact, in literature some non-medical discriminative unfair criteria have been reported to be effective such as expected after treatment life quality, the chance of scientific progress, the job of patient, the existence of disabled people who patient supports leaving behind many ethical problems.[23] Ethical studies emphasizes the application of the fourth principle of justice in resource scarcity or public health crises with a strategy of distribution of sources according to need and utilitarian approach of maximization of benefit.[18,19,24]

After considering the arguments above, widely accepted ethical measures for any pandemic, which are surviving probability, discharge period expectancy and life-cycle principle (years to live by reaching an equality in individuals' whole life-cycle) will be used in the design of the decision algorithm.[18] The decision process of experts and the fuzzy logic algorithm imitating the experts' thinking will be strictly forced to obey these principles representing the utilitarian approach when at the same time taking care of medical inputs of age, SaO_2 level and comorbidities, which also stand for principles of justice, beneficence and non-maleficence of Beauchamp and Childress for COVID-19 ICU insufficiency.

FUZZY-LOGIC DECISION MAKING

The personal experience and conventional wisdom of the medical experts were aimed to be represented by using fuzzy logic rule tables. Three inputs and one output were established. The most common way to represent human knowledge is to split it into natural expressions of the type IF-THEN rule-based form.[25] Therefore, the fuzzy model was consisted of a set of rules with an "IF-THEN" structure:

IF <input 1> and <input 2>, and < input 3> THEN <output>

In this statement <input 1>, <input 2>, and <input 3> represented the input membership functions and <output> identified the value of real-world decision.

The fuzzy logic decision system contained 3 main components. These are fuzzification, fuzzy inference, and defuzzification.[26] These steps performed by the fuzzy logic system were explained in subsections. In fuzzification step, the membership functions for all input and output variables were defined. Using the method of inference, the rule base was constructed with the predefined fuzzy rules which were relied on the knowledge regarding the system characteristics obtained from the experts. After the inference stage, since the calculated results were fuzzy values, they must be converted to certain values with defuzzification.

In this study, a brand-new fuzzy system for the admission of the patients to the ICU was designed. Therefore, a fuzzy logic model was created as shown in Figure 1. The model consists of 3 fundamental sections: fuzzification, inference, and defuzzification. It includes 3 inputs and one output.

The membership functions of the inputs are given in Figure 2. Their ranges were determined by getting information from ICU experienced doctors. The first variable is the age and categorized as young, middle-aged, and old. Patients were also categorized according to their SaO_2 level as serious hypoxemia, medium hypoxemia, slight hypoxemia and normal.

The last parameter was selected as the comorbidities of the patients to the COVID-19 and classified into three degrees (absent, moderate, and serious). For the patient comorbidities, major and minor criteria were defined. Cardiac, pulmonary, renal and liver disease and diabetes mellitus were considered as major criteria while BMI (≥30 kg/m^2), smoking and others were selected as minor criteria.[8] Major and minor diseases were quantified with additive scores provided in Table 1.

Total comorbidity score were calculated by taking into account the grades of major and minor diseases if patients have. The fuzzy logic decision output is presented in Figure 3.

In order to build the rule base for the admission of the patients to the ICU, the influence of each parameter on the admission of the patients to the ICU was determined based on the experiences of the experts. When looking at the age, SaO_2 level and comorbidities of the patients, the ICU experts have reached decisions estimating the surviving probability, discharge period expectancy and life-cycle principle based years (years to live by reaching an equality in individuals' whole life-cycle).[18] It must be noted that, when the medical inputs above are satisfying the principles of justice, beneficence, non-maleficence; the estimation of surviving probability, discharge period and life-cycle principle satisfy a utilitarian approach in case of COVID-19

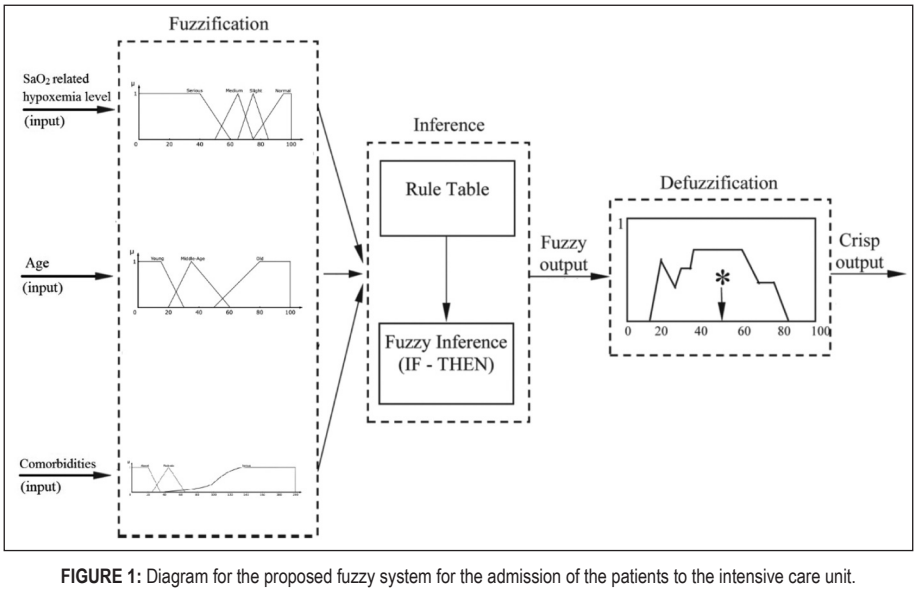

FIGURE 1: Diagram for the proposed fuzzy system for the admission of the patients to the intensive care unit.

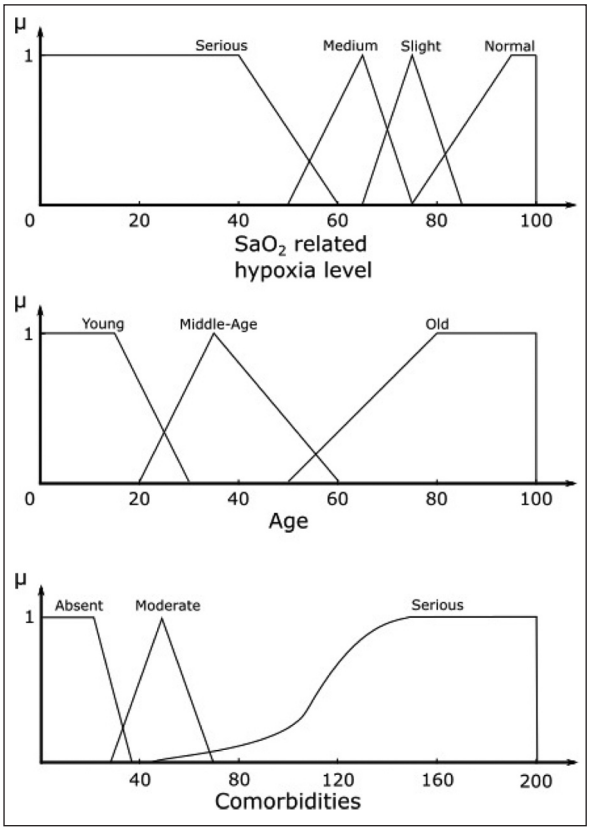

FIGURE 2: Membership functions SaO_2, age, and patients diseases for the input variables.

TABLE 1: Additive score of the major and minor diseases to be used in third input of fuzzy decision.

Number of major comorbidities	Score	Number of minor comorbidities	Score
1	50	1	5
2	80	2	10
3	120	3	15
4+	170	4	20

based ICU insufficiency. The proposed fuzzy system had 36 rules (Table 2). For instance, an old patient with a serious hypoxemia SaO_2 level and serious comorbidities was considered, then the decision was the admission of the patient to the ICU unit. For the second case, a young patient with normal SaO_2 level and no comorbidities, then the decision was a clinical follow-up. One of the well-known and accepted defuzzification methods, the centroid method that is based on computing the centroid of the output area was chosen in the defuzzification step.[27] As a result, a fuzzy logic algorithm has been improved to obtain a priority ranking in case of insufficient conditions in accordance with medical ethics. The experts whom thinking the fuzzy logic imitates have taken "surviving possibility, discharge period and life-cycle principle" into consideration in their decision implicitly.

RESULTS

The scores of the patients for admission to the ICU unit obtained using fuzzy logic algorithm were given in Table 3. The age, SaO_2 and disease data for hypothetical ICU candidates tabulated in Table 3 is obtained from the head of an ICU care unit having 36 beds. Some critical possible patient data representing the pandemic conditions is asked from him to force and test the success of the computer programming software improved. Taking into consideration the SaO_2, age and comorbidities aims to satisfy the principle of justice since it helps to get rid of the non-medical social and physiological effects and also aims to satisfy the principle of beneficence and non-maleficence. On the other hand, the surviving probability, discharge period expectancy and life-cycle principle based years (years to live by reaching an equality in individuals' whole life-cycle) are instructed to the expert and asked him to take them into consideration together with medical inputs in order to have Fuzzy Logic Software imitate his decision algorithm successfully satisfying the utilitarian approach for insufficient ICU facilities. Therefore, the fuzzy logic ICU admission score at Table 3 can be accepted as resulting a fair patient priority ranking for ICU admission for COVID-19 pandemic. Priority order is decided from high score to low score. In tabulating this table, first experts' emergency scores have been asked for these 5 hypothetical patients and then fuzzy logic algorithm has been run on computer.

Agreement between both scores was evaluated by Passing-Bablok regression analysis.[28] The scores obtained from proposed fuzzy logic algorithm were highly positive correlated with those obtained from expert having r=0.993 and p=0.001. r and p are cor-

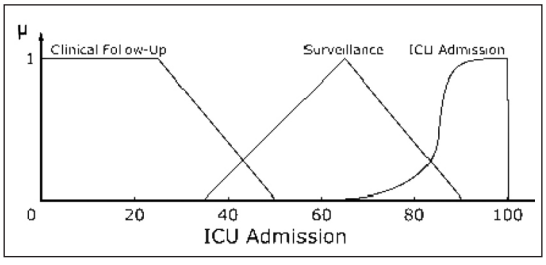

FIGURE 3: Membership functions for the output variable ICU admission decision. ICU: Intensive care unit.

relation coefficient and CUSUM test p value respectively as presented in Figure 4.

Thus, the ICU expert imitation success of computer aided fuzzy logic score ranking has been verified by almost perfect match when compared with ICU expert's one.

DISCUSSION

The scores on Table 3 needs a detailed analysis. On Table 3, though, patient 1 has low SaO_2 level, since he does not have any major comorbidities, has low age and low possibility of death because of his age, he is scored at a low level because of the utilitarian point of view, because he is not under danger very much and there are more vital ones to be saved. On the other hand, though the age of patient 5 is the highest having no major comorbidities, he has the highest priority score since he can be saved and need the most urgent action. Patient 2 who has the highest SaO_2 level and 2 major comorbidities, has the lowest score since he is in low-middle age period. Because because of his medical records, he does not need urgent intervention. The utilitarian thought of saving more lives and years to live is in action again. Table 3 has shown that the patients having low danger of death (depending on their medical records) are reaching low priority score whereas the patients with high risk of danger are gaining priority since they are possible to be saved.

The decision of the experts and the software developed states in Table 3 that SaO_2 and comorbidities are the most important factors affecting the urgency scores, they satisfy principle of justice since non-medical social pressure is not effective to break a fair decision. On the other hand, for the insufficient ICU facilities, the utilitarian approach of maximizing the number of lives and the years saved is to be effective. Of course, it must be noted that the fuzzy logic software puts the patients out of ranking who refuses medical treatment according to legislations as well as the patients who cannot be saved in any case. The software is designed to be valid for the ICU insufficiency for COVID-19 pandemic. But it is also very important to note that, since there has not been any ICU insufficiency resultant death in Türkiye during the peak times of COVID-19 pandemic, the effect of the utilitarian approach is very little effective in ICU allocation priority ranking in this study. Because the ICU expert who was the source of the decision algorithm of the fuzzy logic software did not witnessed such a death toll and drama resulting in ICU insufficiency which was the case in certain countries. Of course it is very easy to update the fuzzy logic software increasing the effect of utilitarian strategy for such catastrophic times.

In this study, it has been aimed to develop a computer-aided approach based on a fair and elegant patient priority ranking for ICU admission in justice depending on patients' medical data as well as four principles of medical ethics which are autonomy, justice (goal of this study), beneficence and non-maleficence together with justified utilitarian strategy of maximizing number of lives and years saved. Medical patient data obtained have been given to ICU experts and for hard pandemic conditions, they have been asked their decisions obeying the 4 principle and utilitarian strategy. Then software has been designed such that it gives a much closed admittance ranking to ICU.

The resultant ranking of the software developed will be accessed with the studies available in literature where several factors were reported to be important for ICU admission. One of the most important parameters of the clinical decision process was patients' age, but sole use of it might cause misleading. In this study, ICU admission score increased by age on condition that utilitarian approach of saving more lives and maximizing the sum of saved years is satisfied for severe pandemic conditions, as is the case for patient no. 3. Kim et al. and Vergano et al. found that the age of the patients with COVID-19 was one of the highest risk factors for ICU admission.[11,29] How-

TABLE 2: Fuzzy decision rules considering the age, SaO_2, and comorbidities for ICU patient admission.

Age	SaO_2 related hypoxemia	Comorbidities	ICU admission*
Young	Serious	Absent	ICU admission
Young	Serious	Moderate	ICU admission
Young	Serious	Serious	ICU admission
Middle age	Serious	Absent	ICU admission
Middle age	Serious	Moderate	ICU admission
Middle age	Serious	Serious	ICU admission
Old	Serious	Absent	ICU admission
Old	Serious	Moderate	ICU admission
Old	Serious	Serious	ICU admission
Young	Medium	Absent	Surveillance
Young	Medium	Moderate	ICU admission
Young	Medium	Serious	ICU admission
Middle age	Medium	Absent	Surveillance
Middle age	Medium	Moderate	ICU admission
Middle age	Medium	Serious	ICU admission
Old	Medium	Absent	ICU admission
Old	Medium	Moderate	ICU admission
Old	Medium	Serious	ICU admission
Young	Slight	Absent	Clinical follow up
Young	Slight	Moderate	Surveillance
Young	Slight	Serious	Surveillance
Middle age	Slight	Absent	Surveillance
Middle age	Slight	Moderate	ICU admission
Middle age	Slight	Serious	ICU admission
Old	Slight	Absent	ICU admission
Old	Slight	Moderate	ICU admission
Old	Slight	Serious	ICU admission
Young	Normal	Absent	Clinical follow up
Young	Normal	Moderate	Surveillance
Young	Normal	Serious	Surveillance
Middle age	Normal	Absent	Clinical follow up
Middle age	Normal	Moderate	Surveillance
Middle age	Normal	Serious	Surveillance
Old	Normal	Absent	Surveillance
Old	Normal	Moderate	ICU admission
Old	Normal	Serious	ICU admission

*The surviving probability, discharge period expectancy and life-cycle principle based years (years to live by reaching an equality in individuals' whole life-cycle) are taken into consideration together with medical inputs in design; ICU: Intensive care unit.

ever, Vergano et al. and Marik also reported that the effect of age should be evaluated with other influential factors.[9,29] These studies are also consistent with the score of patients in Table 3.

SaO_2 level was another influential factor that was considered in this study. Mukhtar et al. and Assandri et al. revealed that the SaO_2 level of the patients is a critical parameter for ICU admission.[13,30] In this study, patients with higher SaO_2 levels were quantified with lower ICU admission scores when compared to those with lower SaO_2 levels. This consequence was in harmony with other researches.

TABLE 3: Fuzzy logic ICU admission scores and expert's scores.

			Comorbidities			
Patient no.	SaO_2	Age	Number of minor diseases	Number of major diseases	Expert's* scores (%)	ICU admission score (%)
1	55	18	0	0	75	78.5
2	70	40	0	2	65	65
3	65	54	1	2	85	86.4
4	60	68	2	1	85	85.9
5	55	82	3	0	90	92

*Expert estimates the surviving probability, discharge period expectancy and life-cycle principle based years (years to live by reaching an equality in individuals' whole life-cycle) and reaches his scores. The fuzzy logic imitates his decision process; ICU: Intensive care unit.

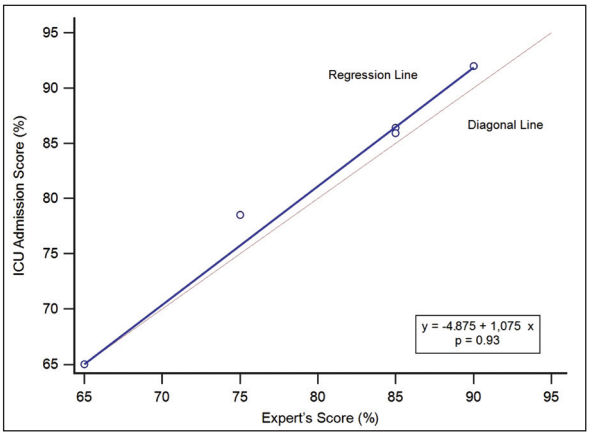

FIGURE 4: Comparison of expert's score and ICU admission score with Passing-Bablok analysis. ICU: Intensive care unit.

Comorbidities, especially major ones with COVID-19 cause patients to be in the-high risk category. That complicates the decision-making process of ICU admission. The fuzzy logic algorithm developed in this study estimates the higher ICU admission scores when the numbers of comorbidities of the patients increases. Valley et al. and Kim et al. reported that patients with comorbidities were the most suitable candidates for the ICU.[11,31] This finding is also reflected in Table 3.

The proposed Fuzzy Logic Decision Making Algorithm is applicable to serious conditions of ICU occupancy at the existence of large number of COVID-19 patients using utilitarian approach.

Non-medical factors such as social position of patient, the affection of personnel towards patients caring infants or elderly parents, the pressure applied by patient companions resulting in violation of important ethical considerations such as beneficence of patients, justice in admission, effective life saving performance of the ICU do not exist in the fuzzy logic decision making algorithm improved.[17] Solely depending on the evaluation background of ICU experts and their knowledge in testing the fuzzy logic ICU priority scores, it has been verified that the proposed computer aided patient admission approach is highly successful in representing the fair decisions of eminent ICU experts depending on only medical criteria such as SaO_2, age and the comorbidities as well as ethical ones. It must be noted that the proposed Fuzzy Logic Decision Making Algorithm is applicable to serious conditions of ICU occupancy at the existence of large number of COVID-19 patients using utilitarian approach. It is expected that the results of this method improved will help ICU personnel a lot in reaching hard decisions under pandemic conditions of COVID-19.

CONCLUSION

The research presents a computer aided decision-making approach to assist physicians during ICU admission. The proposed method is capable of fair decisions in seconds since it depends on only medical measures. The results verify for all patients, the urgency scores calculated using the proposed fuzzy logic algorithm are compatible with those of the ones determined by ICU expert. It was also understood that the SaO_2 level had a substantial effect on outcomes. Occupancy policy of the ICU can be evaluated with the fuzzy model developed. Even if the same algorithm is to be used at high demand rates, it is applicable to hard pandemic conditions since it presents a patient priority ranking for ICU admission

in justice resulting of patients' medical data based ethical principles of beneficence, non-maleficence together with utilitarian ones of maximizing the number of saved lives and years. As a result, the ICU medical staff can enter the age, SaO_2 level and comorbidities of the ICU candidates of pandemic conditions into the computer program and obtain a fair ranking priority of patients on display before reaching a final decision by getting rid of any non-medical effects and ethical accusations.

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

Idea/Concept: *Sevim Yağız, Derya Karabulut, Barış Sandal;* ***Design:*** *Sevim Yağız, Derya Karabulut, Barış Sandal;* ***Control/Supervision:*** *Ziya Salihoğlu;* ***Data Collection and/or Processing:*** *Derya Karabulut, Barış Sandal, Ziya Salihoğlu;* ***Analysis and/or Interpretation:*** *Sevim Yağız, Derya Karabulut, Barış Sandal, Ziya Salihoğlu;* ***Literature Review:*** *Sevim Yağız, Derya Karabulut, Barış Sandal;* ***Writing the Article:*** *Derya Karabulut, Barış Sandal, Sevim Yağız;* ***Critical Review:*** *Ziya Salihoğlu.*

REFERENCES

1. Moridani MK, Setarehdan SK, Nasrabadi AM, Hajinasrollah E. A novel approach to mortality prediction of ICU cardiovascular patient based on fuzzy logic method. Biomed Signal Process Control. 2018;45:160-173. [Crossref]
2. Tanner C. Decision making about end of life care: advance directives, durable power of attorney for healthcare, and talking with patients with heart disease about dying bt - end-of-life care in cardiovascular disease. In: Goodlin SJ, Rich MW, eds. End-of-Life Care in Cardiovascular Disease. 1st ed. London: Springer London; 2015. p.21-32. [Crossref]
3. Fischer GS, Tulsky JA, Arnold RM. Advance directives and advance care planning. In: Post SG, ed. Encyclopedia of Bioethics. 3rd ed. Vol 1. New York: Macmillan Reference USA; 2004. p.74-9.
4. Liu V, Kipnis P, Rizk NW, Escobar GJ. Adverse outcomes associated with delayed intensive care unit transfers in an integrated healthcare system. J Hosp Med. 2012;7(3):224-30. [Crossref] [PubMed]
5. Young MP, Gooder VJ, McBride K, James B, Fisher ES. Inpatient transfers to the intensive care unit: delays are associated with increased mortality and morbidity. J Gen Intern Med. 2003;18(2):77-83. [Crossref] [PubMed] [PMC]
6. Bates JH, Young MP. Applying fuzzy logic to medical decision making in the intensive care unit. Am J Respir Crit Care Med. 2003;167(7):948-52. [Crossref] [PubMed]
7. Baruch M, Messer B. Criteria for intensive care unit admission and severity of illness. Surg. 2015;33(4):158-64. [Crossref]
8. Salihoglu Z, Baca B, Koksal S, Hamzaoglu IH, Karahasanoglu T, Avci S, et al. Analysis of laparoscopic colorectal surgery in high-risk patients. Surg Laparosc Endosc Percutaneous Tech. 2009;19(5):397-400. [Crossref] [PubMed]
9. Marik PE. Should age limit admission to the intensive care unit? Am J Hosp Palliat Care. 2007;24(1):63-6. [Crossref] [PubMed]
10. Azoulay É, Beloucif S, Guidet B, Pateron D, Vivien B, Le Dorze M. Admission decisions to intensive care units in the context of the major COVID-19 outbreak: local guidance from the COVID-19 Paris-region area. Crit Care. 2020;24(1):293. [PubMed] [PMC]
11. Kim L, Garg S, O'Halloran A, Whitaker M, Pham H, Anderson EJ, et al. Risk factors for intensive care unit admission and in-hospital mortality among hospitalized adults identified through the US Coronavirus Disease 2019 (COVID-19)-Associated Hospitalization Surveillance Network (COVID-NET). Clin Infect Dis. 2021;72(9):e206-e14. [Crossref] [PubMed] [PMC]
12. Mathews KS, Durst MS, Vargas-Torres C, Olson AD, Mazumdar M, Richardson LD. Effect of emergency department and ICU Occupancy on admission decisions and outcomes for critically ill patients. Crit Care Med. 2018;46(5):720-7. [Crossref] [PubMed] [PMC]
13. Mukhtar A, Rady A, Hasanin A, Lotfy A, El Adawy A, Hussein A, et al. Admission SpO2 and ROX index predict outcome in patients with COVID-19. Am J Emerg Med. 2021;50:106-10. [Crossref] [PubMed] [PMC]
14. Fernandes M, Mendes R, Vieira SM, Leite F, Palos C, Johnson A, et al. Predicting Intensive Care Unit admission among patients presenting to the emergency department using machine learning and natural language processing. PLoS One. 2020;15(3):e0229331. [Crossref] [PubMed] [PMC]
15. Harutyunyan G, Hauer L, Dünser MW, Moser T, Pikija S, Leitinger M, et al. Risk factors for intensive care unit admission in patients with autoimmune encephalitis. Front Immunol. 2017;8:835. [Crossref] [PubMed] [PMC]
16. White DB, Lo B. A framework for rationing ventilators and critical care beds during the COVID-19 pandemic. JAMA. 2020;323(18):1773-4. [Crossref] [PubMed]
17. Halvorsen K, Førde R, Nortvedt P. The principle of justice in patient priorities in the intensive care unit: the role of significant others. J Med Ethics. 2009;35(8):483-7. [Crossref] [PubMed]
18. White DB, Katz MH, Luce JM, Lo B. Who should receive life support during a public health emergency? Using ethical principles to improve allocation decisions. Ann Intern Med. 2009;150(2):132-8. [Crossref] [PubMed] [PMC]

19. Beauchamp TL, Childress JF. Principles of Biomedical Ethics. 8th ed. New York: Oxford University Press; 2019.
20. Zadeh LA. Fuzy sets. Inf Control. 1965;8(3):338-53. [Crossref]
21. Goode KM, Linkens DA, Bourne PR, Cundill JG. Development of a fuzzy rule-based advisor for the maintenance of mechanically ventilated patients in ICU: A model-based approach. Biomed Eng: Applic Basis Commun. 1998;10(4):236-46. [Link]
22. Davoodi R, Moradi MH. Mortality prediction in intensive care units (ICUs) using a deep rule-based fuzzy classifier. J Biomed Inform. 2018;79:48-59. [Crossref] [PubMed]
23. Akpınar A, Ersoy N. Justice in intensive care: what admission/discharge criteria are used by intensive care practitioners in Turkey? Turk J Anaesthesiol Reanim. 2011;39(3):115-25. [Crossref]
24. Emanuel EJ, Persad G, Upshur R, Thome B, Parker M, Glickman A, et al. Fair allocation of scarce medical resources in the time of Covid-19. N Engl J Med. 2020;382(21):2049-55. [Crossref] [PubMed]
25. Ross TJ. Fuzzy Logic with Engineering Applications. 3rd ed. Chichester, U.K.: John Wiley & Sons; 2010. [Crossref]
26. Mendel JM. Fuzzy logic systems for engineering: a tutorial. Proc IEEE. 1995;83(3):345-77. [Crossref]
27. Seongwon S, Toshiya A, Yongwoo H, Keisuke H. Evaluation of solid waste management system using fuzzy composition. J Environ Eng. 2003;129(6):520-31. [Crossref]
28. Passing H, Bablok. A new biometrical procedure for testing the equality of measurements from two different analytical methods. Application of linear regression procedures for method comparison studies in clinical chemistry, Part I. J Clin Chem Clin Biochem. 1983;21(11):709-20. [Crossref] [PubMed]
29. Vergano M, Bertolini G, Giannini A, Gristina GR, Livigni S, Mistraletti G, et al. SIAARTI recommendations for the allocation of intensive care treatments in exceptional, resource-limited circumstances. Minerva Anestesiol. 2020;86(5):469-72. [Crossref] [PubMed]
30. Assandri R, Buscarini E, Canetta C, Scartabellati A, Viganò G, Montanelli A. Laboratory biomarkers predicting COVID-19 severity in the emergency room. Arch Med Res. 2020;51(6):598-9. [Crossref] [PubMed] [PMC]
31. Valley TS, Sjoding MW, Ryan AM, Iwashyna TJ, Cooke CR. Intensive care unit admission and survival among older patients with chronic obstructive pulmonary disease, heart failure, or myocardial infarction. Ann Am Thorac Soc. 2017;14(6):943-51. [Crossref] [PubMed] [PMC]