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Investigating the Power of Artificial Intelligence Algorithms in Predicting Mortality Rates in Patients with Gastrointestinal Malignancies in ICU

Shiva Ariainezhad [1], Maryam Mahdavi[1], Parastou Kordestani-Moghadam[*2], Khadijeh Heidarizadeh [3], Ahmad Eskandarizadeh[2], Rasool Mohamadi[4]

[1] Student Research Committee, School of Nursing and Midwifery, Lorestan University of Medical Sciences, Khorramabad, Iran

[2] *Critical care and Emergency Nursing, Faculty of Nursing & Midwifery, Lorestan University of Medical Sciences, Khorramabad, Iran*

[3] Lorestan University of Medical Sciences, Khorramabad, Iran

[4] Nutritional Health Research Center, School of Health and Nutrition, Lorestan University of Medical Sciences, Khorramabad, Iran

ABSTRACT

This study aimed to investigate the efficacy of artificial intelligence algorithms in predicting mortality among patients with gastrointestinal malignancie.. In this retrospective cohort study, all the files of patients with gastrointestinal malignancies hospitalized in the intensive care and surgery departments of Imam Khomeini Hospital in Ahvaz from 2013-2018 were reviewed, and 200 patients met the inclusion criteria. Data on laboratory test results, clinical information, and hospitalization outcomes in the intensive care unit was collected. The model was presented utilizing artificial intelligence, a genetic algorithm, and the nearest neighbor method. The artificial intelligence algorithm demonstrated a diagnostic accuracy of 90%, a specificity of 91.67%, and a sensitivity of 83.34% for mortality. The genetic algorithm assigned a high weight to the following variables: gastrointestinal cancer type and hematocrit (0.98), illness status upon admission to the intensive care unit (0.94), bicarbonate rate (0.87), background infection and body temperature (0.86), duration of hospitalization (0.84), and CRP (0.83). These variables were significant and influential in determining mortality. Genetic algorithms are highly effective in predicting the mortality of patients with gastrointestinal malignancies hospitalized in intensive care units.

Keywords: Gastrointestinal Malignancies; Artificial Intelligence Algorithms; Mortality Prediction; Intensive Care Unit

Introduction

Cancer is currently a prevalent disease and the leading cause of mortality globally [1, 2]. Gastrointestinal cancers represent 26% of all cancer cases and account for 35% of cancer-related fatalities worldwide [3]. In Iran, statistics indicate that the digestive system is the most affected, comprising over 38% of all cancer cases. Furthermore, 44.4% of cancer deaths in Iran are attributable to gastrointestinal cancers [4]. According to the available data, the esophagus, stomach, and colon are the most frequently affected organs within the digestive system [3, 6].

Cancer patients require admission to the intensive care unit (ICU) to manage treatment-related complications, drug side effects, and disorders associated with the disease. The ICU would, therefore, play a vital role in the care

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[*] *Corresponding* author: Parastou Kordestani-Moghadam
Faculty of Nursing & Midwifery, Lorestan University of Medical Sciences, Khorramabad, Iran; Email: kparastou@yahoo.com

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and treatment of cancer patients. Research indicates that approximately 15% of cancer patients are admitted to the ICU, with nearly half of the unit's beds designated for this population [7].

Alongside the monitoring and treatment of critically ill patients, the ICU personnel also bear the responsibility of predicting patient prognoses. Recognizing the variables that might affect the survival of patients in the ICU is essential, as it not only aids in prioritizing patient admissions to these units but also provides enhanced accuracy for the attending physician in predicting the outcomes of hospitalized patients, thereby influencing bed occupancy and clinical decision-making [8].

Analytical approaches for predicting survival outcomes are consistently among the most critical concerns. In the meantime, the methodologies employed in survival data analysis predominantly consist of non-parametric techniques. The predominant tests utilized in survival analysis encompass Kaplan-Meier and Nelson-Aalen estimators. At the same time, semi-parametric regression and Cox regression are prominent regression models employed in survival analysis, mainly when the number of predictor variables is considerable.

To examine the connection and mutual effect among certain variables, it is essential to analyze and set assumptions restricting the use of prevalent statistical models such as Kaplan-Meier, Nelson-Aalen, Cox regression, and logistic regression. One method to address such issues is by applying artificial intelligence (AI). AI-based models can categorize information, discover correlations among data, and provide appropriate outputs [9, 10].

AI may evaluate data while accounting for many variables, reducing error rates when evaluating treatment efficacy, survival predictions, and short-term and long-term prognoses [11, 12]. While several research has demonstrated that artificial intelligence algorithms may effectively predict the outcomes for ICU patients, there is insufficient evidence concerning oncology patients, particularly those with malignancies of the digestive system. This study aimed to investigate the effectiveness of artificial intelligence algorithms in predicting mortality among patients with gastrointestinal malignancies admitted to the ICU.

Materials and Methods

This is a retrospective cohort study (code of ethics IR.LUMS.REC.1399.129 from Lorestan University of Medical Sciences) coordinated with Ahvaz University of Medical Sciences. Out of 536 medical records of patients with gastrointestinal malignancies hospitalized in the ICU of Imam Khomeini Hospital in Ahvaz from March 20, 2013, to March 20, 2018, the records of 200 patients met the criteria for inclusion in the study.

The study's inclusion criteria comprised patients over 18 with a confirmed diagnosis of gastrointestinal malignancy and those admitted to intensive care and surgery departments for gastrointestinal malignancy or complications from cancer treatment. Exclusion criteria encompassed medical records with incomplete data, diagnoses not associated with gastrointestinal cancer treatment, and patient mortality within the first 24 hours of ICU admission.

The collected data covered various demographic factors such as age, gender, and body mass index (BMI), alongside disease-related variables, including the type of gastrointestinal cancer, causes of ICU admission, treatment stage, metastasis, concurrent cancers, and chronic conditions. Additionally, laboratory values such as serum albumin, platelet count, sodium and potassium levels, bilirubin, bicarbonate, hematocrit, neutrophil to lymphocyte ratio, serum lactate, pH, ESR, CRP, Paco2, and Sao2 were also included. Other pertinent variables included body temperature, blood pressure, level of consciousness, heart rate, underlying infections, previous hospitalizations, renal replacement therapy, mechanical ventilation, medication use, duration of hospitalization, the necessity for receiving vasopressor drugs, and cardiopulmonary resuscitation (CPR) prior to admission.

Results

Among the 200 patients examined, 55.5% were aged over 65 years, 62.5% were male, 63% were diagnosed with colon cancer, 31% with gastric cancer, and 6% with esophageal cancer. Furthermore, a total of 159 patients, representing 79.5%, passed away (refer to Table 1). The clinical characteristics of the patients are presented in Table 2.

Table 1. Demographic characteristics of patients at the time of admission to the intensive care unit

Variables		**Number (Frequency)**
Age	Above 65 years old	111(55.5%)
	≤65 years old	89(44.50%)
Gender	Female	75(37.50%)
	Male	125(62.50%)
Outcome of hospitalization in the ICU	Alive	41 (20.50%)
	Dead	159(72.50%)
Type of gastrointestinal cancer	Esophagus	12(6.00%)
	Stomach	62(31.00%)
	Colon	126(63.00%)

Table 2-Clinical characteristics of patients at the time of admission to the intensive care unit

Variable		**Number (Frequency)**
Treatment stage at the time of admission	Chemotherapy	183 (5.91)
	Chemotherapy and radiotherapy	11(5.50)
	Brachytherapy	6(3.00)
Reason for admission	Weakness and lethargy	122(61.00)
	Adverse effects of therapy/treatment	21(5.10)
	Gastrointestinal symptoms	5 (5.20)
	Other reasons	52 (27.00)
Patient status at the time of admission	Disease progression	182(91.00)
	No change	12(6.00)
	Recurrence of the disease	6(3.00)
Need to take vasopressor drugs.	Does not need	159(5.79)
	Epinephrine	35(5.17)
	Dobutamine	6(3.00)
Need for mechanical ventilation.	Yes	161(5.80) 161
	No	39(5.19) 39
Previous hospitalization	Yes	22(11.00) 22
	No	175(87.50)
Cardiopulmonary resuscitation	Received	1(0.5)
	Not received	199(99.5)
Dialysis	Yes	12(6.00)
	No	188(94.00)
Drug abuse	Yes	12(6.00)
	No	188(94.00)
Metastasis	Yes	23(11.50)
	No	177(88.50)
Background infection	Yes	182(91.00)
	No	18 (9.00)
Record of chronic disease	Yes	17(7.50)
	No	183(91.50)
Duration of hospitalization	More than six days	77(38.50)
	Less than six days	123(61.50)

Subsequently, for 37 variables encompassing age, sex, type of gastrointestinal cancer, metastasis, background infection, duration of hospitalization, body temperature, heart rate, stage of the disease upon admission to the ICU, reason for admission to the ICU, prior hospitalizations, kidney transplantation, mechanical ventilation, CPR to admission to the ICU, substance and drug abuse, the necessity for vasopressor medications, concurrent cancer, a history of chronic illness, treatment stage, systolic and diastolic blood pressures, platelet counts, creatinine levels and consciousness along with various biochemical markers such as pH, CRP, BMI, Paco2, Sao2, ESR, sodium, potassium, bilirubin, bicarbonate, hematocrit, serum albumin, serum lactate, and the neutrophil to lymphocyte ratio, were systematically and meticulously organized to establish the initial population for analysis. The chromosomal values, encompassing the feature weights, were initialized randomly. At first, we developed the chromosome architecture, represented as binary strings.

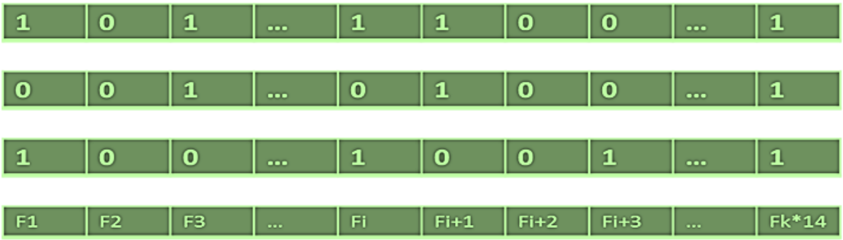
Figure 1 illustrates that the length of each chromosome is 14*k bits, with k being the number of features. The rationale for employing 14 bits is to include the values between one and zero.

Each feature was assigned 14 bits, indexed to a numerical range from 0 to 1. The conversion process begins with transforming the 14-bit string into a base-ten numeral, which is subsequently divided by (1-2^14) to yield a value from 0 to 1. Following the generation of the initial population, the system implemented the K-nearest neighbor algorithm, utilizing the weight of each chromosome.

The performance of each chromosome was subsequently assessed through the evaluation function inherent in the genetic algorithm. The primary objective is to identify optimal or close to optimal parameters, thereby yielding the most precise solution. The evaluation function corresponds to the classification errors observed when applying the K-nearest neighbor algorithm to the evaluation data set. Subsequently, based on the evaluation function's value, the weight assigned to each feature or variable was determined.

Figure 2 illustrates the significance of each feature, indicating that proximity to one correlates with greater importance in mortality determination. Notably, the variables related to the type of digestive cancer and the weighted hematocrit level (0.98), the stage of the disease upon admission to the ICU/surgery ward (0.94), bicarbonate (0.87), background infection and body temperature (0.86), length of hospitalization (0.84), and CPR (0.83) received substantial weight in the genetic algorithm, establishing them as pivotal and influential factors in the process of mortality assessment

After obtaining each feature's weight, the k-nearest neighbor algorithm was employed for recovery. Consequently, the data was partitioned into three segments, with two segments selected for model fitting and the remaining segment designated for error measurement. All three components quantify the error (Figure 3).



1	0	1	…	1	1	0	0	…	1
0	0	1	…	0	1	0	0	…	1
1	0	0	…	1	0	0	1	…	1
F1	F2	F3	…	Fi	Fi+1	Fi+2	Fi+3	…	Fk*14

Figure 1. Gene structure

The mean of the resultant errors estimates the model's error. Figure 4 presents a schematic representation of the algorithm. After determining the error, the model was evaluated based on criteria such as accuracy, specificity, and sensitivity. Applying the genetic algorithm for weighting resulted in a diagnostic accuracy of 90%, specificity of 91.67%, and sensitivity of 83.34% for the model

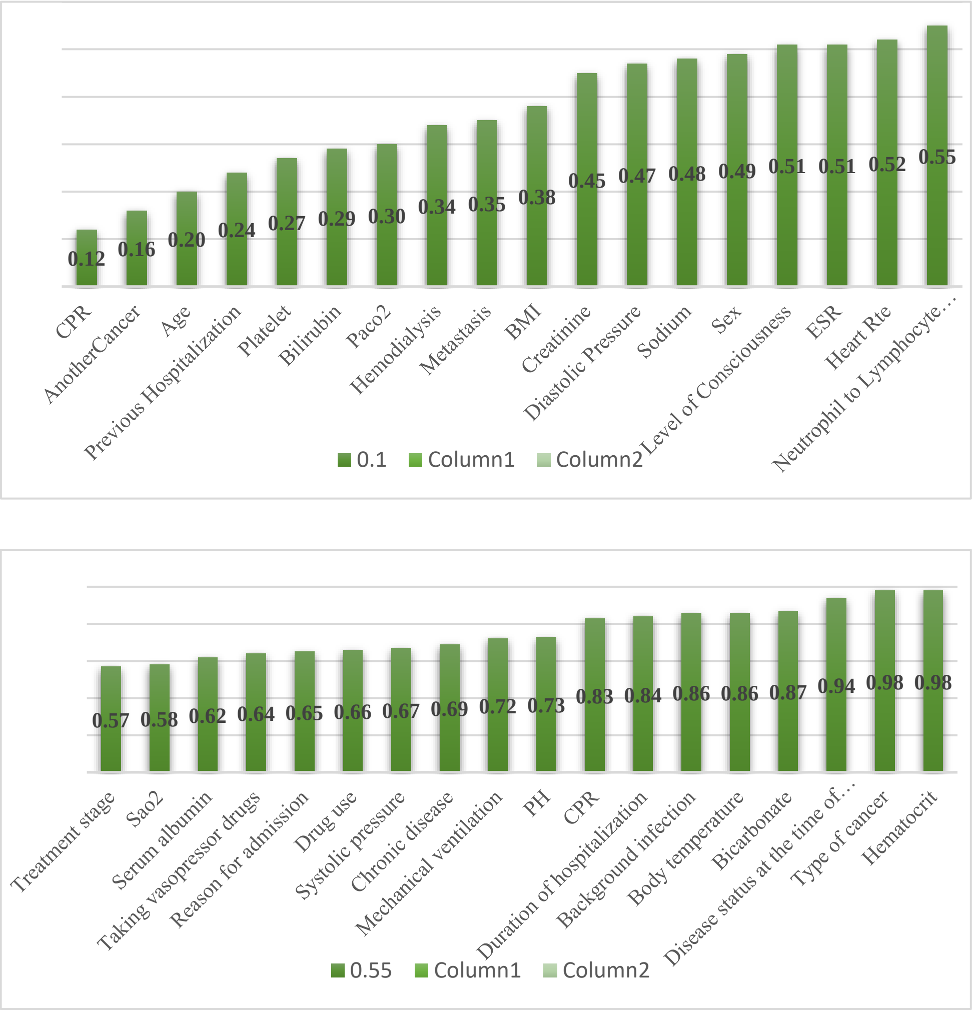


Figure2(A&B). The most effective variables in predicting mortality based on genetic algorithm

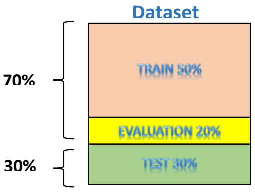


Figure 3. How to divide data

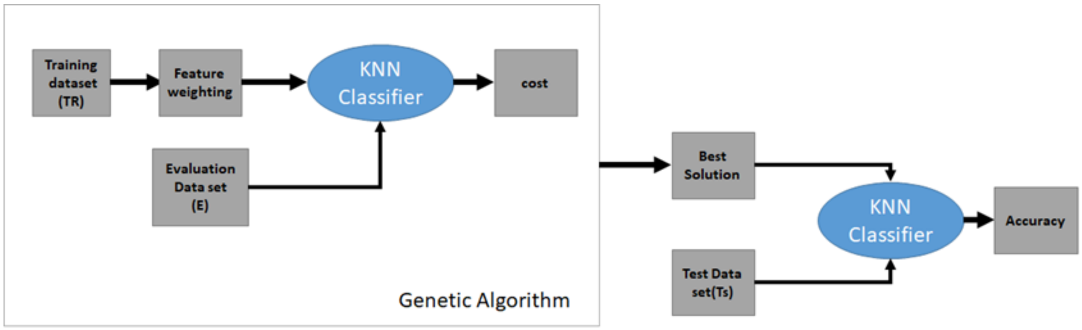


Figure 4. Flowchart of combined genetic algorithm and K nearest neighbor

Discussion

Precisely forecasting patient prognosis serves a dual purpose: aiding healthcare professionals and patients. It equips physicians with the necessary insights to make clinical decisions and effectively oversee treatment strategies. Research has demonstrated that demographic data, pathological indicators, physiological conditions, and even social relationships significantly influence the prognosis of cancer patients. However, conventional statistical approaches need help to analyze the complex internal relationships among these features. In contrast, AI models possess the capacity to explore the survival rates of patients with malignancies, owing to their superior computational power and integrative capabilities [13].

The findings from our study indicate that the genetic algorithm, achieving a prediction accuracy of 90%, demonstrates significant diagnostic precision in predicting the outcomes for patients suffering from gastrointestinal malignancies. Consistent with our research, the investigation by Sadeghi et al. in 2017 in Iran aimed to develop an algorithm for predicting breast cancer recurrence in patients, utilizing genetic and nearest neighbor algorithms. The findings indicated that in comparison to approaches such as decision tree, support vector machine, artificial neural network, and logistic regression, their proposed algorithm demonstrated a notable level of accuracy, providing the physician with a 77% probability regarding the likelihood of cancer recurrence in the patient [14].

Gohri et al.'s research analyzed the survival rates of gastric cancer patients by applying an artificial neural network model. This model successfully predicted the mortality of 50% of patients, and its predictions proved useful in classifying these patients [9].

One significant and influential aspect of the genetic algorithm research was the classification of gastrointestinal cancer. This is attributed to the higher prevalence of colorectal cancer among patients, resulting in an elevated mortality rate for this group. In contrast to our findings, the study conducted by Shadmani et al. presented a different perspective in which the individuals diagnosed with stomach cancer exhibited the highest mortality rate [2].

The study also reveals that, in contrast to the findings of Yazdani et al. in 2018, the age of patients at the time of cancer diagnosis did not serve as a significant variable affecting the survival rates of individuals with digestive tract cancer. This observation may be attributed to these diseases being often diagnosed at more advanced stages [15]. Consequently, early diagnosis of patients in the initial phases of the disease can significantly enhance the likelihood of survival for these patients [16].

Consistent with our research, an investigation revealed that the likelihood of mortality among patients with malignancy escalated alongside prolonged duration of hospitalization [17].

Prolonged mechanical ventilation and electrolyte imbalances may cause this due to inadequate diet and systemic infections caused by inappropriate treatment procedures. The other research indicated that laboratory results, including blood cell count, played a significant role in influencing patient survival [18]. This study identified hematocrit levels, bicarbonate, and CRP levels as significant factors affecting the survival of patients diagnosed with gastrointestinal malignancies. Consequently, examining the laboratory results may assist physicians in predicting the survival outcomes of these patients.

The research conducted by Sabouri et al. in 2017 in Iran aimed to explore the factors influencing the survival of patients diagnosed with colorectal cancer. They showed that the varying levels of BMI significantly influenced patient survival outcomes [19]. Furthermore, the research conducted in Indonesia developed a one-year survival model for patients with upper gastrointestinal malignancies. Their findings indicated that BMI value was an independent factor associated with patient mortality [20]. A study revealed that a variable like BMI level did not serve as a significant or crucial factor in assessing the mortality rates of patients afflicted with esophageal and gastric malignancies [21].

In a study examining gastric cancer patients, those with elevated BMI levels exhibited a more favorable prognosis. This observation may be attributed to the tendency of overweight gastric cancer patients to present with less aggressive tumors [22]. Among various factors that significantly influenced the genetic algorithm were underlying infections and the stage of the disease upon admission to the specialized department/ward, both of which played crucial roles in determining mortality outcomes. These variables may be assessed as factors influencing the survival of these patients; consequently, in scenarios where the number of variables influencing mortality is substantial, applying genetic algorithms and AI becomes essential for elucidating the relationships among these variables. Moreover, their proficiency in non-linear modeling enhances predictive accuracy as available data expands [23, 24].

The greater the frequency of data occurrence within the patient population, the more significant its influence will be on predictive outcomes. Consequently, AI algorithms' efficacy progressively enhances, which constitutes a significant advantage of these algorithms in predicting mortality when compared to statistical methods and linear models. Due to the inherent limitations of conventional tools, which fail to integrate changes across various units and regions, and the fact that these predictive instruments rely on a limited set of variables to assess disease severity and patient outcomes, achieving precise predictions with such tools is considered to be a challenging endeavor [25, 26]. The findings from our study indicate that the genetic algorithm demonstrates a significant level of diagnostic accuracy in predicting the outcomes for patients suffering from gastrointestinal malignancies

Conclusion

In conclusion, both the genetic algorithm and the nearest neighbor algorithm demonstrate significant diagnostic accuracy in predicting outcomes for patients with malignancies of the auditory system, particularly in scenarios characterized by a high number of predictor variables.

The present study has certain limitations, notably the loss of samples attributable to incomplete information in the patient's medical records and the potential for inaccuracies in the data provided.

Conflict of interests

The authors have no financial interest related to this article

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