Ali Abbasov
Kamil Aida-zade (Eds.)

BOOK OF SELECTED PAPERS

6th International Conference on Problems of Cybernetics and Informatics

PCI 2025

August 25-28, 2025
Baku, Azerbaijan

Ali Abbasov
Kamil Aida-zade
Editors

BOOK OF SELECTED PAPERS

6th International Conference on

Problems of Cybernetics and Informatics

PCI 2025

August 25-28, 2025
Baku, Azerbaijan

Table of Contents

Clinical Decision Support System for Hepatocellular Carcinoma Treatment Selection

Masuma Mammadova
Department No. 11 Institute of Information Technology of MSERA
Baku, Azerbaijan
mmg51@mail.ru
0000-0002-2205-1023

Nuru Bayramov
I Department of Surgical Diseases of Azerbaijan Medical University
Baku, Azerbaijan
nurubay2006@yahoo.com,
0000-0001-6958-5412

Zarifa Jabrayilova
Department No. 11 Institute of Information Technology of MSERA
Baku, Azerbaijan
djabrailova_z@mail.ru
0000-0002-9661-5805,

Minara Manafli
Department No. 11 Institute of Information Technology of MSERA
Baku, Azerbaijan
minulya@rambler.ru

Mehriban Huseynova
I Department of Surgical Diseases of Azerbaijan Medical University
Baku, Azerbaijan
mehribanhuseynova9@gmail.com

***Abstract*—The article presents an algorithm for creating an intelligent physician decision support system regarding the initial treatment selection for hepatocellular carcinoma (HCC), which is the 5th-6th most common cancer. HCC is determined by a large number of parameters, and according to the values they can receive, resection, transplantation, ablation, embolization, systemic treatment, symptomatic treatments are selected according to the staged classical approach to the HCC treatment based on the clinical situations that arise. The large number, complexity, quantitative and qualitative character of the input parameters symbolizes the choice of treatment for HCC as a difficult formalized issue and makes the development of an intelligent system for its solution relevant. In this regard, this article solves the issue of integrating the doctors' knowledge collected in a multidisciplinary consultation into the knowledge base of the intelligent system for the individual choice of treatment for HCC, and develops the working principle and implementation algorithm of the system's architectural components.**

Keywords*—*hepatocellular carcinoma; treatment selection; intelligent physician decision support system; descriptive model of knowledge.

INTRODUCTION

Among the most widespread malignant liver tumors, HCC is one of the main causes of cancer-related death in the world [1]. HCC is rated 5-6th in terms of incidence among cancers. HCC is diagnosed in about one million people worldwide every year [2]. HCC, the most widespread among malignant liver tumors, reveals in various clinical conditions and is often mistaken for hepatitis and cirrhosis [3]. The main diagnostic sign of HCC is contrast retention in the arterial phase and contrast washout in the venous phase. It is most common in people aged 60-70 and mainly in males (2.5 times more often than in females). In some risk countries (Far East, Africa), it is more often observed in people aged 30-40. HCC is a progressive and irreversible process and, if not treated, causes complications and lethality within a few months. The following methods are used in the treatment of HCC [4-6]:

- Surgical treatments - liver resection and transplantation;
- Loco-regional treatments – ablations (thermal, electro and chemical destructions), intraarterial embolization (chemoembolization, radioembolization), radiotherapy, arterial infusions;
- Systemic anticancer treatments (targeted, immunotherapy, cytotoxic chemotherapy);
- Symptomatic treatments.

Liver resection, transplantation and ablations of small tumors are considered radical treatments of HCC. Loco-regional and systemic methods aim to reduce tumor progression and aggressiveness. Indications for liver resection in HCC are as follows:

- Tumor is resectable – according to its bio-behavior, it is suitable for surgery, there is no metastasis or it can be removed, the tumor can be completely removed and the blood supply of the remaining liver is preserved, there is no invasion of large vessels and surrounding organs;
- The liver is resectable – it has sufficient reserves (no or minimal parenchymal disease and dysfunction – Child A, MELD<9, ISG<35, Elastography<12), there is no portal hypertension, the remaining liver volume is sufficient (more than 30% in normal liver, more than 50% in cirrhosis);
- The patient is operable – comorbidities and performance allow surgery.

The indications for liver transplantation in HCC are as follows:

- The tumor is transplantable – the tumor can be removed, the tumor has a favorable bio-behavior (low aggressiveness): its size is less than 5 cm, its number is less than 3, there is no invasion or metastasis to large vessels, lymph nodes, or surrounding organs, AFP (α-fetoprotein is a primary liver cancer marker) level is below 200-400.
- Transplantation is possible – there is a donor organ, there are no contraindications to immunosuppression and pulmonary hypertension.
- The patient is operable – concomitant diseases and performance allow surgery and immunosuppression.

In the presence of contraindications to surgery, that is, signs of unresectable, non-transplantable, and inoperability, resection and transplantation are considered contraindicated. In general, the classical approach to the treatment of HCC takes into account the stage of the disease, the tumor's bio-behavior, the liver's condition, the patient's general status, and the effectiveness of the method [7-9].

The first choice in treatment is radical methods (resection, transplantation), the second choice is locoregional treatments (ablation, embolization), the third choice is systemic anticancer therapies, and the last choice is symptomatic treatment. For the general approach algorithm, international classifications (clinical, NCCN, Barcelona, Milan, Malatya, etc.) are recommended, and for the individual treatment selection, discussion in a multidisciplinary council is suggested. The above shows that a large number of parameters refers to in the treatment selection of HCC, which is represented by various clinical symptoms. According to the clinical situations arising from the various combinations of values that these parameters can take, one of the above treatment methods is selected in the multidisciplinary council for stage-based treatment selection.

The large number, complexity, hierarchy, and both quantitative and qualitative nature of the referred parameters justify the fact that the issue of HCC treatment selection is realized in an uncertain environment, and necessitates the development of an intelligent system based on the knowledge of medical specialists.

The creation of such a system requires the development of its architectural and technological principles, the integration of knowledge received from medical specialists into the system, and the algorithm for implementing the system. The presented article is devoted to solving these problems.

Review Of Related Works

Although today, with the application of information technologies and artificial intelligence methods, a traditional methodology has been developed for building medical decision support systems in various fields of medicine [10], there are no instrumental tools in the literature for medical decision support to select treatment for HCC. [11] presents the functioning principles of a medical decision support system for the diagnosis of liver diseases in a local environment. The system includes a knowledge base consisting of 28 rules generated based on the expert physician's knowledge in the diagnosis of liver diseases, a conclusion block, and an interface block. Although the automation of the diagnostic decision-making process related to liver disease is solved in this system, the system doesn't support the decision-making process related to specific diseases such as hepatitis, obesity, cirrhosis, and HCC. [12] describes a complex approach based on principal component analysis and K-nearest neighbors methods in the creation of a liver disease diagnostic system. [13] develops models based on artificial neural networks for the detection of hepatitis disease.

[14] develops a semi-automatic segmentation method for liver tumors, [15] uses fuzzy logic to solve the classification of hepatobiliary diseases. [16] performs the integration of artificial neural networks and fuzzy logic to detect liver diseases, [17] applies the integration of artificial neural networks and fuzzy logic to increase the accuracy of liver disease classification, and [18] uses the integration of artificial neural networks and fuzzy logic to evaluate the accuracy of hepatitis prognosis in addition to the classification of liver diseases. In [19], the integration of artificial neural networks and genetic algorithms is performed to detect liver diseases and stabilize liver fibrosis in chronic hepatitis. In [20], the integration of fuzzy logic and genetic algorithms is used to detect liver diseases, and in [21], the integration of artificial neural networks and genetic algorithms is used to make decisions about liver transplantation. In [22], the possibilities of using machine learning methods for predicting HCC are studied, and the results of the research conducted to select the most effective method are presented. Apparently, these studies generally examined the possibilities of solving various problems with the application of intelligent technologies in liver diseases. The solution of the problem of building intelligent systems based on the knowledge of medical specialists for the diagnosis and selection of treatment methods for HCC, the most widespread among malignant liver tumors, was not considered. In [23-25], it is substantiated that the parameters used for the diagnosis of HCC are multifactorial, manifest themselves with weak and atypical symptoms, information is incomplete and inaccurate, and the decision-making process takes place in terms of uncertainty. In [23], fuzzy rule-based conceptual model of a system based on the decision tree approach for the diagnosis of HCC, namely, the production and logical model of fuzzy logic and knowledge description, is given, and in [24], the mechanisms for transforming knowledge obtained from medical experts into rules based on the production model for the determination of HCC stages, and the formation of the knowledge base of the diagnostic system are developed. The logical continuation of these studies is the development of the functioning principles of an expert system for the diagnosis of HCC [25].

The **purpose of the present work** is to develop a methodology for creating an intelligent physician decision support system using a classical stage-based approach in the selection of HCC treatment.

Result

To achieve the goal set, it is intended to solve the issues of developing and practical implementation of an intelligent support system for the selection of treatment for HCC, that is, the classification of all possible clinical situations of HCC into resection, transplantation, ablation, embolization, systemic and symptomatic treatment.

The intelligent support system for the selection of HCC treatment consists of a database (DB), a knowledge base (KB), inference engine (IE) and an interface block that provides mutual communication between the user and the system. The intended goal is possible to be achieved, when these components interact in a single system. Thus, the solution to the problem is implemented in the following sequence.

Building a database of an intelligent support system for the selection of HCC treatment

The knowledge of the medical specialists of the First Surgical Diseases Clinic of the Azerbaijan Medical University and the classical approach to decision-making are used as a source of knowledge for building an intelligent support system for the selection of HCC treatment.

In the treatment selection of HCC, 44 parameters are referred to, the names of some of which, the values they can take and the conventional designations are presented in Table 1. In the treatment selection of HCC, a database (working memory) of the intelligent system is generated to store the examination data and their current values.

Building a knowledge base of the intelligent support system for the selection of HCC treatment

Consequently, based on the possible values of 44 examination data, shown in Table 1, the knowledge (judgments) obtained from expert physicians regarding the selection of HCC treatment is transformed into rules, which are shown below.

Rule 1. IF [$(x_3=y_{31})$ & $(x_6=y_{62})$ & $(x_7=y_{72})$ & $(x_{12}=y_{122})$ & $(x_{13}=y_{132})$ & $(x_{16}=y_{162})$ & $(x_{17}=y_{172})$ & $(x_{21}=y_{212})$ & $(x_{22}=y_{222})$ & $(x_{23}<3)$ & $(x_{24}<1{,}7)$ & $(x_{27}=y_{272})$ & $(x_{28}=y_{282})$ & $(x_{29}=y_{292})$ & $(x_{30}=y_{302})$ & $(x_{31}<35)$ & $(x_{33}=(A \vee B))$ & $(x_{34}<9)$ & $((x_{35}\geq 30) \vee (x_{36}\geq 40) \vee (x_{37}\geq 35))$ & $(x_{40}=y_{402})$ & $(x_{41}=y_{412})$ & $(x_{42}=y_{422})$ & $(x_{43}=(0 \vee 1 \vee 2))$] **Then “Resection is permissible**”

Rule 2. **IF** [$(x_1\leq 5)$ & $(x_2\leq 3)$ & $(x_3=(y_{31}\vee y_{32}))$ & $(x_4=y_{42})$ & $(x_5=y_{52})$ & $(x_6=y_{62})$ & $(x_7=y_{72})$ & $(x_8=y_{82})$ & $(x_9=y_{92})$ & $(x_{10}=y_{102})$ & $(x_{11}=y_{112})$ & $(x_{12}=y_{122})$ & $(x_{13}=y_{132})$ & $(x_{14}=y_{142})$ & $(x_{15}=y_{152})$ & $(x_{16}=y_{162})$ & $(x_{17}=y_{172})$ & $(x_{19}\leq 200)$ & $(x_{26}\leq 100)$ & $(x_{31}<35)$ & $(x_{38}=y_{381})$ & $(x_{39}=y_{392})$ & $(x_{40}=y_{402})$ & $(x_{41}=y_{412})$ & $(x_{42}=y_{422})$ & $(x_{43}=(0 \vee 1 \vee 2))$] **Then** “**Transplantation is permissible**”

Rule 3. **IF** [$(x_1\leq 3)$ & $(x_2\leq 3)$ & $(x_3=(y_{31}\vee y_{32}))$ & $(x_4=y_{42})$ & $(x_5=y_{52})$ & $(x_6=y_{62})$ & $(x_7=y_{72})$ & $(x_8=y_{82})$ & $(x_9=y_{92})$ & $(x_{10}=y_{102})$ & $(x_{11}=y_{112})$ & $(x_{12}=y_{122})$ & $(x_{13}=y_{132})$ & $(x_{21}=y_{212})$ & $(x_{22}=y_{222})$ & $(x_{24}\leq 1.7)$ & $(x_{28}=y_{282})$ & $(x_{29}=y_{292})$ & $(x_{33}=(A\vee B))$ & $(x_{40}=y_{402})$ & $(x_{41}=y_{412})$ & $(x_{43}=(0 \vee 1 \vee 2))$] **Then “Ablation”**

Rule 4. **IF** [$(x_6=y_{62})$ & $(x_7=y_{72})$ & $(x_{21}=y_{212})$ & $(x_{22}=y_{222})$ & $(x_{23}<3)$ & $(x_{24}\leq 1.7)$ & $(x_{28}=y_{282})$ & $(x_{29}=y_{292})$ & $(x_{30}=y_{302})$ & $((x_{33}=(A\vee B))$ & $(x_{40}=y_{402})$ & $(x_{41}=y_{412})$ & $(x_{42}=y_{422})$ & $(x_{43}=(0 \vee 1 \vee 2))$] **Then “Embolization”.**

Rule 5. **IF** [$(x_{21}=y_{212})$ & $(x_{22}=y_{222})$ & $(x_{23}>3)$ & $(x_{24}<1.7)$ & $(x_{27}=y_{272})$ & $(x_{28}=y_{282})$ & $(x_{29}=y_{292})$ & $(x_{30}=y_{302})$ & $(x_{33}=A)$ & $(x_{40}=y_{402})$ & $(x_{42}=y_{422})$ & $(x_{43}=(0 \vee 1 \vee 2))$] **Then “Systemic treatment”.**

Forming the logical inference mechanism of the HCC diagnostic expert system

The inference engine of the system consists of 4 submodules: examination data processing module (EDPM), result formation module (RFM), scheme formation module (SFM) according to the HCC treatment method (stage), input data tabular display formation module (DDFM) according to the selected treatment method.

Based on the current input data, i.e., examination data, a new fact is formed in EDPM, and when the fact is checked for compliance with the antecedent (condition) part of the rules in KB and the compliance is confirmed, the rule is activated in RFM. Obtaining the scheme corresponding to the activated rule and transferring the result part of the rule to the interface block is performed by SFM, and transferring the values obtained by the examination data entered into the system to the interface block in the form of a table is performed by DDFM.

TABLE 1. EXAMINATION DATA, THE VALUES THEY CAN RECEIVE AND THEIR CONDITIONAL MARKING

No	Examination data	Marking	Possible values examination data may recieve	Makring the examination data values
1.	Size of tumor	x_1	Pcs	
2.	Number of tumors	x_2	Pcs	
3.	Location of tumor	x_3	In one lobe/ in two lobes/ Central bile duct neighboring, Exophyte grown subcapsular derivative	y_{31}/ y_{32}/ y_{33}
4.	Segmental portal vein invasion	x_4	Yes/no	y_{41}/ y_{42}
5.	Portal vein invasion of one lobe	x_5	Yes/no	y_{51}/ y_{52}
6.	Portal vein invasion of both lobes	x_6	Yes/no	y_{61}/ y_{62}
7.	Main portal vein invasion	x_7	Yes/no	y_{71}/ y_{72}
8.	Right hepatic vein invasion	x_8	Yes/no	y_{81}/ y_{82}
9.	Left hepatic vein invasion	x_9	Yes/no	y_{91}/ y_{92}
10.	Middle hepatic vein invasion	x_{10}	Yes/no	y_{101}/ y_{102}
11	Two hepatic veins invasion	x_{11}	Yes/no	y_{111}/ y_{112}
...	…	…	...	...
33.	Child	x_{33}	A/B/C	*A/B/C*
34.	MELD	x_{34}	Pcs	
35.	Residual volume after resection-normal Qc	x_{35}	Pcs	
36.	Residual volume after resection-cirrhotic Qc	x_{36}	Pcs	
37.	Residual volume after resection-fatty Qc	x_{37}	Pcs	
38.	Donor	x_{38}	Yes/no	y_{381}/ y_{382}
39.	Contraindications to immunosup-pression	x_{39}	Yes/no	y_{391}/ y_{32}

40.	Active infections	x_{40}	Yes/no	y_{401}/ y_{402}
41.	Active malignancies	x_{41}	Yes/no	y_{411}/ y_{412}
42.	Extrahepatic organ failure (uncorrectable)	x_{42}	Yes/no	y_{421}/ y_{422}
43.	Performance (ECOG)	x_{43}	Pcs	
44.	Weakness (minute walk distance - m)	x_{44}	Pcs	

Interface block of the intelligent support system for the HCC treatment selection

The interface block is intended to ensure communication between the user-physician and the expert system. This block performs the functions of controlling the screen, organizing a dialogue with the expert system, entering initial data (examination data values) into the system and delivering the results to the user.

System implementation

The intelligent system for the HCC treatment selection is developed in the object-oriented programming language C#. C# is used to develop a wide range of applications, including desktop and web applications, mobile applications, Unity-based games, cloud applications on Microsoft Azure, and database applications. Figure 1 illustrates the block diagram of the treatment selection decision-making algorithm in the system.

After logging into the system, the window illustrated in figure 2 opens in front of the user-physician. This interface window consists of a large number of sub-windows, each of which corresponds to the examination data of HCC and the values they can receive.

Each of these windows is active and enables the user-physician to enter the current examination data. The current values of the examination data are entered into the system from the opened interface window and the "Initial result" button is pressed. The current values of the examination data entered into the system are recorded in the DB. These data also form the EDPM in the ERM. The latter is compared with the condition part of the rules in the KB, and when an overlap occurs, the result (HCC treatment method) part of that rule is recorded in the ERM of the RFM.

Based on the rule corresponding to the formed result, the selected treatment method of HCC in the ERM (for example, "Resection is permittable") is transferred to the interface window via the SFM. Then, the table formed in the DDFM based on the entered data and their values is transferred to the interface. Consequently, the result on the selected treatment method of HCC registered in the ERM ("Resection", "Transplantation", "Ablation", "Embolization", "Systemic treatment", "Symptomatic treatment") and the entered data and their values are presented to the user via the interface block (fig. 3).

The choice of the treatment method appropriate to the situation shown in Figure 2 corresponds to the decision option "Resection". This decision is made as a result of the activation of Rule 1 in the KB of the intelligent support system for the HCC treatment selection.

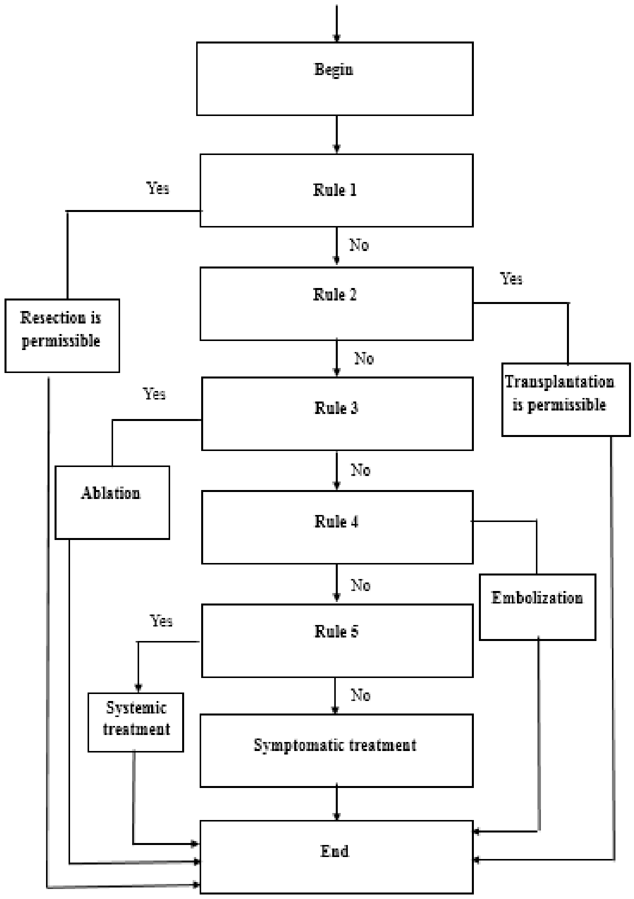


Fig 1. HCC treatment selection decision-making algorithm in the intelligent system

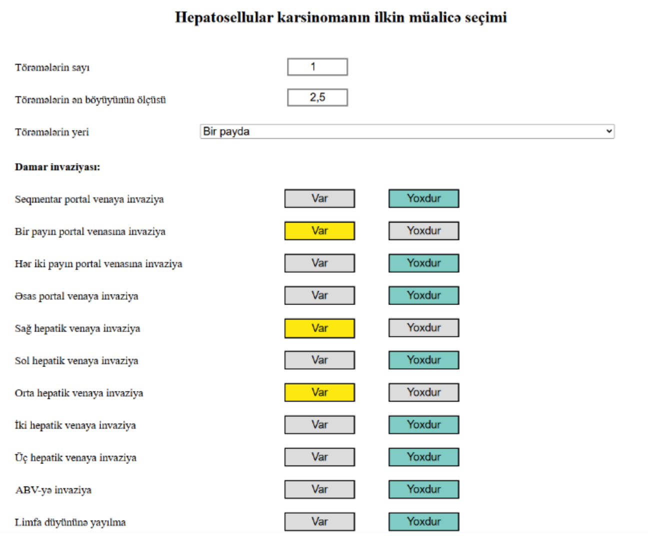
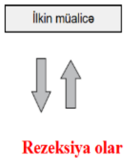


Fig. 2. Entering the examination data values for the HCC treatment selection into the system from the opened interface window

Conclusion

The intelligent support system for the HCC treatment selection was developed to support physician decisions. The system, consisting of architectural components, as a database, a knowledge base, an inference mechanism and an interface block, was implemented in the C# programming language on the Visual Study 2019 platform.



Törəmələrin sayı	1	INR
Törəmələrin ən böyüyünün ölçüsü	2,5	Trombosit
Yeri	Bir payda	QQT
Seqmentar portal venaya invaziya	Yoxdur	Assit
Bir payın portal venasına invaziya	Var	Varikoz qanaxma
Hər iki payın portal venasına invaziya	Yoxdur	Ensefalopatiya
Əsas portal venaya invaziya	Yoxdur	Dekompensasiya
Sağ hepatik venaya invaziya	Var	Pulmonar hipertenziya
Sol hepatik venaya invaziya	Yoxdur	ISG (15 dəqiqəlik)
Orta hepatik venaya invaziya	Var	Child
İki hepatik venaya invaziya	Yoxdur	MELD
Üç hepatik venaya invaziya	Yoxdur	Rezeksiyadan sonra qalan həcm-normal Qc
ABV-yə invaziya	Yoxdur	Rezeksiyadan sonra qalan həcm-sirrotik Qc
Limfa düyününə yayılma	Yoxdur	Rezeksiyadan sonra qalan həcm-yağlı Qc
Metastaz-tək çıxabilir	Var	Donor
Metastaz-tək çıxabilməz	Yoxdur	İmmunosuporessiyaya əks göstəriş
Metastaz çoxsaylı	Yoxdur	Aktiv infeksiyalar
Dərəcəsi	Aşağı	Aktiv bədxasssəli xəstəliklər
AFP	77	Ekstrahepatik orqan yetməzliyi (korreksiya olunmayan)
Sirroz	Yoxdur	Performans (ECOG)
Kəskin hepatit	Yoxdur	Zəiflik (6 dəqiqəlik yerimə məsafəsi - m)
Kəskin qaraciyər yetməzliyi	Yoxdur	
Bilirubin	2,9	

Fig. 3. Interface window for delivering the result to the user in the intelligent system for the HCC treatment selection

During the tests of the intelligent system supporting the treatment selection of HCC with the involvement of physician-specialists of the Department of Surgical Diseases of the Azerbaijan Medical University, it was confirmed that it was suitable for use as an expert physician decision support system in a multidisciplinary concilium for individual treatment selection.

References

[1] R. R. Arich, F. Alessandro, T. F David, S. Eizaburo, A. B. Amir, T. H. Matthew, E. T. Mitchell, "Infiltrative hepatocellular carcinoma: what radiologists need to know", Radiographics, 35(2), 371-386 (2015). doi: 10.1148/rg.352140114.

[2] N. Y. Bayramov, "Surgical diseases of the liver", 2012, in press. Baku: Qismet.

[3] D. Q. Huang, A. Tran, E. X. Tan, S. N. Nerurkar, R. Teh, M. L. P Teng, E. J. Yeo, B. Zou, C. Wong, C. O. Esquivel, C. A. Bonham, M. H. Nguyen, "Characteristics and outcomes of hepatocellular carcinoma patients with macrovascular invasion following surgical resection: a meta-analysis of 40 studies and 8,218 patients", Hepatobiliary Surg Nutr, 2022, vol.11, no. 6, pp. 848-860.

[4] S. Ray, N. N. Mehta, A. Golhar, S. Nundy, "Post hepatectomy liver failure – A comprehensive review of current concepts and controversies", Annals of Medicine and Surgery, 2018, no. 34, pp.4-10. doi:10.1016/j.amsu.2018.08.012

[5] F. Calderon, E. Masino, L. Caram, V. Ardiles, "Short-and-Long-Term Outcomes of Hepatic Resection for Hepatocellular Carcinoma in Cirrhotic and Non-Cirrhotic Liver Parenchyma", Journal of Surgery and Clinical Reports, 2021, May.

[6] D. Citterio, A. Facciorusso, C. Sposito, R Rota, S. Bhoori, V. Mazzaferro, "Hierarchic Interaction of Factors Associated With Liver Decompensation After Resection for Hepatocellular Carcinoma", JAMA Surgery, 2016, Vol. 151, no. 9. doi:10.1001/jamasurg.2016.1121

[7] S. Park, A. M. Davis, A. A. Pillai, "Prevention, Diagnosis, and Treatment of Hepatocellular Carcinoma", JAMA, Published online August 29, 2024. doi:10.1001/jama.2024.14101

[8] Z.J. Brown, D. I. Tsilimigras, S. M. Ruff, et al.,"Management of Hepatocellular Carcinoma: A Review", JAMA surgery, 2023, vol. 158, no. 4, pp. 410-420. doi:10.1001/jamasurg.2022.7989

[9] D. J. H. Tan, C. WongC, C. H. Ng, et al., "A Meta-Analysis on the Rate of Hepatocellular Carcinoma Recurrence after Liver Transplant and Associations to Etiology, Alpha-Fetoprotein, Income and Ethnicity", Journal of Clinical Medicine, 2021, vol 10. doi:10.3390/jcm10020238

[10] Российский патент 2021 года по МПК G16H10/60 G16H50/20 «Система для поддержки принятия врачебных решений» RU2752792C1.

[11] M. Mirmozaffari, "Developing an expert system for diagnosing liver diseases", European Journal of Engineering Research and Science, vol. 4, no. 3, March 2019. https://www.ej-eng.org/index.php/ejeng/article/view/1168/462

[12] S. Aman, P. Babita, "An Efficient Diagnosis System for Detection of Liver Disease Using a Novel Integrated Method Based on Principal Component Analysis and K-Nearest Neighbor (PCA-KNN)", International Journal of Healthcare Information Systems and Informatics, 2016, vol. 11, no. 4, pp. 56–61.

[13] J. S. Sartakhti, M. H. Zangooei, K. Mozafari, "Hepatitis disease diagnosis using a novel hybrid method based on support vector machine and simulated annealing (SVM-SA)", Computer Methods and Programs in Biomedicine, 2015, vol. 108, no. 2, pp. 570–579.

[14] D. N. Li, C. K. Chui, S. Chang, S. H. Ong, "A new unified level set method for semi-automatic liver tumor segmentation on contrast-enhanced CT images", Expert Systems with Applications, 2012, vol.39, no.10, pp.9661–9668.

[15] L. K. Ming, L. C. Kiong, L. W. Soong, "Autonomous and deterministic supervised fuzzy clustering with data imputation capabilities. Applied Soft Computing, 2011, vol.11, no.1, pp.1117–1125.

[16] S. Kulluk, L. Ozbakır, A. Baykasoğlu, "Fuzzy DIFACONN-miner: A novel approach for fuzzy rule extraction from neural networks", Expert Systems with Applications, 2013, vol. 40, no.3, pp.938–946.

[17] D. C. Li, C. W. Liu, S. C. Hu, "A learning method for the class imbalance problem with medical data sets", Computers in Biology and Medicine, 2010, vol.40, no.5, pp.509–518.

[18] E. Mezyk, O. Unold, "Mining fuzzy rules using an Artificial Immune System with fuzzy partition learning", Applied Soft Computing, 2011, vol.11, no.2, pp.1965–1974.

[19] F. Gorunescu, S. Belciug., M. Gorunescu, R. Badea, "Intelligent decision-making for liver fibrosis stadialization based on tandem feature selection and evolutionary-driven neural network", Expert Systems with Applications, 2012, vol.39, no.17, pp.12824–12832.

[20] Y. Torun, G. Tohumoglu, "Designing simulated annealing and subtractive clustering based fuzzy classifier", Applied Soft Computing, 2011, vol.11, no.2, pp.2193–2201.

[21] M. Aldape-Perez, C. Yanez-Marquez, O. J. Camacho-Nieto, A. Arguelles-Cruz, "An associative memory approach to medical decision support systems", Computer Methods and Programs in Biomedicine, 2012, vol.106, pp.287–307. doi:10.1016/j.cmpb.2011.05.002 PMID:21703713

[22] M. H. Mammadova, Z. G. Jabrayilova, L. A. Garayeva, A. I. Ahmadova, "Prediction of hepatocellular carcinoma using a machine learning", The 16th IEEE International Conference Application of Information and Communication Technologies (AICT-2022), Washington DC, 12-14 Oct 2022, INSPEC Accession Number: 22541899, DOI: 10.1109/AICT55583.2022.10013575https://ieeexplore.ieee.org/document/10013575

[23] M. H. Mammadova, N. Y. Bayramov, Z. G. Jabrayilova, "Development of the principles of fuzzy rule-based system for hepatocelular carcinoma staging", EUREKA: Physics and Engineering, 2021, no. 3, pp. 3–13, doi:https://doi.org/10.21303/2461-4262.2021.001829

[24] M. H. Mammadova, N. Y. Bayramov, Z. G. Jabrayilova, M. I. Manafli, M. R. Huseynova, "Knowledge transformation in the intelligent system for hepatocellular carcinoma staging" Proceedings of the 8th International Conference on Control and Optimization with Industrial Applications (COIA'2022), 24-26 August 2022, Baku, Azerbaijan, vol.1, pp. 318-321.

[25] M. H. Mammadova, N. Y. Bayramov, Z. G. Jabrayilova, M. I. Manafli, M. R. Huseynova, "Decision support system for the hepatocellular carcinoma diagnosis", Azerbaijan Medical Journal, 2024, No. 4, pp. 163–169.