Automatic Diagnosis of Lung Diseases (Pneumonia, Cancer) with given Reliabilities on the Basis of an Irradiation Images of Patients

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Abstract: The article proposes algorithms for the automatic diagnosis of human lung diseases pneumonia and cancer, based on images obtained by radiation irradiation, which allow us to make decisions with the necessary reliability, that is, to restrict the probabilities of making possible errors to a pre-planned level. Since the information obtained from the observation is random, Wald's sequential analysis method and Constrained Bayesian Method (CBM) of statistical hypothesis testing are used for making a decision, which allow us to restrict both types of possible errors. Both methods have been investigated using statistical simulation and real data, which fully confirmed the correctness of theoretical reasoning and the ability to make decisions with the required reliability using artificial intelligence. The advantage of CBM compared to Wald's method is shown, which is expressed in the relative scarcity of observation results needed to make a decision with the same reliability. The possibility of implementing the proposed method in modern computerized X-ray equipment due to its simplicity and promptness of decision-making is also shown.

Keywords: Automatic diagnosis, lung diseases, pneumonia, cancer, making decision, simulation, artificial intelligence.

1. INTRODUCTION

Making a diagnosis of the disease is the initial and very important stage of the treatment of a sick person, the correctness of which greatly depends on the successful completion of the subsequent stages of treatment. Accurate and timely diagnosis practically (with high probability) ensures the cure of the patient's disease. The diagnosis is made based on the examination of the patient's condition by the doctor. Examination of the condition involves blood, urine and other analyzes of the patient, as well as observation of various organs, which can be done by many different methods, including the use of X-rays and radiation. Based on the results of the observation, the doctor of the relevant profile makes a decision about the presence or absence of the disease. The correctness of the decision depends greatly on the qualification and experience of the doctor. Different doctors can make different decisions on the same data. A misdiagnosis can lead to a disastrous outcome with high probability. In order to avoid such subjective errors and to improve the quality of diagnosis, in recent decades, attempts have been made to use modern computers for diagnosis through machine learning and artificial intelligence methods (see, for example, [1]). While diagnosing, as well as when making any decision, two types of errors are possible: mistaking a sick person for healthy, and mistaking a healthy person for sick. The correctness of the decision depends greatly on the qualification and experience of the doctor. The results caused by such errors are diametrically (significantly) different from each other. In the second case, after some stress experienced by the patient, on the basis of additional examinations, the real condition of the patient will be established, and in the first case, the result will be fatally disastrous with a high probability. Based on what has been said, the requirements for automatic diagnosis methods are clearly visible. They should minimize possible errors of both types, especially the possibility of errors of the first type.

Among the diseases that exist today, human lung diseases with pneumonia and cancer occupy an important place. „Pneumonia is a form of acute respiratory infection that affects the lungs. The lungs are made up of small sacs called alveoli, which fill with air when a healthy person breathes. When an individual has pneumonia, the alveoli are filled with pus and fluid, which makes breathing painful and limits oxygen intake that can cause the death [2]. „Cancer is a generic term for a large group of diseases that can affect any part of the body and cause the death. One defining feature of cancer is the rapid creation of

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abnormal cells that grow beyond their usual boundaries, and which can then invade adjoining parts of the body and spread to other organs; the latter process is referred to as metastasis. Widespread metastases are the primary cause of death from cancer“ [3]. According to the World Health Organization “Pneumonia is the single largest infectious cause of death in children worldwide. Pneumonia killed 740 180 children under the age of 5 in 2019, accounting for 14% of all deaths of children under 5 years old but 22% of all deaths in children aged 1 to 5 years” [4]. Also “Cancer is a leading cause of death worldwide, accounting for nearly 10 million deaths in 2020, or nearly one in six deaths. The most common cancers are breast, lung, colon and rectum and prostate cancers. Each year, approximately 400 000 children develop cancer. Cancer mortality is reduced when cases are detected and treated early” [5]. Thus, timely correct diagnosis of the presence of the mentioned diseases is a very necessary and important problem.

The article proposes methods of automatic diagnosis of pneumonia and lung cancer, which allow to reduce both types of errors mentioned above to the desired levels. Besides their widespread, these diseases are interrelated as mentioned in the paper [6]: “We found a positive association between incident cancer and risk of death pneumonia in this study. These results imply the possibility that the immunocompromised status and respiratory failure due to antitumor treatment.”

Two types of lung cancer are discussed in the paper: adenocarcinoma and carcinoma. „Carcinoma is the most common form of cancer. It starts in the epithelial tissue of your skin or internal organs. Adenocarcinoma is a subtype of carcinoma. It grows in the glands that line the insides of your organs“ [7].

To make a decision about the diagnosis of the disease, the observation results extracted from the images obtained by radiation irradiation are used, which, like most of the observation results, contain a random component and, therefore, has a random character. Therefore, statistical hypothesis testing methods are used to make decisions, which allow restricting both types of possible errors. Such methods are Wald's sequential analysis method and constrained Bayesian method [8-10]. It is shown that both methods provide the opportunity to solve the given problem. It is also shown that the constrained Bayesian method, as a rule, requires a relatively small number of observations to make a decision with a given reliability than the Wald method, which is completely consistent with the results obtained earlier by the author of CBM and is its advantage [10-12].

The results of the investigation are distributed in the paper as follows. Materials and Methods are presented in Section 2. The results of the investigation of the applied methods using simulation and real data are given in Section 3. Short discussion and conclusion are offered in Sections 4 and 5, respectively. In Appendices A-I attached to the paper are given the results of processing of experimental data. In particular, Appendices A-E show the results of statistical processing of the data of lung diseases by pneumonia, adenocarcinoma and carcinoma, as well as the results of combined data of both kinds of the cancer. In Appendices F-I are given the results of diagnosis on the basis of the data of pneumonia, adenocarcinoma, carcinoma and the combined data of both kinds of cancer.

2. MATERIALS AND METHODS

2.1. Disease Data Acquisition and Preprocessing Results

Data from lung pneumonia and lung cancer patients, as well as from healthy patients examined by the same method, were obtained from the Internet at the following web addresses under the appropriate names:

- Chest X-Ray Images (Pneumonia) (https://www.kaggle.com/datasets/paultimothymooney /chest-xray-pneumonia)
- RSNA Pneumonia Detection Challenge (https://www.kaggle.com/competitions/rsna-pneumonia-detection-challenge/overview)
- VinBigData Chest X-ray Abnormalities Detection (https://www.kaggle.com/competitions/ vinbigdata-chest-xray-abnormalities-detection/data)
- Viral Pneumonia, Normal (https://www.kaggle. com/datasets/pranavraikokte/covid19-image-dataset)
- Chest CT-Scan images Dataset (Cancer) (https://www.kaggle.com/datasets/mohamedhanyyy/chest-ctscan-images)

As it is clear from the indicated addresses, the examination of pneumonia patients was carried out on the basis of X-ray images, and cancer patients - on the basis of computer tomography (CT) Scan images. At the mentioned addresses, photographs showing the condition of the lungs of the examined patients obtained by appropriate methods are provided. Photos are in black and white format. For the digital representation of visual images, for their further processing, a code was written using the Python programming language, which read the photo using the OpenCV library and displayed the image (information) on it in an Excel file with a certain number of lines and columns, in each cell a number between 0-255 is recorded, which represents the intensity of the corresponding point of the photo image, i.e. pixel intensity value. In order to make a decision about the health status of the patient, the data given under the name Chest X-Ray Images (Pneumonia) of patients suffering from pneumonia were processed using a convolutional neural network (CNN) method [13, 14], which is realized in the programing language Python, under the framework Pytorch. The CNN is a class of artificial neural networks most commonly applied to analyze visual imagery. CNNs use a mathematical operation called convolution in place of general matrix multiplication in at least one of their layers [15]. They are specifically designed to process pixel data and are used in image recognition and processing. For learning the network model, the data was distributed as follows: 3900 photos were used for model training, 300 photos for model validation, and 300 photos for model testing. The dimensions of all the photographs used in the practically acceptable time period to make a decision about the final result or the patient's condition were reduced to the standard size $384\,pixel \times 384\,pixel$. Processing such data (training, validation, testing) took about 25 minutes. 93.91% accuracy was achieved on the validation data, and 95% accuracy on the test data. Using the mentioned method, the processing of photo images with initial sizes (the sizes of which, in the case of pneumonia, are significantly larger than $1000\,pixel \times 1000\,pixel$ for both healthy and diseased patients) is practically impossible without powerful computing resources, because network models take up a lot of space in the computer's RAM, and when a high-dimensional photo is added to it, the problem becomes even worse. As a rule, the processing of photos larger than $800\,pixel \times 800\,pixel$ dimensions requires quite powerful computing resources, in the absence of which, models of small dimensions are used, which greatly reduces the accuracy of the obtained results.

It is clear that the level of 95% accuracy of the diagnosis is unacceptable for modern medicine. Therefore, in order to increase the reliability of the diagnosis, as well as to develop a simple, fast method that can be implemented in modern, computerized X-ray equipment, it was decided to use statistical hypothesis testing methods for decision-making, which allow to simultaneously restrict both types of possible errors when making a decision. Such methods are Wald's sequential analysis method and CBM, the essence of which is briefly described in the next paragraph. In order to use the mentioned methods, it is necessary to define a vector representing the state of the objects under investigation (about the state of which a decision must be made), which takes different values depending on the state of the object under investigation. In our case, such a vector turned out to be the dimensions of the patient's photo image represented in pixels, which are equal to the number of rows and columns of the corresponding Excel files. It was found that they take different values for healthy and sick patients and vary randomly from patient to patient.

Appendices A, B, C, and D show the results obtained by processing of the data of pneumonia, adenocarcinoma, carcinoma, and combined data of both types of cancer with the help of statistical package SPSS, while Appendix E shows the results of statistical processing of lung examination data of healthy patients, obtained by CT Scan method. Based on these results, we conclude that for each of these diseases, the two-dimensional random vector corresponding to the dimensions of the patient's state photo is a normally distributed vector with correlated parameters. In particular, in the case of pneumonia, the parameters of the normal distribution for healthy patients, the vector of mathematical expectation and the covariance matrix, are given as

$$\mu = (\mu_1, \mu_2) = (1811.1923, 1412.9308),$$

$$W = \begin{pmatrix} w_{11}, w_{12} \\ w_{21}, w_{22} \end{pmatrix} = \begin{pmatrix} 120850.699, 114569.20 \\ 114569.20, 144827.429 \end{pmatrix},$$

and for patients suffering from pneumonia –

$$\mu = (\mu_1, \mu_2) = (1144.60, 788.1538),$$

$$W = \begin{pmatrix} w_{11}, w_{12} \\ w_{21}, w_{22} \end{pmatrix} = \begin{pmatrix} 51120.211, 45821.4796 \\ 45821.4796, 51735.682 \end{pmatrix}.$$

For patients with carcinoma, we have:

$$\mu = (407.4846, 269.6385), \; W = \begin{pmatrix} 667.911, 384.875 \\ 384.875, 1673.861 \end{pmatrix}.$$

For the combined data of both types of cancer, we have:

$$\mu = (401.0615, 265.1538),\ W = \begin{pmatrix} 818.382, 171.3007 \\ 171.3007, 1349.544 \end{pmatrix}.$$

For healthy patients examined by computer tomography method, we have:

$$\mu = (632.6, 476.2857),\ W = \begin{pmatrix} 33007.718, 18500.7969 \\ 18500.7969, 14801.798 \end{pmatrix}.$$

The number of observation results used for computations for each case are given in the corresponding tables of descriptive statistics results (see appropriate appendices).

2.2. The Methods Used for Making a Decision

On the basis of the investigation results given in the previous paragraph, the problem of making a decision about the condition of a patient can be formulated as follows. On the basis of the observed values of a random vector $\xi = (\xi_1, \xi_2) \sim N(\mu, W)$, where μ is the vector of mathematical expectation and W is the covariance matrix, must be tested basic hypothesis $H_0 : \mu = \mu_0$, $W = W_0$ vs. alternative one $H_1 : \mu = \mu_A$, $W = W_A$. Here μ_0 and W_0 correspond to the supposition that a patient is healthy while μ_A and W_A correspond to a diseased patient. Let us consider the set of sequentially obtained i.i.d. observation results $x_1, x_2, ..., x_n, ...$ of a patient concerning of which a decision must be made. A decision must be made in such a way that the probabilities of incorrectly rejected or incorrectly accepted hypotheses, i.e. the Type I and Type II error rates were restricted on the desired levels. For this purpose, let us consider the Wald's test and the method of sequential analysis of Bayesian type (MSABT) [8-10, 12].

2.2.1. The Wald's Test

The essence of the Wald's sequential test consists in the following [8, 9]: compute the likelihood ratio $B(x) = p(x_1, x_2, ..., x_n \mid H_0) / p(x_1, x_2, ..., x_n \mid H_A)$ for n sequentially obtained observation results, and, if

$$B < B(x) < A,$$

do not make a decision and continue the observation of the random variable. If

$$B(x) \geq A,$$

accept the hypothesis H_0 on the basis of n observation results. If

$$B(x) \leq B,$$

accept the hypothesis H_A on the basis of n observation results.

The thresholds A and B are chosen so that

$$A = \frac{1-\beta}{\alpha} \text{ and } B = \frac{\beta}{1-\alpha}.$$

Here α and β are the desirable values of the error probabilities of Types I and II, respectively.

It is proved [8, 9] that in this case the real values of the error probabilities of Types I and II are close enough to the desired values, but still are distinguished from them.

2.2.2. The Method of Sequential Analysis of Bayesian Type

Let us consider a set of hypotheses H_i, $i = 1, ..., S$ ($S \geq 2$), involving that the random vector X is distributed by the law $p(x, \theta_i)$, i.e. $H_i : X \sim p(x, \theta_i) \equiv p(x \mid H_i)$; $p(H_i)$ is a priori probability of hypothesis H_i; Γ_i is the region of acceptance of H_i (Γ_i belongs to the observation space of random variable X, i.e. $\Gamma_i \in R^n$, where n is the dimension of the observation vector). The decision is made on the basis of $\mathbf{x}^T = (x_1, ..., x_n)$, the measured value of the random vector $\mathbf{X}$. It is possible to formulate different constrained tasks of testing the considered hypotheses [10, 12]. Here we consider only one of them, namely the task with restrictions on the averaged probability of rejection of true hypotheses for stepwise loss function with two possible values 0 and 1. The essence of this method is the minimization of the averaged probability of incorrect acceptance of hypotheses at restriction of the averaged probability of rejection of true hypotheses, i.e.

$$\min_{\{\Gamma_i\}} \left\{ 1 - \sum\nolimits_{i=1}^{S} p(H_i) P(\mathbf{X} \in \Gamma_i \mid H_i) \right\}, \qquad (1)$$

subject to

$$p(H_i) \sum\nolimits_{j=1, j \neq i}^{S} P(\mathbf{X} \in \Gamma_j \mid H_i) \leq \gamma_i,\ i = 1, ..., S. \qquad (2)$$

Solution of task (1) and (2) is [5]

$$\Gamma_j = \{\mathbf{x} : \lambda_j p(H_j) p(\mathbf{x} \mid H_j) > \sum\nolimits_{i=1, i \neq j}^{S} p(H_i) p(\mathbf{x} \mid H_i)\},$$
$$j = 1, ..., S. \qquad (3)$$

Coefficient λ_j are determined so that in (2) the equality takes place.

The sequential test developed on the basis of CBM consists in the following [10, 12]. Let Γ_i^n be the H_i hypothesis acceptance region (3) on the basis of n sequentially obtained repeated observation results; R_n^m is the decision-making space in the sequential method; m is the dimensionality of the observation vector; I_i^n is the population of sub-regions of intersections of hypotheses H_i acceptance regions Γ_i^n $(i=1,...,S)$ with the regions of acceptance of other hypotheses H_j, $j=1,...,S$, $j \neq i$; $E_n^m = R_n^m - \bigcup_{i=1}^{S} \Gamma_i^n$ is the population of regions of space R_n^m which do not belong to any of hypotheses acceptance regions.

The H_i hypotheses acceptance regions for n sequentially obtained observation results in the sequential method are:

$$R_{n,i}^m = \Gamma_i^n / I_i^n, \ i=1,...,S; \tag{4}$$

the no-decision region is:

$$R_{n,S+1}^m = \left(\bigcup_{i=1}^{S} I_i^n\right) \bigcup E_n^m, \tag{5}$$

where Γ_i^n, $i=1,...,n$, are defined by (3) on the basis of n sequentially obtained observation results.

This test is called *the sequential test of Bayesian type* [10]. Such tests could be considered for all constrained Bayesian methods offered in [10, 12] and differing from each other in restrictions.

When the number of hypotheses is equal to two and their a priori probabilities are equal to $1/2$, solution (3) can be rewritten using the Bayes factor:

$$\Gamma_0 : \frac{p(x \mid H_0)}{p(x \mid H_A)} > \frac{1}{\lambda_0}, \ \Gamma_A : \frac{p(x \mid H_0)}{p(x \mid H_A)} < \lambda_A,$$

where λ_0 and λ_A are determined so that in the conditions (2) equalities take place.

It is worth noting the shortcoming of Wald's method: 1) it is optimal for normal distribution in the limit case when $n \to \infty$; 2) it is developed for the case of two hypotheses; 3) its generalization for more than two hypotheses is quite problematic. Although this is done using the Bayes approach, its practical implementation is very difficult.

CBM is free from all these drawbacks. It works for hypotheses of any number and dimension (both continuous and discrete distributions), and the complexity of its implementation practically does not changes.

3. RESULTS

Appendix F presents the results of the diagnosis of lung pneumonia by sequential methods of testing the hypotheses described in the previous paragraph based on the data. Appendices G, H, and I present the results of the sequential methods of testing the hypotheses described in the previous paragraph based on lung cancer disease data. In particular, the results of diagnosis by sequential methods are presented: adenocarcinoma - in Appendix G, carcinoma - in Appendix H, and combined data of adenoma and adenocarcinoma - in Appendix I. The Bayesian decision-making method for all these diseases used the same values of Lagrange multipliers, which are given in Table **1** and calculated for the pneumonia data for different levels of type I and type II errors. In this case, the Kullback-Leibler divergence between the hypotheses to be tested is minimal compared to the cancer diseases discussed in the paper (see Table **2**). The Kullback–Leibler divergence between two multivariate Gaussian distributions is [16]

$$D_{KL}(p \parallel q) = \frac{1}{2}\left[\begin{array}{l} \log\frac{|W_q|}{|W_p|} - n + \left(\mu_p - \mu_q\right)^T \\ W_q^{-1}\left(\mu_p - \mu_q\right) + tr\left\{W_q^{-1} W_p\right\} \end{array}\right].$$

Table 1: Dependence of Lagrange Multipliers on Type 1 and Type II Error Rates

Type 1 error rate	Type II error rate	CBM			Wald's test	
		Lagrange multipliers			Thresholds for making decisions	
α	β	λ_0	$1/\lambda_0$	λ_A	A	B
0.05	0.05	3.4429	0.2904528	3.1893	19	0.052631578947368
0.01	0.01	22.6699	0.0789272	15.1790	99	0.010101010101010
0.001	0.001	65.9375	0.01516587	53.7500	999	0.001001001001001
0.0001	0.0001	355.9375	0.0028095	316.1787	9,999	1.000100010001000e-04
0.00001	0.00001	2555.9375	0.00039124587	2416.1787	99,999	1.000010000100001e-05

Table 2: The Kullback–Leibler Divergence between Tested Hypotheses at the Consideration of Pneumonia, Adenocarcinoma, Carcinoma and Adenocarcinoma Plus Carcinoma Data

Type of the disease	The Kullback–Leibler divergence
Pneumonia	2.241213728077075
Adenocarcinoma	3.339872625127654
Carcinoma	3.824174027990074
Adenocarcinoma plus carcinoma	3.187334583538381

It has been proved and shown in papers [10-12] that the Lagrange multipliers in CBM that are calculated to ensure decision making with given reliability for hypotheses with minimum Kullback-Leibler distance, ensure making correct decision with higher reliability when the Kullback-Leibler distance between hypotheses increases.

3.1. Statistical Analysis

The first tables in Appendices G, H and I show the results obtained with 200,000 data points generated by the distribution parameters corresponding to the observations of healthy and diseased patients given in paragraph 2. The calculation results show that the reliability of diagnosis for healthy and sick patients for each considered case, that is, for each considered restriction of the first and second type error levels, is satisfied both by the Wald criterion and for the decisions made by the MSABT. However, Wald's criterion requires a larger number of observations for each considered case (see Tables **G.2**, **H.2**, **I.2**). Tables **3** and **4** of the same appendices, respectively, show the results of decisions made with real data of sick and healthy patients, which completely match the results obtained by modeling and assure us that with the proposed methods it is possible to automatically diagnose the considered diseases with a predetermined reliability.

The results given in Tables **3** and **4** of the appendices F-I are obtained with real data of different numbers of sick and healthy patients for different diseases. This is due to the limited possibilities of obtaining them from the Internet and in general as well.

For the visibility of the calculation results, the graphical representation of the data of Tables **F.1** and **F.2** are given on Figure **1** and Figure **2** respectively as an example.

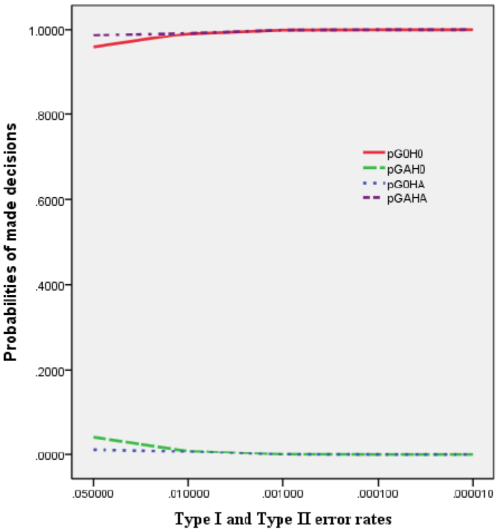

Figure 1: Dependencies of the reliabilities of made decisions on Type I and Type II error rates.

pG0H0 – $P(x \in \Gamma_0 \mid H_0)$, pGAH0 – $P(x \in \Gamma_A \mid H_0)$, pG0HA – $P(x \in \Gamma_0 \mid H_A)$, pGAHA - $P(x \in \Gamma_A \mid H_A)$.

4. DISCUSSION

Both sequential analysis methods of Wald and of Bayesian type give opportunities to diagnose lung pneumonia and lung cancer with given reliabilities. Sequential analysis method of Bayesian type needs comparatively small quantity of observations for diagnosis with given reliability in comparison with Wald's method. It is especially important to emphasize the fact that both sequential analysis methods (of Wald and CBM) require practically negligible time (less than one second) and memory for their implementation in modern computerized X-ray equipment (in contrast to the methods based on modern neural networks mentioned in paragraph 2), which allows their widespread implementation in serial equipment.

5. CONCLUSION

A method of automatic diagnosis of pneumonia and lung cancer with computerized X-ray equipment is proposed, which requires very little memory and time to make a decision. At the same time, both types of possible errors can be limited to predetermined levels with guarantee. The method is based on the method of sequential analysis of Bayesian type of statistical hypothesis testing. The results of the experimental investigation, both on modeled and real data, showed the ease of implementation, high reliability and accuracy of the proposed method of automatic diagnosis. In our opinion, the implementation of the mentioned method in serially produced relevant

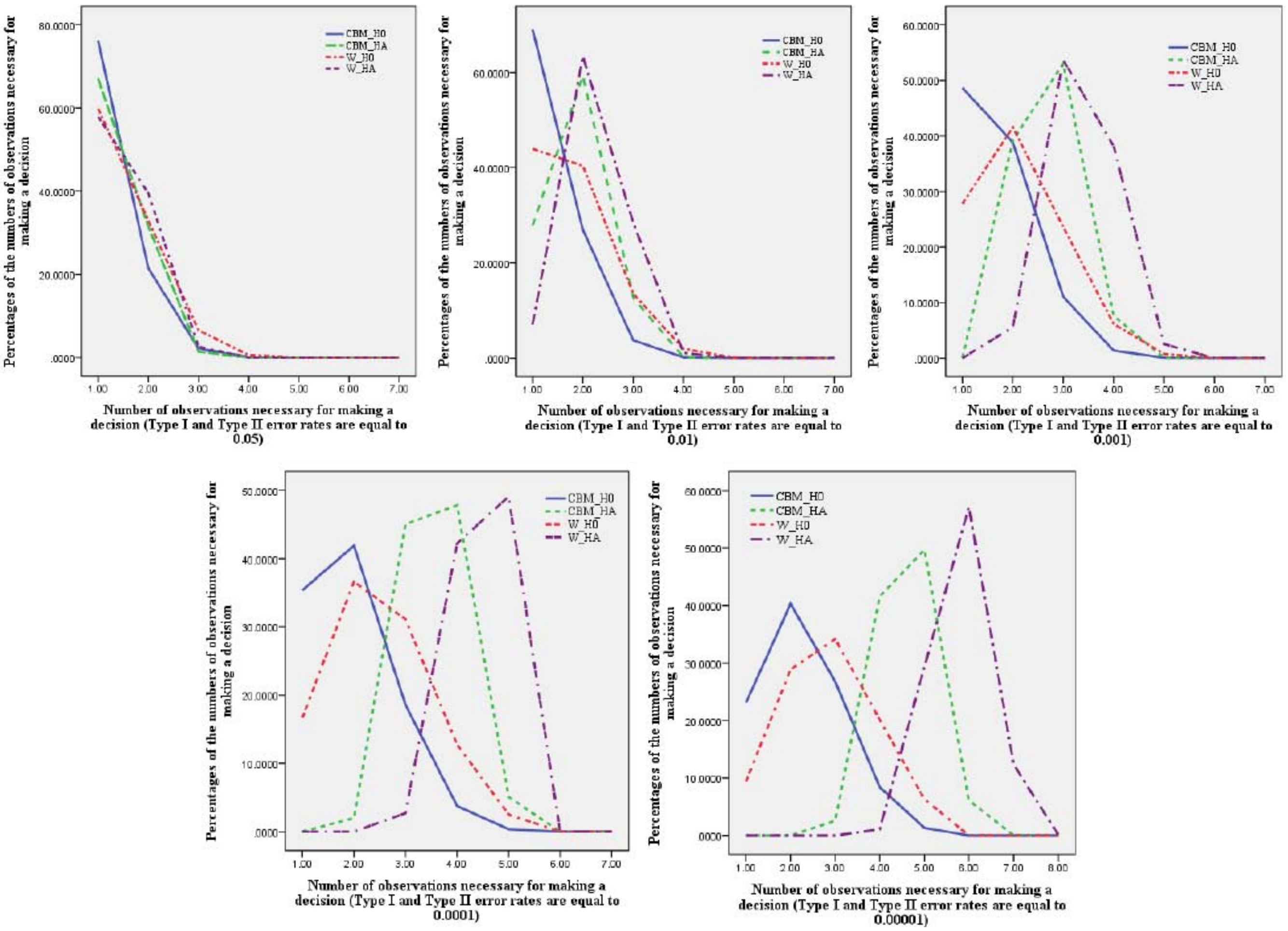

Figure 2: Percentage distribution of the number of observations necessary for making a decision at different Type I and Type II error rates.

CBM_H0 - Hypothesis H_0 is true at applying CBM, CBM_HA - Hypothesis H_A is true at applying CBM, W_H0 - Hypothesis H_0 is true at applying Wald's test, W_HA - Hypothesis H_A is true at applying Wald's test.

equipment will significantly increase the quality of the diagnosis, which in turn will play a decisive role in the final recovery of the patient. It should be noted here that the implementation of this method in serially produced modern relevant equipment, provided with microprocessor equipment, requires insignificant time and material costs. If necessary, we can provide the relevant computer program implemented on MATLAB to the interested party.

ABBREVIATIONS

CBM = Constrained Bayesian Method

CT = computer tomography

CNN = convolutional neural network

MSABT = the method of sequential analysis of Bayesian type

ETHICS APPROVAL

Not applicable.

CONSENT TO PARTICIPATE

All authors participated in the development of the paper.

HUMAN AND ANIMAL RIGHTS

All Human and Animal Rights are Reserved.

CONFLICT OF INTEREST

Not applicable.

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APPENDIX A. RESULTS OF STATISTICAL PROCESSING OF DATA SHOWING LUNG PNEUMONIA.

Descriptive statistics results

Statistics

		x_nor_R	x_nor_L	x_pne_R	x_pne_L
N	Valid	130	130	130	130
	Missing	0	0	0	0
Mean		1811.1923	1412.9308	1144.6000	788.1538
Median		1786.0000	1318.5000	1114.0000	744.0000
Mode		1753.00[a]	1125.00	943.00[a]	656.00
Std. Deviation		347.63587	380.56199	226.09779	227.45479
Variance		120850.699	144827.429	51120.211	51735.682
Skewness		.395	.546	.941	1.330
Std. Error of Skewness		.212	.212	.212	.212
Kurtosis		.288	-.220	.783	2.306
Std. Error of Kurtosis		.422	.422	.422	.422

Note 1. The first two columns contain the results of processing the quantities of columns (x_nor_R) and rows (x_nor_L) of the Excel files of healthy patients, and the next two rows contain the same data for patients with pneumonia. The same type of designations are used for other diseases.

The results of correlation analysis.

Correlations

		x_nor_R	x_nor_L	x_pne_R	x_pne_L
x_nor_R	Pearson Correlation	1	.866**	.051	.067
	Sig. (2-tailed)		.000	.563	.448
	N	130	130	130	130
x_nor_L	Pearson Correlation	.866**	1	.020	.035
	Sig. (2-tailed)	.000		.825	.695
	N	130	130	130	130
x_pne_R	Pearson Correlation	.051	.020	1	.891**
	Sig. (2-tailed)	.563	.825		.000
	N	130	130	130	130
x_pne_L	Pearson Correlation	.067	.035	.891**	1
	Sig. (2-tailed)	.448	.695	.000	
	N	130	130	130	130

**. Correlation is significant at the 0.01 level (2-tailed).

The results of testing the normality of the observation results with the χ^2 -criterion.

Test Statistics

	x_nor_R	x_nor_L	x_pne_R	x_pne_L
Chi-Square	13.415	9.615	46.231	46.923
df	117	120	78	99
Asymp. Sig.	1.000	1.000	.998	1.000

Based on the results of the research, we conclude that the vector representing the patient's condition is distributed according to the two-dimensional normal distribution law with different values of the parameters of healthy and sick patients. From the results of statistical processing presented in Appendices 2, 3 and 4, it is clear that the same conclusion is correct for other cases discussed in the article.

APPENDIX B. RESULTS OF STATISTICAL PROCESSING OF DATA SHOWING LUNG ADENOCARCINOMA DISEASE.

Descriptive statistics results.

Statistics

		Adeno_Width	Adeno_length
N	Valid	130	130
	Missing	0	0
Mean		394.6385	260.6692
Median		394.0000	258.5000
Mode		372.00[a]	263.00
Std. Deviation		29.86715	31.54605
Variance		892.047	995.153
Skewness		-.281	.141
Std. Error of Skewness		.212	.212
Kurtosis		-.174	-.235
Std. Error of Kurtosis		.422	.422
Range		158.00	164.00
Minimum		309.00	179.00
Maximum		467.00	343.00

The results of correlation analysis.

Correlations

		Adeno_Width	Adeno_length
Adeno_Width	Pearson Correlation	1	.290**
	Sig. (2-tailed)		.001
	N	130	130
Adeno_length	Pearson Correlation	.290**	1
	Sig. (2-tailed)	.001	
	N	130	130

**Correlation is significant at the 0.01 level (2-tailed).

The results of testing the normality of the observation results with the χ^2-criterion.

Test Statistics

	Adeno_Width	Adeno_length
Chi-Square	30.523	36.077
df	73	84
Asymp. Sig.	1.000	1.000

APPENDIX C. RESULTS OF STATISTICAL PROCESSING OF DATA SHOWING LUNG CARCINOMA.

Descriptive statistics results.

Statistics

		Large_Width	Large_Length
N	Valid	130	130
	Missing	0	0
Mean		407.4846	269.6385
Median		410.0000	275.0000
Mode		399.00	266.00
Std. Deviation		25.84397	40.91284
Variance		667.911	1673.861
Skewness		-.260	-.494
Std. Error of Skewness		.212	.212
Kurtosis		-.680	-.192
Std. Error of Kurtosis		.422	.422
Range		124.00	189.00
Minimum		345.00	161.00
Maximum		469.00	350.00

The results of correlation analysis.

Correlations

		Large_Width	Large_Length
Large_Width	Pearson Correlation	1	.364**
	Sig. (2-tailed)		.000
	N	100	100
Large_Length	Pearson Correlation	.364**	1
	Sig. (2-tailed)	.000	
	N	100	100

The results of testing the normality of the observation results with the χ^2-criterion.

Test Statistics

	Large_Width	Large_Length
Chi-Square	37.308	32.400
df	74	90
Asymp. Sig.	1.000	1.000

APPENDIX D. RESULTS OF STATISTICAL PROCESSING OF DISEASE WITH COMBINED DATA OF BOTH TYPES OF LUNG CANCER.

Descriptive statistics results.

Statistics

		Combained_Ade_Cansir_W	Combained_Ade_Cansir_L
N	Valid	260	260
	Missing	0	0
Mean		401.0615	265.1538
Median		403.0000	265.5000
Mode		384.00^a	259.00
Std. Deviation		28.60738	36.73614
Variance		818.382	1349.544
Skewness		-.345	-.201
Std. Error of Skewness		.151	.151
Kurtosis		-.231	-.228
Std. Error of Kurtosis		.301	.301
Range		160.00	189.00
Minimum		309.00	161.00
Maximum		469.00	350.00
Sum		104276.00	68940.00

The results of correlation analysis.

Correlations

		Combained_Ade_Cansir_W	Combained_Ade_Cansir_L
Combained_Ade_Cansir_W	Pearson Correlation	1	.163**
	Sig. (2-tailed)		.008
	N	260	260
Combained_Ade_Cansir_L	Pearson Correlation	.163**	1
	Sig. (2-tailed)	.008	
	N	260	260

**Correlation is significant at the 0.01 level (2-tailed).

The results of testing the normality of the observation results with the χ^2-criterion.

Test Statistics

	Combained_Ade_Cansir_W	Combained_Ade_Cansir_L
Chi-Square	89.154	90.077
df	101	122
Asymp. Sig.	.794	.987

APPENDIX E. RESULTS OF STATISTICAL PROCESSING OF LUNG EXAMINATION DATA OF HEALTHY PATIENTS BY COMPUTER TOMOGRAPHY OR CT SCAN METHOD.

Descriptive statistics results.

Statistics

		Nor_Width1	Nor_Length1
N	Valid	88	88
	Missing	21	21
Mean		632.6000	476.2857
Median		617.0000	491.0000
Mode		940.00	627.00
Std. Deviation		181.68026	121.66264
Variance		33007.718	14801.798
Skewness		.232	-.376
Std. Error of Skewness		.398	.398
Kurtosis		-.975	-.527
Std. Error of Kurtosis		.778	.778
Range		580.00	466.00
Minimum		360.00	234.00
Maximum		940.00	700.00

The results of correlation analysis

Correlations

		Nor_Width1	**Nor_Length1**
Nor_Width1	Pearson Correlation	1	.837**
	Sig. (2-tailed)		.000
	N	88	88
Nor_Length1	Pearson Correlation	.837**	1
	Sig. (2-tailed)	.000	
	N	88	88

**Correlation is significant at the 0.01 level (2-tailed).

The results of testing the normality of the observation results with the χ^2-criterion.

Test Statistics

	Nor_Width1	**Nor_Length1**
Chi-Square	8.714	8.714
df	82	82
Asymp. Sig.	1.000	1.000

APPENDIX F. RESULTS OF DIAGNOSIS BASED ON LUNG PNEUMONIA DATA.

Results obtained by simulation

Table F.1: Decisions Made on the Basis of Simulated Data

Number of experiments	Type 1 error rate	Type II error rate	CBM						Wald's test					
			Average number of observations necessary for making a decision when H_0 is true	Probability of acceptance of basic hypothesis when it is true	Probability of acceptance of alternative hypothesis when basic hypothesis is true	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Average number of observations necessary for making a decision when H_0 is true	Probability of acceptance of basic hypothesis when it is true	Probability of acceptance of alternative hypothesis when basic hypothesis is true	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true
m	α	β	AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$	AN	$P(x \in \Gamma_0 \mid H_A)$	$P(x \in \Gamma_A \mid H_A)$	AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$	AN	$P(x \in \Gamma_0 \mid H_A)$	$P(x \in \Gamma_A \mid H_A)$
200,000	0.05	0.05	Ex. 1: 1.2605	0.9584	0.0416	1.3427	0.0131	0.9869	1.4785	0.9654	0.0346	1.4468	0.0022	0.9978
			Ex. 2: 1.2617	0.9580	0.0420	1.3454	0.0134	0.9866	1.4770	0.9663	0.0337	1.4480	0.0021	0.9979
			Ex. 3: 1.2620	0.9580	0.0420	1.3430	0.0131	0.9869	1.4774	0.9661	0.0339	1.4476	0.0021	0.9979
			Ex. 4: 1.2608	0.9582	0.0418	1.3424	0.0136	0.9864	1.4775	0.9664	0.0336	1.4487	0.0021	0.9979
			Ex. 5: 1.2611	0.9579	0.0421	1.3431	0.0130	0.9870	1.4796	0.9658	0.0342	1.4492	0.0021	0.9979
200,000	0.01	0.01	Ex. 1: 1.3519	0.9904	0.0096	1.8512	0.0084	0.9916	1.7394	0.9963	0.0037	2.2364	0.0016	0.9984
			Ex. 2: 1.3498	0.9903	0.0097	1.8459	0.0085	0.9915	1.7426	0.9962	0.0038	2.2361	0.0016	0.9984
			Ex. 3: 1.3515	0.9907	0.0093	1.8474	0.0081	0.9919	1.7410	0.9962	0.0038	2.2361	0.0017	0.9983
			Ex. 4: 1.3492	0.9903	0.0097	1.8477	0.0082	0.9918	1.7439	0.9962	0.0038	2.2345	0.0016	0.9984
			Ex. 5: 1.3496	0.9906	0.0094	1.8493	0.0079	0.9921	1.7366	0.9963	0.00375	2.2355	0.0017	0.9983
200,000	0.001	0.001	Ex. 1: 1.6537	0.9992	7.70e-04	2.6844	6.50e-04	0.9993	2.1061	0.9997	2.6500e-04	3.3767	1.1000e-04	0.99989
			Ex. 2: 1.6595	0.9991	9.00e-04	2.6843	7.20e-04	0.9993	2.1021	0.9998	2.400e-04	3.3728	1.5500e-04	0.99984
			Ex. 3: 1.6591	0.9990	0.0010	2.6884	6.00e-04	0.9994	2.1042	0.9998	2.0000e-04	3.3757	1.2500e-04	0.99988
			Ex. 4: 1.6576	0.9991	9.20e-04	2.6850	7.00e-04	0.9993	2.1008	0.9998	2.3500e-04	3.3713	1.4000e-04	0.99986
			Ex. 5: 1.6638	0.9992	8.00e-04	2.6840	6.50e-04	0.9993	2.1049	0.9998	2.3000e-04	3.3739	1.3500e-04	0.99987
200,000	0.0001	0.0001	Ex. 1: 1.9191	0.9999	1.10e-04	3.5608	1.10e-04	0.9999	2.4877	0.99999	1.00e-05	4.5829	1.0000e-05	0.99999
			Ex. 2: 1.9222	0.9999	9.00e-05	3.5623	8.00e-05	0.9999	2.4846	1	0	4.5818	0	1
			Ex. 3: 1.9199	0.9999	1.40e-04	3.5600	6.00e-05	0.9999	2.4872	0.999995	5.0000e-06	4.5831	1.0000e-05	0.99999
			Ex. 4: 1.9201	0.9999	1.00e-04	3.5687	9.00e-05	0.9999	2.4886	1	0	4.5820	0	1
			Ex. 5: 1.9214	0.9999	6.00e-05	3.5638	1.10e-04	0.9999	2.4896	0.99999	1.0000e-05	4.5825	1.0000e-05	0.99999
200,000	0.00001	0.00001	Ex. 1: 2.2502	0.999995	5.00e-06	4.5942	1.00e-05	0.999990	2.8869	1	0	5.8102	0	1
			Ex. 2: 2.2437	0.999995	5.00e-06	4.5940	1.00e-05	0.999990	2.8848	1	0	5.8081	0	1
			Ex. 3: 2.2473	0.999995	5.00e-06	4.5934	5.00e-06	0.999995	2.8858	1	0	5.8107	0	1
			Ex. 4: 2.2467	0.999995	5.00e-06	4.5933	0	1	2.8904	1	0	5.8099	0	1
			Ex. 5: 2.2420	0.999995	5.00e-06	4.5935	5.00e-06	0.999995	2.8912	1	0	5.8108	0	1

Table F.2: Percentage distribution of the number of observations necessary for making a decision.

Type 1 error rate	Type II error rate	Experiment	Number of observations necessary for making a decision	CBM		Wald's test	
				Hypothesis H_0 is true	Hypothesis H_A is true	Hypothesis H_0 is true	Hypothesis H_A is true
α	β	Ex.	NO	Percentage %	Percentage %	Percentage %	Percentage %
0.05	0.05	Ex. 1	1	76.2888	67.1152	59.8984	57.9160
			2	21.4662	31.5022	32.9562	39.4988
			3	2.1546	1.3806	6.5646	2.5774
			4	0.0870	0.0020	0.5566	0.0078
			5	0.0034	0	0.0238	0
		Ex. 2	1	76.1834	66.9046	60.0284	57.8868
			2	21.5562	31.6580	32.8380	39.4326
			3	2.1666	1.4350	6.5564	2.6736
			4	0.0920	0.0024	0.5602	0.0070
			5	0.0018	0	0.0162	0
		Ex. 3	1	76.1404	67.1030	59.9716	57.8458
			2	21.6138	31.4998	32.9088	39.5508
			3	2.1548	1.3944	6.5470	2.5970
			4	0.0894	0.0028	0.5508	0.0064
			5	0.0016	0	0.0216	0
		Ex. 4	1	76.2454	67.1560	59.9638	57.8040
			2	21.5288	31.4466	32.9088	39.5332
			3	2.1258	1.3952	6.5572	2.6534
			4	0.0986	0.0022	0.5478	0.0094
			5	0.0014	0	0.0216	0
		Ex. 5	1	76.2558	67.0714	59.8239	57.6812
			2	21.4720	31.5508	32.9920	39.7250
			3	2.1832	1.3758	6.6060	2.5876
			4	0.0872	0.0020	0.5584	0.0062
			5	0.0018	0	0.0196	0
0.01	0.01	Ex. 1	1	69.0630	27.8360	43.9655	7.0510
			2	26.9850	59.2880	40.3740	63.3785
			3	3.7480	12.6690	13.5620	28.4515
			4	0.2010	0.2070	1.9615	1.1175
			5	0.0030	0	0.1330	0.0015
		Ex. 2	1	69.1030	28.1320	43.8955	7.0540
			2	27.0670	59.2870	40.2880	63.4360
			3	3.6070	12.4180	13.6320	28.3600
			4	0.2160	0.1630	2.0360	1.1485
			5	0.0070	0	0.1395	0.0015
		Ex. 3	1	69.1120	28.0530	43.9115	7.0985
			2	26.9810	59.2990	40.3990	63.3100
			3	3.6950	12.4600	13.5330	28.4715
			4	0.2100	0.1880	2.0015	1.11850
			5	0.0020	0	0.1485	0.0015
		Ex. 4	1	69.1440	28.0120	43.6445	7.1140
			2	26.9480	59.3430	40.5495	63.4545
			3	3.6850	12.4750	13.7065	28.2980
			4	0.2200	0.1690	1.9705	1.1305
			5	0.0030	0.0010	0.1245	0.0030

		Ex. 5	1	69.3990	27.8880	44.1720	7.1500
			2	26.6880	59.2910	40.2810	63.3055
			3	3.6840	12.6550	13.4040	28.3870
			4	0.2240	0.1660	2.0030	1.1555
			5	0.0050	0	0.1345	0.0020
0.001	0.001	Ex. 1	1	48.6730	0.0650	27.8145	0.0110
			2	38.8260	39.1860	41.5780	5.5910
			3	11.0440	53.0480	23.6305	53.6745
			4	1.3780	7.6480	6.1760	38.1665
			5	0.0750	0.0530	0.7625	2.5510
			6	0	0	0.0375	0.0060
			7	0	0	0.0010	0
		Ex. 2	1	48.3950	0.0710	27.9110	0.0155
			2	38.8380	39.2330	41.6210	5.6215
			3	11.2930	52.9510	23.6300	53.9015
			4	1.3730	7.6880	6.0650	37.9960
			5	0.1000	0.0570	0.7295	2.4580
			6	0	0	0.0410	0.0075
			7	0	0	0.0025	0
		Ex. 3	1	48.4890	0.0600	27.7740	0.0125
			2	38.7670	39.0110	41.8145	5.4970
			3	11.1870	53.0340	23.4910	53.9355
			4	1.4610	7.8200	6.1035	38.0210
			5	0.0900	0.0750	0.7725	2.5265
			6	0	0	0.0430	0.0075
			7	0	0	0.00150	0
		Ex. 4	1	48.4610	0.0700	28.0015	0.0140
			2	38.8850	39.1180	41.6595	5.5635
			3	11.1650	53.1130	23.4555	54.2050
			4	1.4150	7.6410	6.0725	37.7220
			5	0.0720	0.0580	0.7610	2.4885
				0	0	0.0485	0.0070
				0	0	0.0015	0
		Ex. 5	1	48.2900	0.0650	27.9170	0.0135
			2	38.6420	39.2520	41.5440	5.5660
			3	11.5550	52.9550	23.5540	53.8990
			4	1.4310	7.6710	6.1575	38.0640
			5	0.0790	0.0570	0.7740	2.4510
				0	0	0.0530	0.0065
				0	0	0.0005	0
0.0001	0.0001	Ex. 1	1	35.3750	0.0110	16.6810	0.0010
			2	41.8840	1.9950	36.6105	0
			3	18.5910	45.0490	31.1120	2.7285
			4	3.7780	47.8190	12.7700	42.2245
			5	0.3550	5.0980	2.5255	49.1065
		Ex. 2	1	35.3730	0.0080	16.6945	0
			2	41.6180	2.0050	36.7585	0
			3	18.8440	45.1030	31.1295	2.7150
			4	3.7690	47.5550	12.5410	42.2850
			5	0.3770	5.2930	2.5760	49.1370
		Ex. 3	1	35.3430	0.0060	16.6235	0.0010
			2	41.8530	2.0040	36.8840	0
			3	18.6890	45.1460	30.9165	2.6455
			4	3.7290	47.6980	12.6085	42.3175
			5	0.3640	5.1200	2.67100	49.152

		Ex. 4	1	35.1920	0.0090	16.6825	0
			2	41.9930	1.9280	36.6175	0
			3	18.8310	44.5900	31.0655	2.7125
			4	3.6030	48.1510	12.7480	42.2360
			5	0.3620	5.2970	2.5815	49.2250
		Ex. 5	1	35.1230	0.0110	16.5670	0.0010
			2	42.1050	1.9250	36.7045	0
			3	18.6840	44.9790	31.1520	2.7180
			4	3.7010	47.8630	12.6705	42.2545
			5	0.3690	5.2020	2.6075	49.1130
0.00001	0.00001	Ex. 1	1	23.0970	0.0010	9.3650	0
			2	40.3080	0	28.8705	0
			3	26.7710	2.5770	34.1725	0
			4	8.3960	41.5835	20.1370	1.0840
			5	1.3300	49.7085	6.3065	29.3580
			6	0	6.0975	0	57.1675
			7	0	0.0325	0	12.2355
			8	0	0	0	0.1550
		Ex. 2	1	23.4670	0.0010	9.3355	0
			2	40.1140	0	28.9360	0
			3	26.8110	2.5575	34.2535	0
			4	8.1640	41.5620	20.1430	1.0775
			5	1.3320	49.8220	6.1550	29.4505
			6	0	6.0335	0	57.1860
			7	0	0.0240	0	12.1550
			8	0	0	0	0.1310
		Ex. 3	1	23.0740	0.0005	9.3745	0
			2	40.2450	0	28.9090	0
			3	26.7940	2.5950	34.1910	0
			4	8.4640	41.6630	20.0915	1.0655
			5	1.3190	49.5865	6.2690	29.4165
			6	0	6.1160	0	57.0550
			7	0	0.0390	0	12.3120
			8	0	0	0	0.1510
		Ex. 4	1	23.1030	0	9.3080	0
			2	40.2300	0	28.9475	0
			3	26.9340	2.5540	33.9995	0
			4	8.2460	41.6795	20.1555	1.1030
			5	1.3040	49.6760	6.4250	29.3280
			6	0	6.0660	0	57.1985
			7	0	0.0245	0	12.2210
			8	0	0	0	0.1495
		Ex. 5	1	23.3780	0.0005	9.3735	0
			2	40.1940	0	28.7005	0
			3	26.7720	2.5655	34.1695	0
			4	8.2890	41.6155	20.2255	1.0775
			5	1.2720	49.7470	6.3540	29.3465
			6	0	6.0410	0	57.1345
			7	0	0.0305	0	12.2970
			8	0	0	0	0.1445

Table F.3: Decisions made on the basis of real data of sick patients.

Number of patients	Type I error rate	Type II error rate	CBM				Wald			
			Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions
m	α	β	AN	$P(x\in\Gamma_0 \mid H_A)$	$P(x\in\Gamma_A \mid H_A)$	N	AN	$P(x\in\Gamma_0 \mid H_A)$	$P(x\in\Gamma_A \mid H_A)$	N
100	0.05	0.05	1	0	1	100	1	0	1	100
	0.01	0.01	1	0	1	100	2	0	1	50
	0.001	0.001	2	0	1	50	3	0	1	33
	0.0001	0.0001	3	0	1	33	3	0	1	33
	0.00001	0.00001	3	0	1	33	4	0	1	25
214	0.05	0.05	1	0	1	214	1	0	1	214
	0.01	0.01	1	0	1	214	2	0	1	107
	0.001	0.001	2	0	1	107	3	0	1	71
	0.0001	0.0001	3	0	1	71	3	0	1	71
	0.00001	0.00001	3	0	1	71	4	0	1	54
214 (the sequence of observations is changed)	0.05	0.05	1	0	1	214	1	0	1	214
	0.01	0.01	1	0	1	214	2	0	1	107
	0.001	0.001	2	0	1	107	3	0	1	71
	0.0001	0.0001	3	0	1	71	3	0	1	71
	0.00001	0.00001	3	0	1	71	4	0	1	53

Table F.4: Decisions Made on the Basis of Real Data of Healthy Patients

Number of patients	Type I error rate	Type II error rate	CBM				Wald			
			Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions
m	α	β	AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$		AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$	
90	0.05	0.05	1	1	0	90	1	1	0	90
	0.01	0.01	1	1	0	90	1	1	0	90
	0.001	0.001	1	1	0	90	2	1	0	45
	0.0001	0.0001	1	1	0	90	2	1	0	45
	0.00001	0.00001	2	1	0	45	2	1	0	45
90 (the sequence of observations is changed)	0.05	0.05	2	1	0	45	2	1	0	45
	0.01	0.01	2	1	0	45	2	1	0	45
	0.001	0.001	2	1	0	45	2	1	0	45
	0.0001	0.0001	2	1	0	45	2	1	0	45
	0.00001	0.00001	2	1	0	45	2	1	0	45

APPENDIX G. **RESULTS OF LUNG ADENOCARCINOMA DIAGNOSIS BASED ON DATA.**

Table G.1: Decisions Made on the Basis of Simulated Data

Number of experiments	Type 1 error rate	Type II error rate	CBM						Wald's test					
			Average number of observations necessary for making a decision when H_0 is true	Probability of acceptance of basic hypothesis when it is true	Probability of acceptance of alternative hypothesis when basic hypothesis is true	Average number of observations necessary for making a decision when	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Average number of observations necessary for making a decision when H_0 is true	Probability of acceptance of basic hypothesis is when it is true	Probability of acceptance of alternative hypothesis when basic hypothesis is true	Average number of observations necessary for making a decision when	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis is when it is true
						H_A is true						H_A is true		
m	α	β	AN	$P(x\in\Gamma_0\mid H_0)$	$P(x\in\Gamma_A\mid H_0)$	AN	$P(x\in\Gamma_0\mid H_A)$	$P(x\in\Gamma_A\mid H_A)$	AN	$P(x\in\Gamma_0\mid H_0)$	$P(x\in\Gamma_A\mid H_0)$	AN	$P(x\in\Gamma_0\mid H_A)$	$P(x\in\Gamma_A\mid H_A)$
200,000	0.05	0.05	Ex. 1: 1.0549	0.9685	0.0315	1.0955	0.0022	0.9978	1.0864	0.9726	0.0274	1.1328	3.9600e-04	0.99960
			Ex. 2: 1.0554	0.9685	0.0315	1.0949	0.0022	0.9978	1.0875	0.9722	0.0279	1.1329	4.1000e-04	0.99959
			Ex. 3: 1.0551	0.9682	0.0318	1.0951	0.0022	0.9978	1.0869	0.9730	0.0270	1.1312	3.3000e-04	0.99967
			Ex. 4: 1.0552	0.9683	0.0317	1.0947	0.0022	0.9978	1.0869	0.9724	0.0276	1.1324	4.0500e-04	0.99960
			Ex. 5: 1.0553	0.9687	0.0313	1.0955	0.0024	0.9976	1.0868	0.9723	0.0277	1.1333	3.2000e-04	0.99968
200,000	0.01	0.01	Ex. 1: 1.0796	0.9955	0.0045	1.3418	0.0013	0.9987	1.1344	0.9936	0.0064	1.6536	3.1500e-04	0.9997
			Ex. 2: 1.0797	0.9955	0.0045	1.3405	0.0015	0.9985	1.1349	0.9936	0.0064	1.6566	2.7000e-04	0.9997
			Ex. 3: 1.0809	0.9956	0.0044	1.3407	0.0012	0.9988	1.1331	0.9938	0.0062	1.6546	2.9500e-04	0.9997
			Ex. 4: 1.0801	0.9957	0.0043	1.3419	0.0013	0.9987	1.1355	0.9935	0.0065	1.6551	2.8000e-04	0.9997
			Ex. 5: 1.0800	0.9955	0.0045	1.3412	0.0014	0.9986	1.1356	0.9936	0.0064	1.6537	3.0500e-04	0.9997
200,000	0.001	0.001	Ex. 1: 1.1325	0.9997	3.1000e-04	2.1940	1.5000e-04	0.9999	1.1763	0.99998	2.0000e-05	3.0652	3.0000e-05	0.99997
			Ex. 2: 1.1321	0.9997	3.4000e-04	2.1964	1.1000e-04	0.9999	1.1753	0.99999	1.5000e-05	3.0660	5.5000e-05	0.99995
			Ex. 3: 1.1300	0.9998	1.9500e-04	2.1927	8.0000e-05	0.9999	1.1764	0.99998	2.0000e-05	3.0664	2.5000e-05	0.99998
			Ex. 4: 1.1302	0.9997	3.4000e-04	2.1958	1.3000e-04	0.9999	1.1775	0.99997	3.0000e-05	3.0653	3.0000e-05	0.99997
			Ex. 5: 1.1313	0.9997	3.3000e-04	2.1978	1.5000e-04	0.9999	1.1744	0.99998	2.0000e-05	3.0661	2.0000e-05	0.99998
200,000	0.0001	0.0001	Ex. 1: 1.1564	1	0	3.1634	2.0000e-05	1	1.2111	1	0	4.2511	0	1
			Ex. 2: 1.1592	1	0	3.1621	2.0000e-05	1	1.2111	1	0	4.2509	0	1
			Ex. 3: 1.1597	1	0	3.1627	1.0000e-05	1	1.2107	1	0	4.2528	0	1
			Ex. 4: 1.1577	1	0	3.1621	1.0000e-05	1	1.2116	1	0	4.2521	1.0000e-05	0.99999
			Ex. 5: 1.1594	1	0	3.1612	2.0000e-05	1	1.2107	1	0	4.2495	0	1
200,000	0.00001	0.00001	Ex. 1: 1.1874	1	0	4.2622	5.0000e-06	0.999995	1.2440	1	0	5.6658	0	1
			Ex. 2: 1.1906	1	0	4.2594	0	1	1.2427	1	0	5.6658	0	1
			Ex. 3: 1.1886	1	0	4.2612	0	1	1.2450	1	0	5.6676	0	1
			Ex. 4: 1.1899	1	0	4.2608	0	1	1.2431	1	0	5.6667	0	1
			Ex. 5: 1.1903	1	0	4.2617	0	1	1.2434	1	0	5.6678	0	1

Table G.2: Percentage Distribution of the Number of Observations Necessary for Making a Decision

Type 1 error rate	Type II error rate	Experiment	Number of observations necessary for making a decision	CBM		Wald's test	
				Hypothesis H_0 is true	Hypothesis H_A is true	Hypothesis H_0 is true	Hypothesis H_A is true
α	β	Ex.	NO	Percentage %	Percentage %	Percentage %	Percentage %
0.05	0.05	Ex. 1	1	94.5950	90.4652	91.5902	86.7558
			2	5.3182	9.5184	8.1858	13.2062
			3	0.0866	0.0164	0.2226	0.0380
			4	0.0002	0	0.0014	0
			5	0	0	0	0
		Ex. 2	1	94.5510	90.5248	91.4915	86.7465
			2	5.3544	9.4572	8.2660	13.2190
			3	0.0940	0.0180	0.2415	0.03450
			4	0.0006	0	0.0010	0
			5	0	0	0	0
		Ex. 3	1	94.5734	90.5000	91.5350	86.9090
			2	5.3386	9.4856	8.2475	13.0595
			3	0.0878	0.0144	0.2145	0.0315
			4	0.0002	0	0.0030	0
			5	0	0	0	0
		Ex. 4	1	94.5696	90.5506	91.5380	86.7940
			2	5.3430	9.4316	8.2390	13.1695
			3	0.0870	0.0178	0.2195	0.0365
			4	0.0004	0	0.0035	0
			5	0	0	0	0
		Ex. 5	1	94.5480	90.4660	91.5425	86.7040
			2	5.3714	9.5174	8.2355	13.2585
			3	0.0806	0.0166	0.2200	0.0375
			4	0	0	0.0020	0
			5	0	0	0	0
0.01	0.01	Ex. 1	1	92.2220	66.1170	87.1055	37.4495
			2	7.6080	33.3910	12.3605	59.7450
			3	0.1680	0.4920	0.5250	2.8045
			4	0.0020	0	0.0090	0.0010
			5	0	0	0	0
		Ex. 2	1	92.2840	66.5680	87.0195	37.0900
			2	7.5380	32.9850	12.4745	60.1655
			3	0.1780	0.4470	0.5005	2.7430
			4	0	0	0.0055	0.0015
			5	0	0	0	0
		Ex. 3	1	92.1240	66.3820	87.2345	37.2675
			2	7.6680	33.1330	12.2320	60.0035
			3	0.2060	0.4850	0.5240	2.7285
			4	0.0020	0	0.0095	0.0005
			5	0	0	0	0
		Ex. 4	1	92.1550	66.5040	87.0255	37.2680
			2	7.6790	33.0140	12.4045	59.9535
			3	0.1620	0.4820	0.5615	2.7770
			4	0.0040	0	0.0085	0.0015
			5	0	0	0	0

		Ex. 5	1	92.0540	66.4390	86.9690	37.4285
			2	7.7700	33.0500	12.5100	59.7755
			3	0.1760	0.5110	0.5125	2.7945
			4	0	0	0.0085	0.0015
			5	0	0	0	0
0.001	0.001	Ex. 1	1	87.2440	0.0150	83.3910	0.0030
			2	12.2730	80.6500	15.6120	1.7780
			3	0.4760	19.2540	0.9750	89.9300
			4	0.0070	0.0810	0.0215	8.2765
			5	0	0	0.0005	0.0125
			6	0	0	0	0
			7	0	0	0	0
		Ex. 2	1	87.2980	0.0110	83.4380	0.0055
			2	12.1965	80.4430	15.6115	1.7770
			3	0.4980	19.4410	0.9305	89.8360
			4	0.0075	0.1050	0.0200	8.3750
			5	0	0	0	0.0065
			6	0	0	0	0
			7	0	0	0	0
		Ex. 3	1	87.5065	0.0080	83.3465	0.0025
			2	11.9980	80.8180	15.6825	1.7105
			3	0.4885	19.0700	0.9550	89.9355
			4	0.0070	0.1040	0.0160	8.3440
			5	0	0	0	0.0075
			6	0	0	0	0
			7	0	0	0	0
		Ex. 4	1	87.4820	0.0130	83.2715	0.0030
			2	12.0215	80.5150	15.7320	1.7200
			3	0.4930	19.3480	0.9720	90.0300
			4	0.0035	0.1240	0.0245	8.2395
			5	0	0	0	0.0075
			6	0	0	0	0
		Ex. 5	1	87.3850	0.0150	83.5245	0.0020
			2	12.1030	80.2760	15.5255	1.7235
			3	0.5050	19.6180	0.9350	89.9490
			4	0.0070	0.0910	0.0150	8.3185
			5	0	0	0	0.0070
			6	0	0	0	0
0.0001	0.0001	Ex. 1	1	85.1250	0.0020	80.2725	0
			2	14.1250	0	18.3730	0
			3	0.7360	83.7170	1.3250	0
			4	0.0140	16.2210	0.0295	74.9960
			5	0	0.0600	0	24.8940
			6	0	0	0	0.1100
			7	0	0	0	0
		Ex. 2	1	84.8890	0.0020	80.2790	0
			2	14.3140	0	18.3655	0
			3	0.7850	83.8290	1.3200	0
			4	0.0120	16.1210	0.0355	75.0180
			5	0	0.0480	0	24.8735
			6	0	0	0	0.1085
			7	0	0	0	0

		Ex. 3	1	84.7870	0.0010	80.3230	0
			2	14.4700	0	18.3235	0
			3	0.7320	83.7720	1.3145	0
			4	0.0110	16.1800	0.0390	74.8200
			5	0	0.0470	0	25.0800
			6	0	0	0	0.1000
			7	0	0	0	0
		Ex. 4	1	85.0250	0.0010	80.3075	0.0010
			2	14.2000	0	18.2585	0
			3	0.7590	83.8400	1.3985	0
			4	0.0150	16.1090	0.0345	74.8900
			5	0.0010	0.0500	0.0010	25.0010
			6	0	0	0	0.1080
			7	0	0	0	0
		Ex. 5	1	84.8250	0.0020	80.3575	0
			2	14.4220	0	18.2545	0
			3	0.7460	83.9100	1.3485	0
			4	0.0070	16.0570	0.0390	75.1415
			5	0	0.0310	0.0005	24.7640
			6	0	0	0	0.0945
			7	0	0	0	0
0.00001	0.00001	Ex. 1	1	82.4030	0.0005	77.5545	0
			2	16.5230	0	20.5480	0
			3	1.0500	0	1.8395	0
			4	0.0240	73.9025	0.0570	0
			5	0	25.9760	0.0010	34.8940
			6	0	0.1210	0	63.6315
			7	0	0	0	1.4745
			8	0	0	0	0
		Ex. 2	1	82.1590	0	77.6885	0
			2	16.7240	0	20.4180	0
			3	1.0940	0	1.8300	0
			4	0.0230	74.1755	0.0630	0
			5	0	25.7125	0.0005	34.8860
			6	0	0.1120	0	63.6440
			7	0	0	0	1.4700
			8	0	0	0	0
		Ex. 3	1	82.2290	0	77.4640	0
			2	16.6730	0	20.6225	0
			3	1.0670	0	1.8635	0
			4	0.0310	73.9925	0.0500	0
			5	0	25.8925	0	34.6935
			6	0	0.1150	0	63.8485
			7	0	0	0	1.4580
			8	0	0	0	0
		Ex. 4	1	82.2050	0	77.6010	0
			2	16.6240	0	20.5360	0
			3	1.1560	0	1.8135	0
			4	0.0150	74.0625	0.0485	0
			5	0	25.7975	0.0010	34.8020
			6	0	0.1400	0	63.7310
			7	0	0	0	1.4670
			8	0	0	0	0

		Ex. 5	1	82.1430	0	77.6215	0
			2	16.7680	0	20.4780	0
			3	1.0610	0	1.8395	0
			4	0.0280	73.9405	0.0610	0
			5	0	25.9510	0	34.6780
			6	0	0.1085	0	63.8665
			7	0	0	0	1.4555
			8	0	0	0	0

Table G.3: Decisions Made on the Basis of Real Data of Sick Patients

Number of patients	Type I error rate	Type II error rate	CBM				Wald			
			Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions
m	α	β	AN	$P(x \in \Gamma_0 \mid H_A)$	$P(x \in \Gamma_A \mid H_A)$	N	AN	$P(x \in \Gamma_0 \mid H_A)$	$P(x \in \Gamma_A \mid H_A)$	N
100	0.05	0.05	1	0	1	100	1	0	1	100
	0.01	0.01	1	0	1	100	1	0	1	100
	0.001	0.001	2	0	1	50	3	0	1	33
	0.0001	0.0001	4	0	1	25	4	0	1	25
	0.00001	0.00001	5	0	1	20	5	0	1	20
196	0.05	0.05	1	0	1	196	2	0	1	98
	0.01	0.01	1	0	1	196	2	0	1	98
	0.001	0.001	2	0	1	98	4	0	1	49
	0.0001	0.0001	4	0	1	49	5	0	1	39
	0.00001	0.00001	5	0	1	39	7	0	1	28
196 (the sequence of observations is changed)	0.05	0.05	1	0	1	196	2	0	1	98
	0.01	0.01	1	0	1	196	2	0	1	98
	0.001	0.001	2	0	1	98	3	0	1	65
	0.0001	0.0001	3	0	1	65	4	0	1	49
	0.00001	0.00001	4	0	1	49	5	0	1	39

Table G.4: Decisions Made on the Basis of Real Data of Healthy Patients

Number of patients	Type I error rate	Type II error rate	CBM				Wald			
			Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions
m	α	β	AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$		AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$	

90	0.05	0.05	1	1	0	88	1	1	0	88
	0.01	0.01	1	1	0	88	1	1	0	88
	0.001	0.001	1	1	0	88	1	1	0	88
	0.0001	0.0001	1	1	0	88	1	1	0	88
	0.00001	0.00001	1	1	0	88	1	1	0	88
90 (the sequence of observations is changed)	0.05	0.05	2	1	0	44	2	1	0	44
	0.01	0.01	2	1	0	44	2	1	0	44
	0.001	0.001	2	1	0	44	2	1	0	44
	0.0001	0.0001	2	1	0	44	2	1	0	44
	0.00001	0.00001	2	1	0	44	2	1	0	44

APPENDIX H. RESULTS OF LUNG CARCINOMA DIAGNOSIS BASED ON DATA.

Table H.1: Decisions Made on the Basis of Simulated Data

Number of experiments	Type 1 error rate	Type II error rate	CBM						Wald's test					
			Average number of observations necessary for making a decision when H_0 is true	**Probability of acceptance of basic hypothesis when it is true**	**Probability of acceptance of alternative hypothesis when basic hypothesis is true**	**Average number of observations necessary for making a decision when H_A is true**	**Probability of acceptance of basic hypothesis when alternative hypothesis is true**	**Probability of acceptance of alternative hypothesis when it is true**	**Average number of observations necessary for making a decision when H_0 is true**	**Probability of acceptance of basic hypothesis when it is true**	**Probability of acceptance of alternative hypothesis when basic hypothesis is true**	**Average number of observations necessary for making a decision when H_A is true**	**Probability of acceptance of basic hypothesis when alternative hypothesis is true**	**Probability of acceptance of alternative hypothesis when it is true**
m	α	β	**AN**	$P(x\in \Gamma_0 \mid H_0)$	$P(x\in \Gamma_A \mid H_0)$	**AN**	$P(x\in \Gamma_0 \mid H_A)$	$P(x\in \Gamma_A \mid H_A)$	**AN**	$P(x\in \Gamma_0 \mid H_0)$	$P(x\in \Gamma_A \mid H_0)$	**AN**	$P(x\in \Gamma_0 \mid H_A)$	$P(x\in \Gamma_A \mid H_A)$
200,000	0.05	0.05	Ex. 1: 1 Ex. 2: 1 Ex. 3: 1 Ex. 4: 1 Ex. 5: 1	1 1 1 1 1	0 0 0 0 0	1.0670 1.0664 1.0670 1.0662 1.0667	0.00193 0.001925 0.00177 0.0017 0.001795	0.99807 0.998075 0.99823 0.9983 0.998205	1.0654 1.0653 1.0650 1.0657 1.0664	0.979714 0.97985 0.979425 0.97934 0.979405	0.020286 0.02015 0.020575 0.02066 0.020595	1.0927 1.0913 1.0922 1.0921 1.0917	3.6200e-04 3.1500e-04 2.9500e-04 2.7500e-04 3.0500e-04	0.999638 0.999685 0.999705 0.999725 0.999695
200,000	0.01	0.01	Ex. 1: 1 Ex. 2: 1 Ex. 3: 1 Ex. 4: 1 Ex. 5: 1	1 1 1 1 1	0 0 0 0 0	1.2257 1.2248 1.2262 1.2257 1.2252	0.00106 0.001305 0.00111 0.00119 0.001185	0.99894 0.998695 0.99889 0.99881 0.998815	1.1006 1.1010 1.0994 1.1018 1.0999	0.992775 0.99285 0.99286 0.99288 0.992745	0.007225 0.00715 0.00714 0.00712 0.007255	1.4154 1.4156 1.4157 1.4151 1.4145	2.6500e-04 1.9000e-04 2.4500e-04 2.5500e-04 2.3500e-04	0.999735 0.99981 0.999755 0.999745 0.999765
200,000	0.001	0.001	Ex. 1: 1 Ex. 2: 1	1 1	0 0	2.0352 2.0318	1.4500e-04 1.2000e-	0.999855 0.99988	1.1381 1.1393	0.999965 0.99995	3.5000e-05 5.0000e-	2.6902 2.6904	1.0000e-05 3.5000e-	0.99999 0.999965

			Ex. 3: 1 Ex. 4: 1 Ex. 5: 1	1 1 1	0 0 0	2.0327 2.0326 2.0333	04 6.5000e-05 1.2500e-04 1.4500e-04	0.999935 0.999875 0.999855	1.1404 1.1390 1.1399	0.999935 0.999955 0.999965	05 6.5000e-05 4.5000e-05 3.5000e-05	2.6921 2.6916 2.6916	05 4.5000e-05 2.5000e-05 1.5000e-05	0.999955 0.999975 0.999985
200,000	0.0001	0.0001	Ex. 1: 1 Ex. 2: 1 Ex. 3: 1 Ex. 4: 1 Ex. 5: 1	1 1 1 1 1	0 0 0 0 0	2.9855 2.9857 2.9850 2.9858 2.9863	2.0000e-05 3.0000e-05 1.0000e-05 1.0000e-05 5.0000e-06	0.99998 0.99997 0.99999 0.99999 0.999995	1.1678 1.1700 1.1690 1.1686 1.1703	1 1 1 1 0.999995	0 0 0 0 5.0000e-06	4.2198 4.2214 4.2210 4.2195 4.2211	0 5.0000e-06 5.0000e-06 0 1.0000e-05	1 0.999995 0.999995 1 0.99999
200,000	0.00001	0.00001	Ex. 1: 1 Ex. 2: 1 Ex. 3: 1 Ex. 4: 1 Ex. 5: 1	1 1 1 1 1	0 0 0 0 0	4.2368 4.2352 4.2356 4.2336 4.2374	1.0000e-05 0 0 0 0	0.99999 1 1 1 1	1.1995 1.1973 1.2014 1.1989 1.1993	1 1 1 1 1	0 0 0 0 0	5.6545 5.6535 5.6516 5.6531 5.6549	0 0 0 0 0	1 1 1 1 1

Table H.2: **Percentage Distribution of the Number of Observations Necessary for Making a Decision**

Type 1 error rate	Type II error rate	Experiment	Number of observations necessary for making a decision	CBM		Wald's test	
				Hypothesis H_0 is true	Hypothesis H_A is true	Hypothesis H_0 is true	Hypothesis H_A is true
α	β	Ex.	NO	Percentage %	Percentage %	Percentage %	Percentage %
0.05	0.05	Ex. 1	1	100	93.3135	93.6230	90.7556
			2	0	6.6760	6.2108	9.2224
			3	0	0.0105	0.1646	0.0220
			4	0	0	0.0016	0
			5	0	0	0	0
		Ex. 2	1	100	93.3680	93.6315	90.8890
			2	0	6.6235	6.2075	9.0905
			3	0	0.0085	0.1590	0.0205
			4	0	0	0.0020	0
			5	0	0	0	0
		Ex. 3	1	100	93.3080	93.6765	90.7945
			2	0	6.6855	6.1545	9.1895
			3	0	0.0065	0.1665	0.0160
			4	0	0	0.0025	0
			5	0	0	0	0
		Ex. 4	1	100	93.3885	93.6020	90.8185
			2	0	6.6040	6.2270	9.1560
			3	0	0.0075	0.1705	0.0255
			4	0	0	0.0005	0
			5	0	0	0	0
		Ex. 5	1	100	93.3340	93.5285	90.8515
			2	0	6.6575	6.3020	9.1225
			3	0	0.0085	0.1660	0.0260
			4	0	0	0.0035	0
			5	0	0	0	0

0.01	0.01	Ex. 1	1	100	77.7005	90.3075	59.7890
			2	0	22.0320	9.3305	38.8800
			3	0	0.2675	0.3555	1.3300
			4	0	0	0.0065	0.0010
			5	0	0	0	0
		Ex. 2	1	100	77.7675	90.3180	59.6565
			2	0	21.9815	9.2810	39.1275
			3	0	0.2510	0.3945	1.2155
			4	0	0	0.0065	0.0005
			5	0	0	0	0
		Ex. 3	1	100	77.6400	90.4405	59.6720
			2	0	22.1025	9.1850	39.0895
			3	0	0.2575	0.3710	1.2385
			4	0	0	0.0035	0
			5	0	0	0	0
		Ex. 4	1	100	77.6870	90.2050	59.7740
			2	0	22.0535	9.4155	38.9445
			3	0	0.2595	0.3715	1.2815
			4	0	0	0.0075	0
			5	0	0	0.0005	0
		Ex. 5	1	100	77.7375	90.3945	59.8580
			2	0	22.0065	9.2315	38.8385
			3	0	0.2560	0.3685	1.3030
			4	0	0	0.0055	0.0005
			5	0	0	0	0
0.001	0.001	Ex. 1	1	100	8.6955	86.9295	0.0010
			2	0	79.1410	12.3500	35.4110
			3	0	12.1100	0.7055	60.1660
			4	0	0.05350	0.0150	4.4145
			5	0	0	0	0.0075
		Ex. 2	1	100	8.8040	86.8350	0.0035
			2	0	79.2765	12.4165	35.4885
			3	0	11.8585	0.7300	59.98350
			4	0	0.06100	0.0185	4.5170
			5	0	0	0	0.0075
		Ex. 3	1	100	8.8195	86.7400	0.0045
			2	0	79.1555	12.5080	35.3210
			3	0	11.9615	0.7290	60.1475
			4	0	0.06350	0.0230	4.5180
			5	0	0	0	0.0090
		Ex. 4	1	100	8.8465	86.8905	0.0025
			2	0	79.1120	12.3420	35.3650
			3	0	11.9785	0.7480	60.1080
			4	0	0.0630	0.0195	4.5180
			5	0	0	0	0.0065
		Ex. 5	1	100	8.7740	86.8025	0.0015
			2	0	79.1870	12.4185	35.2955
			3	0	11.9705	0.7620	60.2525
			4	0	0.06850	0.0165	4.4405
			5	0	0	0.0005	0.0100

0.0001	0.0001	Ex. 1	1	100	0.0020	84.3960	0
			2	0	12.5905	14.4635	0
			3	0	76.3085	1.1005	0.5050
			4	0	11.0505	0.0400	77.1765
			5	0	0.0485	0	22.1475
			6	0	0	0	0.1710
		Ex. 2	1	100	0.0030	84.2045	0.0005
			2	0	12.5630	14.6250	0
			3	0	76.3420	1.1345	0.5060
			4	0	11.0460	0.0360	77.0435
			5	0	0.0460	0	22.2535
			6	0	0	0	0.1965
		Ex. 3	1	100	0.0010	84.2915	0.0005
			2	0	12.5760	14.5595	0
			3	0	76.3935	1.1115	0.4940
			4	0	10.9845	0.0360	77.0860
			5	0	0.0450	0.0015	22.2475
			6	0	0	0	0.1720
		Ex. 4	1	100	0.0010	84.3480	0
			2	0	12.5565	14.4855	0
			3	0	76.3585	1.1260	0.5240
			4	0	11.0320	0.0405	77.1635
			5	0	0.0520	0	22.1495
			6	0	0	0	0.1630
		Ex. 5	1	100	0.0005	84.12450	0.0010
			2	0	12.4275	14.7655	0
			3	0	76.5545	1.0655	0.5070
			4	0	10.9755	0.0435	77.0560
			5	0	0.0420	0.0010	22.2515
			6	0	0	0	0.1845
0.00001	0.00001	Ex. 1	1	100	0.0010	81.7670	0
			2	0	0	16.5835	0
			3	0	0.1275	1.5865	0
			4	0	76.26250	0.0610	0
			5	0	23.4080	0.0020	37.5470
			6	0	0.2010	0	59.4605
			7	0	0	0	2.9915
			8	0	0	0	0.0010
		Ex. 2	1	100	0	81.9295	0
			2	0	0	16.4760	0
			3	0	0.1195	1.5285	0
			4	0	76.4385	0.0650	0
			5	0	23.2440	0.0010	37.6740
			6	0	0.1980	0	59.3015
			7	0	0	0	3.0220
			8	0	0	0	0.0025
		Ex. 3	1	100	0	81.5745	0
			2	0	0	16.7795	0
			3	0	0.1265	1.5785	0
			4	0	76.3900	0.0670	0
			5	0	23.2805	0.0005	37.8870
			6	0	0.2030	0	59.0685
			7	0	0	0	3.0435
			8	0	0	0	0.0010

		Ex. 4	1	100	0	81.7780	0
			2	0	0	16.6180	0
			3	0	0.1290	1.5405	0
			4	0	76.5670	0.0615	0
			5	0	23.1190	0.0020	37.6935
			6	0	0.1850	0	59.3055
			7	0	0	0	2.9980
			8	0	0	0	0.0030
		Ex. 5	1	100	0	81.7690	0
			2	0	0	16.6095	0
			3	0	0.1255	1.5485	0
			4	0	76.2205	0.0725	0
			5	0	23.4405	0.0005	37.6160
			6	0	0.2135	0	59.2845
			7	0	0	0	3.0980
			8	0	0	0	0.0015

Table H.3: Decisions Made on the Basis of Real Data of Sick Patients

Number of patients	Type I error rate	Type II error rate	CBM				Wald			
			Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions
m	α	β	AN	$P(x \in \Gamma_0 \mid H_A)$	$P(x \in \Gamma_A \mid H_A)$	N	AN	$P(x \in \Gamma_0 \mid H_A)$	$P(x \in \Gamma_A \mid H_A)$	N
38	0.05	0.05	3	0	1	12	3	0	1	12
	0.01	0.01	3	0	1	12	18	0	1	2
	0.001	0.001	18	0	1	2	18	0	1	2
	0.0001	0.0001	18	0	1	2	19	0	1	2
	0.00001	0.00001	19	0	1	2	22	0	1	1
130	0.05	0.05	2	0	1	65	2	0	1	65
	0.01	0.01	2	0	1	65	2	0	1	65
	0.001	0.001	3	0	1	43	4	0	1	32
	0.0001	0.0001	5	0	1	26	5	0	1	26
	0.00001	0.00001	5	0	1	26	7	0	1	19

Table H.4: Decisions Made on the Basis of Real Data of Healthy Patients

Number of patients	Type I error rate	Type II error rate	CBM				Wald			
			Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions
m	α	β	AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$		AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$	
88	0.01	0.01	1	1	0	88	1	1	0	88
	0.001	0.001	1	1	0	88	1	1	0	88
	0.0001	0.0001	1	1	0	88	1	1	0	88
	0.00001	0.00001	1	1	0	88	1	1	0	88

88 (the sequence of observations is changed)	0.01	0.01	2	1	0	44	2	1	0	44
	0.001	0.001	2	1	0	44	4	1	0	22
	0.0001	0.0001	4	1	0	22	4	1	0	22
	0.00001	0.00001	4	1	0	22	4	1	0	22

APPENDIX I. RESULTS OF LUNG ADENOMA AND ADENOCARCINOMA DIAGNOSIS BASED ON COMBINED DATA.

Table I.1: Decisions Made on the Basis of Simulated Data

Number of experiments	Type 1 error rate	Type II error rate	CBM						Wald's test					
			Average number of observations necessary for making a decision when H_0 is true	Probability of acceptance of basic hypothesis when it is true	Probability of acceptance of alternative hypothesis when basic hypothesis is true	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Average number of observations necessary for making a decision when H_0 is true	Probability of acceptance of basic hypothesis when it is true	Probability of acceptance of alternative hypothesis when basic hypothesis is true	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alter-native hypothesis is true	Probability of acceptance of alternative hypothesis when it is true
m	α	β	AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$	AN	$P(x \in \Gamma_0 \mid H_A)$	$P(x \in \Gamma_A \mid H_A)$	AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$	AN	$P(x \in \Gamma_0 \mid H_A)$	$P(x \in \Gamma_A \mid H_A)$
200,000	0.05	0.05	Ex. 1: 1.0676	0.9652	0.0348	1.1148	0.0024	0.9976	1.1051	0.970305	0.029695	1.1594	0.00163	0.99837
			Ex. 2: 1.0685	0.9651	0.0349	1.1154	0.002645	0.997355	1.1059	0.96999	0.03001	1.1595	0.00162	0.99838
			Ex. 3: 1.0665	0.9656	0.0344	1.1140	0.002815	0.997185	1.1034	0.9702	0.0298	1.1593	0.001645	0.998355
			Ex. 4: 1.0666	0.9663	0.0337	1.1153	0.00269	0.99731	1.1050	0.970035	0.029965	1.1597	0.001755	0.998245
			Ex. 5: 1.0664	0.9656	0.0344	1.1162	0.002905	0.997095	1.1043	0.97041	0.02959	1.1604	0.0017	0.9983
200,000	0.01	0.01	Ex. 1: 1.1243	0.9935	0.0065	1.6974	4.1500e-04	0.999585	1.1587	0.994675	0.005325	1.7600	3.4500e-04	0.999655
			Ex. 2: 1.1238	0.9934	0.0066	1.6999	4.8000e-04	0.99952	1.1563	0.994815	0.005185	1.7597	3.0000e-04	0.9997
			Ex. 3: 1.1234	0.9935	0.0065	1.6986	6.3500e-04	0.999365	1.1589	0.994515	0.005485	1.7615	3.6500e-04	0.999635
			Ex. 4: 1.1234	0.9935	0.0066	1.6997	4.5500e-04	0.999545	1.1586	0.99459	0.00541	1.7593	2.7500e-04	0.999725
			Ex. 5: 1.1248	0.9936	0.0064	1.6992	6.1500e-04	0.999385	1.1575	0.994145	0.005855	1.7591	3.0000e-04	0.9997
200,000	0.001	0.001	Ex. 1: 1.1521	0.999665	3.3500e-04	2.2998	1.7000e-04	0.99983	1.2016	0.999975	2.500e-05	3.1752	3.0000e-05	0.99997
			Ex. 2: 1.1521	0.99967	3.3000e-04	2.2996	1.2500e-04	0.999875	1.2023	0.999995	5.000e-06	3.1754	2.0000e-05	0.99998
			Ex. 3: 1.1542	0.999705	2.9500e-04	2.2992	1.3500e-04	0.999865	1.2030	0.999975	2.500e-05	3.1774	2.0000e-05	0.99998
			Ex. 4: 1.1523	0.999625	3.7500e-04	2.2999	1.3000e-04	0.99987	1.2015	0.99999	1.000e-05	3.1757	4.5000e-05	0.999955
			Ex. 5: 1.1521	0.999665	3.3500e-04	2.2979	1.9500e-04	0.9998	1.2025	0.999985	1.500e-05	3.1750	2.0000e-05	0.99998
200,000	0.0001	0.0001	Ex. 1: 1.1834	1	0	3.2997	2.5000e-05	0.999975	1.2371	1	0	4.4788	5.0000e-06	0.999995
			Ex. 2: 1.1829	0.99999	1.0000e-05	3.3007	5.0000e-06	0.999995	1.2397	1	0	4.4783	5.0000e-06	0.999995
			Ex. 3: 1.1834	1	0	3.3017	3.5000e-05	0.999965	1.2381	1	0	4.4809	0	1
			Ex. 4: 1.1833	0.999995	5.0000e-06	3.3006	3.0000e-05	0.99997	1.2385	1	0	4.4792	1.0000e-05	0.99999
			Ex. 5: 1.1844	1	0	3.3024	3.0000e-05	0.99997	1.2373	1	0	4.4799	1.0000e-05	0.99999
200,000	0.00001	0.00001	Ex. 1: 1.2171	1	0	4.4932	0	1	1.2718	1	0	5.9638	0	1
			Ex. 2: 1.2165	1	0	4.4930	0	1	1.2697	1	0	5.9622	0	1
			Ex. 3: 1.2166	1	0	4.4913	5.0000e-06	0.999995	1.2730	1	0	5.9629	0	1
			Ex. 4: 1.2166	1	0	4.4922	0	1	1.2709	1	0	5.9626	0	1
			Ex. 5: 1.2158	1	0	4.4901	0	1	1.2715	1	0	5.9600	0	1

Table I.2: Percentage Distribution of the Number of Observations Necessary for Making a Decision

Type 1 error rate	Type II error rate	Experiment	Number of observations necessary for making a decision	CBM		Wald's test	
				Hypothesis H_0 is true	Hypothesis H_A is true	Hypothesis H_0 is true	Hypothesis H_A is true
α	β	Ex.	NO	Percentage %	Percentage %	Percentage %	Percentage %

0.05	0.05	Ex. 1	1	93.5070	88.5565	89.8450	84.1345
			2	6.3510	11.4105	9.8035	15.7895
			3	0.1410	0.0330	0.3475	0.0760
			4	0.0010	0	0.0040	0
			5	0	0	0	0
		Ex. 2	1	93.2670	88.4950	89.7765	84.1265
			2	6.5810	11.4700	9.8670	15.8015
			3	0.1510	0.0350	0.3515	0.0720
			4	0.0010	0	0.0050	0
			5	0	0	0	0
		Ex. 3	1	93.5530	88.6320	90.0335	84.1505
			2	6.3180	11.3380	9.5995	15.7660
			3	0.1290	0.0300	0.3615	0.0835
			4	0	0	0.0055	0
			5	0	0	0	0
		Ex. 4	1	93.5910	88.5115	89.8435	84.1095
			2	6.2530	11.4460	9.8150	15.8105
			3	0.1550	0.0425	0.3380	0.0800
			4	0.0010	0	0.0035	0
			5	0	0	0	0
		Ex. 5	1	93.5110	88.4200	89.9320	84.0410
			2	6.3350	11.5440	9.7125	15.8810
			3	0.1530	0.0360	0.3520	0.0780
			4	0.0010	0	0.0035	0
			5	0	0	0	0
0.01	0.01	Ex. 1	1	88.1060	34.5285	84.9245	29.3240
			2	11.4010	61.2090	14.3040	65.3610
			3	0.4840	4.2575	0.7530	5.3070
			4	0.0090	0.0050	0.0185	0.0080
			5	0	0	0	0
		Ex. 2	1	87.9970	34.3245	85.1780	29.3615
			2	11.5520	61.3665	14.0335	65.3195
			3	0.4470	4.3035	0.7695	5.3100
			4	0.0040	0.0055	0.0190	0.0090
			5	0	0	0	0
		Ex. 3	1	88.0400	34.4155	84.9445	29.1895
			2	11.5370	61.3150	14.2330	65.4850
			3	0.4170	4.2635	0.8075	5.3180
			4	0.0060	0.0060	0.0150	0.0075
			5	0	0	0	0
		Ex. 4	1	88.3300	34.3355	84.9360	29.4460
			2	11.1990	61.3695	14.2810	65.1885
			3	0.4680	4.2885	0.7665	5.3575
			4	0.0030	0.0065	0.0165	0.0080
			5	0	0	0	0
		Ex. 5	1	87.9510	34.4825	85.0665	29.4550
			2	11.5730	61.1225	14.1340	65.1900
			3	0.4700	4.3900	0.7810	5.3480
			4	0.0060	0.0050	0.0185	0.0070
			5	0	0	0	0
0.001	0.001	Ex. 1	1	85.5090	0.0170	81.2540	0.0030
			2	13.7190	70.4265	17.3705	0
			3	0.7600	29.1195	1.3370	82.5560

			4	0.0120	0.4365	0.0370	17.3575
			5	0	0.0005	0.0015	0.0835
			6	0	0	0	0
			7	0	0	0	0
		Ex. 2	1	85.6550	0.0125	81.1615	0.0020
			2	13.6060	70.4370	17.4880	0
			3	0.7230	29.1275	1.3120	82.5475
			4	0.0150	0.4230	0.0375	17.3580
			5	0.0010	0	0.0010	0.0925
			6	0	0	0	0
			7	0	0	0	0
		Ex. 3	1	85.3470	0.0135	81.1310	0.0020
			2	13.9340	70.5180	17.4780	0
			3	0.7070	29.0080	1.3520	82.3405
			4	0.0120	0.4605	0.0390	17.5745
			5	0	0	0	0.0830
			6	0	0	0	0
			7	0	0	0	0
		Ex. 4	1	85.6470	0.0130	81.2505	0.0045
			2	13.5830	70.4080	17.3905	0
			3	0.7600	29.1490	1.3195	82.5085
			4	0.0100	0.4300	0.0395	17.3915
			5	0	0	0	0.0955
			6	0	0	0	0
		Ex. 5	1	85.4520	0.0195	81.1960	0.0020
			2	13.7840	70.5825	17.3940	0
			3	0.7510	28.9870	1.3765	82.5895
			4	0.0130	0.4110	0.0335	17.3110
			5	0	0	0	0.0975
			6	0	0	0	0
0.0001	0.0001	Ex. 1	1	82.7070	0.0025	78.1810	0.0005
			2	16.2110	0	19.9835	0
			3	1.0600	70.3970	1.7795	0
			4	0.0220	29.2280	0.0555	53.1555
			5	0	0.3725	0.0005	45.8050
			6	0	0	0	1.0390
			7	0	0	0	0
		Ex. 2	1	82.7680	0.0005	78.0030	0.0005
			2	16.1570	0	20.0970	0
			3	1.0490	70.2780	1.8260	0
			4	0.0260	29.3755	0.0725	53.2155
			5	0	0.3460	0.0015	45.7400
			6	0	0	0	1.0435
			7	0	0	0	0.0005
		Ex. 3	1	82.8600	0.0035	78.1220	0
			2	16.0070	0	20.0160	0
			3	1.1020	70.1705	1.7980	0
			4	0.0310	29.4765	0.0630	52.9985
			5	0	0.3495	0.0010	45.9180
			6	0	0	0	1.0835
			7	0	0	0	0

		Ex. 4	1	82.8950	0.0030	78.1450	0.0010
			2	16.0260	0	19.9325	0
			3	1.0560	70.2760	1.8550	0
			4	0.0230	29.3760	0.0660	53.18250
			5	0	0.3450	0.0015	45.7155
			6	0	0	0	1.1005
			7	0	0	0	0.0005
		Ex. 5	1	82.7620	0.0030	78.2795	0.0010
			2	16.0440	0	19.7815	0
			3	1.1760	70.1145	1.8660	0
			4	0.0180	29.5195	0.0710	53.1090
			5	0	0.3630	0.0020	45.7905
			6	0	0	0	1.0995
			7	0	0	0	0
0.00001	0.00001	Ex. 1	1	79.8970	0	75.4475	0
			2	18.5450	0	22.0250	0
			3	1.5110	0	2.4325	0
			4	0.0460	51.8275	0.0930	0
			5	0.0010	47.0250	0.0020	13.3405
			6	0	1.1475	0	76.9435
			7	0	0	0	9.7085
			8	0	0	0	0.0075
		Ex. 2	1	79.9850	0	75.6255	0
			2	18.4700	0	21.8860	0
			3	1.5070	0	2.3830	0
			4	0.0370	51.8770	0.1035	0
			5	0.0010	46.9465	0.0020	13.4460
			6	0	1.1760	0	76.9075
			7	0	0.0005	0	9.6300
			8	0	0	0	0.0165
		Ex. 3	1	79.7910	0.0005	75.3355	0
			2	18.6880	0	22.1295	0
			3	1.4760	0	2.4400	0
			4	0.0450	52.0160	0.0940	0
			5	0	46.8310	0.0010	13.3755
			6	0	1.1525	0	76.9710
			7	0	0	0	9.6405
			8	0	0	0	0.0130
		Ex. 4	1	80.0250	0	75.5490	0
			2	18.3550	0	21.9195	0
			3	1.5730	0	2.4265	0
			4	0.0460	51.9230	0.1030	0
			5	0.0010	46.9330	0.0020	13.3715
			6	0	1.1440	0	77.0065
			7	0	0	0	9.6080
			8	0	0	0	0.0140
		Ex. 5	1	80.2830	0	75.4665	0
			2	18.1310	0	22.0315	0
			3	1.5350	0	2.3940	0
			4	0.0510	52.1185	0.1065	0
			5	0	46.7490	0.0015	13.5560
			6	0	1.1320	0	76.9080
			7	0	0.0005	0	9.5190
			8	0	0	0	0.0170

Table I.3: Decisions Made on the Basis of Real Data of Sick Patients

Number of patients	Type I error rate	Type II error rate	CBM				Wald			
			Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions
m	α	β	AN	$P(x \in \Gamma_0 \mid H_A)$	$P(x \in \Gamma_A \mid H_A)$	N	AN	$P(x \in \Gamma_0 \mid H_A)$	$P(x \in \Gamma_A \mid H_A)$	N
364	0.05	0.05	1	0	1	364	1	0	1	364
	0.01	0.01	1	0	1	364	1	0	1	364
	0.001	0.001	1	0	1	364	3	0	1	121
	0.0001	0.0001	1	0	1	364	4	0	1	91
	0.00001	0.00001	1	0	1	364	6	0	1	60
364 (the sequence of observations is changed)	0.05	0.05	1	0	1	364	1	0	1	364
	0.01	0.01	1	0	1	364	2	0	1	182
	0.001	0.001	1	0	1	364	4	0	1	92
	0.0001	0.0001	1	0	1	364	5	0	1	72
	0.00001	0.00001	1	0	1	364	7	0	1	52

Table I.4: Decisions Made on the Basis of Real Data of Healthy Patients

Number of patients	Type I error rate	Type II error rate	CBM				Wald			
			Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions	Average number of observations necessary for making a decision when H_A is true	Probability of acceptance of basic hypothesis when alternative hypothesis is true	Probability of acceptance of alternative hypothesis when it is true	Number of made decisions
m	α	β	AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$		AN	$P(x \in \Gamma_0 \mid H_0)$	$P(x \in \Gamma_A \mid H_0)$	
88	0.05	0.05	1	1	0	88	1	1	0	88
	0.01	0.01	1	1	0	88	1	1	0	88
	0.001	0.001	1	1	0	88	1	1	0	88
	0.0001	0.0001	1	1	0	88	1	1	0	88
	0.00001	0.00001	1	1	0	88	1	1	0	88
88 (the sequence of observations is changed)	0.05	0.05	1	1	0	88	1	1	0	88
	0.01	0.01	1	1	0	88	1	1	0	88
	0.001	0.001	1	1	0	88	1	1	0	88
	0.0001	0.0001	1	1	0	88	1	1	0	88
	0.00001	0.00001	1	1	0	88	1	1	0	88

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