Evaluation of the quality and usefulness of information technologies for supporting medical decision-making based on civil law

Tetiana Hovorushchenko[1,*,†], Houda El Bouhissi[2,†] and Yelyzaveta Hnatchuk[1,†]

[1] *Khmelnytskyi National University, Institutska str., 11, Khmelnytskyi, 29016, Ukraine*
[2] *LIMED Laboratory, Faculty of Exact Sciences, University of Bejaia, 06000, Bejaia, Algeria*

Abstract

The article develops a method for determining the quality and usefulness of information technologies for supporting medical decision-making based on civil law, which provides a conclusion on the quality and usefulness of these information technologies in terms of classifying decisions into possible and impossible ones. All the calculated metrics' values indicate the quality of the work of all the developed information technologies for supporting various medical decisions based on civil law. The conducted experiments and the obtained results showed that the usefulness of information technology for supporting decision-making on the possibility of using reproductive technologies for reproductive clinics is to ensure that it increases the legal correctness of the medical decisions provided – by 47.2% for 193 cases of surrogacy and by 44.4% for 320 cases of in vitro fertilization. The usefulness of the information technology for supporting decision-making on the possibility of donation and transplantation for surgical and transplantation clinics and departments is to ensure that it increases the legal correctness of medical decisions – by 10.8% for 102 reviewed cases of donation and by 5.9% for 102 reviewed cases of transplantation. The usefulness of the information technology for supporting decision-making on the possibility of providing medical services, therapeutic services, and dental services for family medicine outpatient clinics, clinics and hospitals is to ensure that it increases the legal correctness of the decisions made – by 37.3% for 1943 cases (including by 57.3% for 328 cases of general medical services, by 25.9% for 1090 cases of therapeutic services, and by 48.4% for 525 cases of dental services).

Keywords

Information technologies for supporting medical decision-making based on civil law; quality and usefulness of information technologies; datasets; confusion matrix; quality metrics *Accuracy, Precision, Recall, F1, Specificity, AUC*.

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* Corresponding author.
† These authors contributed equally.
tat_yana@ukr.net (T. Hovorushchenko); hnatchuky@khmnu.edu.ua (Ye. Hnatchuk); houda.elbouhissi@gmail.com (H. El Bouhissi)
0000-0002-7942-1857 (T. Hovorushchenko); 0000-0003-2989-3183 (Ye. Hnatchuk); 0000-0003-3239-8255 (H. El Bouhissi)

1. Introduction

Every year, the use of information technologies in medicine is rapidly expanding [1, 2]. The need for efficient use of large amounts of information to solve diagnostic, therapeutic, statistical, managerial and other tasks leads to the active introduction of information technologies in medical institutions [3, 4].

Information technologies significantly improves the functioning of the healthcare system by introducing organizational changes, making it more accessible to the public and ensuring greater transparency in the activities of medical institutions [5, 6]. They help to improve the efficiency and quality of healthcare services, reduce the cost of providing them, reduce the time required for examination and treatment of patients, optimize the use of medical staff time, and provide consulting support to doctors [7, 8]. In addition, they facilitate the integration of the country's healthcare system into the global medical information space, allowing doctors to communicate effectively, access medical archives and libraries, and interact with various medical equipment [9, 10].

Currently, decision-making processes in the medical field are characterized as time-consuming, complex, non-transparent, and ambiguous for both patients and many doctors [11, 12].

A modern physician makes decisions based on several medical specialties and a wide range of diagnostic and therapeutic methods, medicines, etc. In his/her practice, a physician must take into account various factors and peculiarities, guided by his/her own experience, knowledge and clinical guidelines [13-15]. Sometimes a physician is also forced to take into account civil law grounds relating to a particular medical decision and the legal capacity to provide it, as many problems in the field of medicine have legal roots [7, 16, 17]. Thus, with the growing amount of medical and other knowledge and limited time for decision-making, it is becoming increasingly difficult for a doctor to provide accurate and timely diagnoses. This can lead to an increase in the number of medical errors [1, 13].

Thus, medical practice is characterized by a shortage of time, rapid disease dynamics, and a high cost of medical errors. The introduction of information technology can help reduce the number of medical errors, provide more reliable solutions, and reduce healthcare costs [18, 19]. The development of cross-disciplinary information technologies (e.g., information technologies for supporting medical decision-making based on civil law) is currently *an important, relevant, but complex and time-consuming problem*, since, on the one hand, such technology ensures that the norms of current legislation are taken into account when making medical decisions, the correctness of the medical procedure from a legal point of view, protects the doctor and the patient from legal conflicts, and, on the other hand, requires taking into account the standards and principles of development of information technologies along with regulatory documents in the field of medical law.

To solve this problem, the authors paid considerable attention and developed theoretical and applied principles of information technology for medical decision-making support based on civil law [22], and implemented this information technology for medical decision-making support based on civil law [23, 24].

2. Analysis of statistical metrics for evaluating the quality of information technologies for medical decision-making support based on civil law

The analysis of the subject area carried out in [22-24] showed that the problem of medical decision-making based on civil law, which, in general, is an optimization problem (which consists in finding the extremum of the objective function by systematically selecting input values from the allowed set and calculating the value of the function), can be considered as a problem of binary classification regarding the possibility/impossibility of providing a certain medical service. Based on this, the considered problem is to synthesize appropriate methods of binary classification a_z to solve the task of medical decision support (solved in [22-24]) and analyze the obtained binary classifier solutions, which is the *purpose of our study*.

By synthesis for the considered problem, we mean the combination of abstracted aspects of the problem and their reflection as a concrete integrity. That is, in [22-24], an abstract model for supporting medical decision-making based on civil law is proposed. The final result of this synthesis is the information technology for supporting medical decision-making based on civil law, developed in [22-24].

By analysis for the considered problem, we mean obtaining an optimal solution as a result of the classification task about impossibility (class 0) or possibility (class 1) of providing a certain medical service based on the available civil law grounds.

Thus, for the problem being solved, the abstract model can be represented as follows: $D \rightarrow PM$, where D is a text document (data on potential patients and/or a contract for the provision of a specific medical service), PM is the information technology parameters for a specific medical service.

The classification task is as follows: for a sample $X_z = \{x_1,\ldots,x_w\}$ (civil law grounds (essential conditions) in real patient data or in real contracts for the providing the z-th medical service) and known binary answers $Y_z = y(X_z) \in \{0;1\}$ (conclusion about the impossibility (0) or the possibility (1) of providing the z-th medical service) there is a method a_z (solution function, strategy, etc.), that approximates Y_z on the entire set of objects X_z, i. e. $a_z: X_z \rightarrow Y_z$ (Fig. 1).

To analyze the obtained solutions of the binary classifier, it will be important to measure the quality of each information technology a_z, i.e., in essence, the quality of the binary classifier az. The quality assessment will answer the question of how well the classifier a_z separates classes in a given sample.

Let's analyze the known statistical metrics for evaluating the quality of classifiers in terms of their application to the considered problem.

As a rule, the results of solving a binary classification problem are denoted as positive and negative. As a result of binary classification, all sample objects are divided into four types, forming a confusion matrix [25] – Fig. 2.

Using the confusion matrix from Fig. 1, let's consider several quality metrics of the binary classification model [25], which are not mutually exclusive, complement each other, and can be used simultaneously:

- *Accuracy* metric – the ratio of all correct conclusions to the total number of all conclusions
- *Precision* metric – the ratio of correctly generated positive decisions among all positive decisions of the classifier
- *Recall* metric – the ratio of correctly generated positive decisions among all really positive cases
- *F1* metric – combines information about Precision and Recall metrics and is their harmonic mean value
- *Specificity* metric – the ratio of correctly generated negative decisions among all really negative cases
- *TPR* metric – the frequency of true-positive results, which coincides with the Recall metric
- *FPR* metric – the frequency of false-positives results
- *AUC* metric – area under the ROC-curve (Receiver Operating Characteristic) – *FPR* and *TPR* metrics should be plotted on the same graph in the coordinate system with the *FPR* and *TPR* axes, resulting in a curve, which is the ROC-curve; for binary responses of the algorithm, the ROC-curve consists of three points connected by lines: *(0,0), (FPR, TPR), (1, 1)*, so the ROC-curve built for a binary dataset (for a binary classifier) is a line containing only three points.

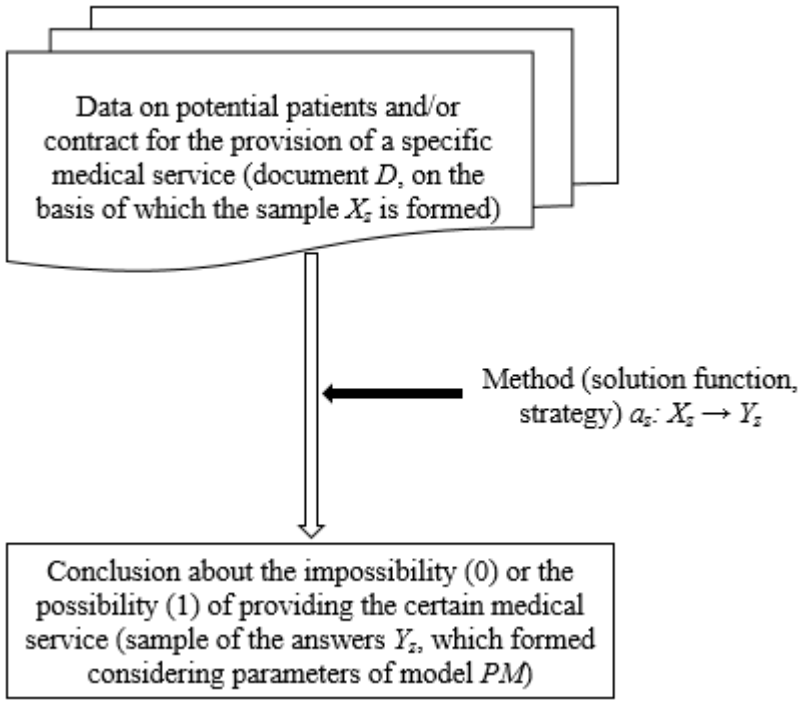

Figure 1: Synthesis and analysis of information technologies for supporting medical decision-making based on civil law).

TP True Positive – the predicted decision is positive, and it is correct *(correct operation)*	**TN** True Negative – the predicted decision is negative, and that is correct *(correct operation)*
FP False Positive – the predicted decision is positive, but it is wrong *(incorrect operation)*	**FN** False Negative – the predicted decision is negative, but it is wrong *(incorrect operation)*

Figure 2: Confusion matrix [25].

In various fields, when making a "binary" decision (yes/no) based on a certain criterion, type I and type II errors are often used. If a true hypothesis is mistakenly rejected, this error is called a type I error. If a false hypothesis is mistakenly accepted, it is a type II error.

Type II errors are a significant problem for the medical field. They lead to a false belief that a disease is not present, when in fact it is. This often leads to inadequate treatment. Type II errors cause serious and difficult to understand problems, especially when the condition in question is widespread. If a test with a 10% type II error rate is used to screen a group where the probability of "true-positive" cases is 70%, many negative test results will be false [25].

Type I errors can also cause serious and difficult-to-understand problems. This happens when the condition being sought is rare. If the rate of type I errors in a test is one case in ten thousand, but the probability of "true-positive" cases in the group of samples under test is on average one case in a million, then most of the positive results of this test will be false [25, 26].

Therefore, the above metrics *Accuracy, Precision, Recall, F1, Specificity, TPR, FPR, AUC* are still more correct and understandable criteria for determining the quality of a classifier.

3. Method for determining the quality and usefulness of information technologies for supporting medical decision-making based on civil law

Method for determining the quality and usefulness of information technologies for supporting medical decision-making based on civil law (binary classifiers a_z: $X_z \rightarrow Y_z$) consists of the following steps:

1. Description of each data set used for experimental studies of the quality of the proposed binary classifiers a_z: $X_z \rightarrow Y_z$ in terms of data balance (percentage of positive and percentage of negative conclusions), data representativeness (ability of the selected data to reproduce the main characteristics of the total data set) and data markup quality (compliance by experts with the classification criteria by which the classifier operates)
2. Filling the confusion matrix with data to support decision-making on the possibility/impossibility of a particular medical service based on the civil law – Fig. 3

TP The medical service is possible from the point of view of civil law, and the classifier recommended a conclusion that such a service is possible (*correct operation*)	***TN*** The medical service is not possible from the point of view of civil law, and the classifier recommended the conclusion that such a service is not possible (*correct operation*)
FP The medical service is not possible from the point of view of civil law, but the classifier recommended a conclusion that such a service is possible (*incorrect operation*)	***FN*** The medical service is possible from the point of view of civil law, but the classifier recommended the conclusion that such a service is impossible (*incorrect operation*)

Figure 3: Confusion matrix for the task of supporting decision-making on the possibility/impossibility of a certain medical service based on the civil law.

3. Determination of the Accuracy metric by the formula: $Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$, although in some problems the Accuracy metric may be uninformative, especially in unbalanced samples where only a few percent of the conclusions about the impossibility to provide a medical service may be made
4. Determination of the *Precision* metric by the formula: $Precision = \frac{TP}{TP + FP}$ – the ratio of correct conclusions about the possibility of a medical service among all classifier's decisions about the possibility of a medical service; the higher the value of the metric, the fewer incorrect decisions the classifier has proposed
5. Determination of the Recall metric by the formula: $Recall = \frac{TP}{TP + FN}$ – the ratio of conclusions about the possibility of a medical service among all cases of the possibility of providing a medical service; the higher the value of the *Recall* metric, the fewer correct decisions about the possibility of a medical service are missed during classification; obviously, the higher the values of the *Precision* and *Recall* metrics, the better, so it is necessary to find the right balance between the *Precision* and *Recall* metrics
6. Determination of the *F1* metric by the formula: $F1 = \frac{2 \cdot Precision \cdot Recall}{Precision + Recall}$ – high value of the *F1* metric proves that the classifier is not primitive
7. Determination of the *Specificity* metric by the formula: $Specificity = \frac{TN}{FP + TN}$ – the ratio of correct conclusions about the impossibility of a medical service among all cases of impossibility of providing a medical service
8. Determination of the *AUC* metric (area under the ROC-curve) – the higher the value of the *AUC* metric, the better the classifier works, with a value of 0.5 demonstrating the unsuitability of the chosen classification method (corresponds to a simple guess)
9. Forming a conclusion about the quality of binary classifiers $a_z: X_z \to Y_z$ based on the values of the metrics *Accuracy, Precision, Recall, Specificity, F1, AUC*

10. Analysis of the reasons for misclassification – why the classifier recommended the conclusion that the service is possible when this medical service is impossible from the point of view of civil law, as well as why the classifier recommended the conclusion that the service is impossible when such a medical service is possible from the point of view of civil law
11. Determination of the usefulness of the proposed binary classifiers a_z: $X_z \to Y_z$ based on the value *TN* (the number of cases when a medical service is impossible from the point of view of civil law, and the classifier recommended the conclusion that such a service is impossible), which demonstrates in how many cases the developed binary classifier helped prevent the provision of a medical service when such a service is impossible from the point of view of current civil law, thus protecting the patient and the doctor.

The proposed method for determining the quality and usefulness of information technologies for supporting medical decision-making based on civil law provides a conclusion about the quality and usefulness of these information technologies (binary classifiers a_z: $X_z \to Y_z$) in terms of classifying decisions into possible and impossible decisions.

4. Evaluation of the quality and usefulness of information technologies for supporting medical decision-making based on civil law

As noted above, the authors designed and implemented information technology foe supporting decision-making on the possibility of using reproductive technologies based on civil law (classifiers a_1 and a_2), information technology for supporting decision-making on the possibility of donation and transplantation based on civil law (classifiers a_3 and a_4), information technology for supporting decision-making on the possibility of providing medical services, therapeutic services, dental services based on the civil law (classifiers a_5, a_6 and a_7), and information technology for supporting decision-making on the need and possibility of vaccination against Covid'19 based on the civil law (classifiers a_8 and a_9) [22-24]. Let's evaluate the quality and usefulness of each of the implemented information technologies in accordance with the proposed method for determining the quality and usefulness of information technologies for supporting medical decision-making based on the civil law.

4.1. Description of datasets and confusion matrices

First, in accordance with steps 1 and 2 of the method for determining the quality and usefulness of information technologies for supporting medical decision-making based on civil law, let's consider the datasets used to assess the quality of each information technology, as well as the resulting confusion matrices.

To evaluate the quality of information technology for supporting decision-making on the possibility of using reproductive technologies based on the civil law (quality of classifiers a_1 – surrogacy, a_2 – in vitro fertilization) we used data sets, marked by experts in the field of

medical law (according to the criterion for making a decision about possibility/impossibility of provision of a particular medical service, developed in [24]), on surrogacy collected in reproductive clinics in Khmelnytskyi and Lviv for the period from February 2021 to November 2023, and on in vitro fertilization collected in reproductive clinics in Khmelnytskyi and Lviv for the period from November 2019 to October 2022. Each case was evaluated for the possibility of providing or refusing surrogacy or in vitro fertilization services by two legal experts. The total volume of the surrogacy dataset is 193 cases (193 data on potential parents (biological parents and surrogate mother) and contracts on the use of reproductive technology submitted to the information technology input, as well as 193 conclusions on the possibility or impossibility of providing surrogacy services based on the current civil law). The total volume of the data set on in vitro fertilization is 320 cases (320 data on potential parents and contracts on the use of reproductive technology submitted to the information technology input, as well as 320 conclusions on the possibility or impossibility of providing in vitro fertilization based on the current civil law). According to the experts, in 100 cases (51.8%) surrogacy is possible, for the remaining 93 cases (48.2%) it is not; in 177 cases (55.3%) in vitro fertilization is possible, for the remaining 143 cases (44.7%) it is not; the ratio of decisions on the possibility/impossibility of decisions for both datasets indicates a balance of data. To ensure the representativeness of the dataset, cases with different age groups of the surrogate mother and biological parents, with different places of residence of the surrogate mother and biological parents (different countries; urban/rural, etc.) were selected.

As a result of the use of information technology for supporting decision-making on the possibility of using reproductive technologies based on the civil law, 96 decisions on the impossibility of performing the surrogacy procedure and 97 decisions on the possibility of performing the surrogacy procedure were generated for the 193 reviewed surrogacy cases; 150 decisions on the impossibility of performing the in vitro fertilization procedure and 170 decisions on the possibility of performing the in vitro fertilization procedure were generated for the 320 reviewed in vitro fertilization cases.

The values of the elements of the confusion matrices are as follows – Fig. 4, Fig. 5.

TP = 95 *(correct operation)*	***TN = 91*** *(correct operation)*
FP = 2 *(incorrect operation)*	***FN = 5*** *(incorrect operation)*

Figure 4: Confusion matrix for information technology for supporting decision-making on the possibility of using reproductive technologies (surrogacy) based on the civil law.

TP = 169 *(correct operation)*	***TN = 142*** *(correct operation)*
FP = 1 *(incorrect operation)*	***FN = 8*** *(incorrect operation)*

Figure 5: Confusion matrix for information technology for supporting decision-making on the possibility of using reproductive technologies (in vitro fertilization) based on the civil law.

To evaluate the quality of information technology for supporting decision-making on the possibility of donation and transplantation based on the civil law (quality of classifiers a_3 – possibility of donation and a_4 – possibility of transplantation) we used data sets, marked by experts in the field of medical law (according to the criterion for making a decision about possibility/impossibility of provision of a particular medical service, developed in [24]), on donation and transplantation in Ukraine, collected mainly from the UNOS (The United Network for Organ Sharing) database for the period from October 2020 to October 2023. Each case was evaluated for the possibility of providing or refusing donation and transplantation services by two legal experts. The total volume of the dataset is 102 cases (102 data on potential donors and recipients submitted to the information technology input, as well as 102 conclusions on the possibility or impossibility of donation and transplantation based on the current civil legislation of Ukraine). According to the experts, in 90 cases (88.2%) donation is possible, for the remaining 12 cases (11.8%) it is not; in 95 cases (93.1%) transplantation is possible, for the remaining 7 cases (6.9%) it is not; the ratio of decisions on the possibility/impossibility of the decision to provide donation/transplantation indicates a certain imbalance of data, but it should be noted that the cases of transplant operations performed, for which the legal framework is carefully studied, were studied. To ensure the representativeness of the dataset, cases with different age groups of both donors and recipients, with different places of residence of both donors and recipients (different countries; urban/rural, etc.) were selected.

As a result of the use of information technology for supporting decision-making on the possibility of donation and transplantation based on the civil law, 14 decisions on the impossibility of donation and 88 decisions on the possibility of donation were generated for the 102 reviewed cases, as well as 8 decisions on the impossibility of transplantation and 94 decisions on the possibility of transplantation were generated for the 102 reviewed cases.

The values of the elements of the confusion matrices are as follows – Fig. 6, Fig. 7.

TP = 87 *(correct operation)*	***TN = 11*** *(correct operation)*
FP = 1 *(incorrect operation)*	***FN = 3*** *(incorrect operation)*

Figure 6: Confusion matrix for information technology for supporting decision-making on the possibility of donation and transplantation based on the civil law (donation possibility).

TP = 93 *(correct operation)*	***TN = 6*** *(correct operation)*
FP = 1 *(incorrect operation)*	***FN = 2*** *(incorrect operation)*

Figure 7: Confusion matrix for information technology for supporting decision-making on the possibility of donation and transplantation based on the civil law (transplantation possibility).

To evaluate the quality of information technology for supporting decision-making on the possibility of providing medical services, therapeutic services, dental services based on civil law (quality of classifiers a_5 – general medical services, a_6 – therapeutic services, a_7 – dental services) we used data sets, marked by experts in the field of medical law (according to the criterion for making a decision about possibility/impossibility of provision of a particular medical service, developed in [24]), on general medical services, collected in outpatient clinics of family medicine of Khmelnytskyi region for the period from January 2022 to January 2023, on therapeutic services, collected in outpatient clinics of family medicine of Khmelnytskyi region for the period from January 2022 to January 2023, on dental services, collected in dental clinics of Khmelnytskyi region for the period from June 2022 to February 2023. Each case was assessed for the possibility of providing or refusing the service by two legal experts. The total volume of the dataset includes 328 cases of general medical services (328 medical service contracts submitted to the information technology input, as well as 328 conclusions on the possibility or impossibility of providing general medical services based on the current civil law), 1090 cases of therapeutic services (1090 therapeutic service contracts submitted to the information technology input, as well as 1090 conclusions on the possibility or impossibility of providing therapeutic services based on the current civil law), 525 cases of dental services (525 dental service contracts submitted to the information technology input, as well as 525 conclusions on the possibility or impossibility of providing dental services based on the current civil law). According to the experts, in 136 cases (41.5%) general medical service is possible, in other 192 cases (58.5%) it is not; in 795 cases (72.9%) therapeutic service is possible, in other 295 cases (27.1%) it is not; in 266 cases (50.7%) dental service is possible, in other 259 cases (49.3%) it is not; the ratio of decisions on the possibility/impossibility of the decision to provide general medical and dental services indicates a balance of data, the ratio of decisions on the possibility/impossibility of the decision to provide therapeutic services indicates a certain imbalance of data, which is explained by the careful preparation of contracts for the provision of therapeutic services. To ensure the representativeness of the data set, we selected cases with different age groups of patients, with different places of residence of patients (urban/rural, etc.).

As a result of using the information technology for supporting decision-making on the possibility of providing medical services, therapeutic services, dental services based on the civil law, 191 decisions on the impossibility of providing medical services and 137 decisions on the possibility of providing medical services were generated for the 328 reviewed cases; 302 decisions on the impossibility of providing therapeutic services and 788 decisions on the possibility of providing therapeutic services were generated for the 1090 reviewed cases; 270 decisions on the impossibility of providing dental services and 255 decisions on the possibility of providing dental services were generated for the 525 reviewed cases.

The values of the elements of the confusion matrices are as follows – Fig. 8, Fig. 9, Fig. 10.

To evaluate the quality of information technology for supporting decision-making on the need and possibility of vaccination against Covid'19 based on civil law (quality of classifiers a_8 – determining the need/optionality of vaccination and a_9 – determining the possibility/contraindications to vaccination) we used data sets, marked by experts in the field of medical law (according to the criterion for making a decision about possibility/impossibility of provision of a particular medical service, developed in [24]), on

Covid'19 vaccination, collected in family medicine outpatient clinics of Khmelnytskyi region for the period from June 2021 to February 2022. Each case was assessed for necessity/optionality and possibility/contraindications for vaccination by two legal experts. The total dataset comprises 62 cases (62 data sets about a person who intends to be vaccinated against Covid'19 submitted to the information technology input, as well as 62 conclusions on the need/optionality of vaccination and 62 conclusions on the possibility/contraindications for vaccination based on the current civil law). According to experts, in 42 cases (67.7%) vaccination is mandatory, for the remaining 20 cases (32.3%) it is optional; in 49 cases (79%) vaccination is possible, for the remaining 13 cases (21%) there are contraindications to vaccination; the ratio of decisions on necessity/optional and possibility/contraindications to vaccination shows some imbalance in data for decisions on possibility/contraindications to vaccination, which is explained by a significantly lower number of people with contraindications to vaccination compared to healthy people. To ensure the representativeness of the dataset, cases with different age groups of patients, with different places of residence (urban/rural, etc.), and with different types of patient activities were selected.

TP = 133 *(correct operation)*	***TN = 188*** *(correct operation)*
FP = 4 *(incorrect operation)*	***FN = 3*** *(incorrect operation)*

Figure 8: Confusion matrix for information technology for supporting decision-making on the possibility of providing medical services, therapeutic services, dental services based on civil law (on the example of general medical services).

TP = 775 *(correct operation)*	***TN = 282*** *(correct operation)*
FP = 13 *(incorrect operation)*	***FN = 3*** *(incorrect operation)*

Figure 9: Confusion matrix for information technology for supporting decision-making on the possibility of providing medical services, therapeutic services, dental services based on civil law (on the example of therapeutic services).

TP = 250 *(correct operation)*	***TN = 254*** *(correct operation)*
FP = 5 *(incorrect operation)*	***FN = 16*** *(incorrect operation)*

Figure 10: Confusion matrix for information technology for supporting decision-making on the possibility of providing medical services, therapeutic services, dental services based on civil law (on the example of dental services).

As a result of the use of information technology for supporting decision-making on the need and possibility of vaccination against Covid'19 based on the civil law, 42 decisions on mandatory vaccination and 20 decisions on optional vaccination were generated for the 62 reviewed cases; 49 decisions on the possibility of vaccination and 13 decisions on existing contraindications to vaccination were generated for the 62 reviewed cases.

The values of the elements of the confusion matrices are as follows – Fig. 11, Fig. 12.

TP = 42 *(correct operation)*	***TN = 20*** *(correct operation)*
FP = 0 *(incorrect operation)*	***FN = 0*** *(incorrect operation)*

Figure 11: Confusion matrix for information technology for supporting decision-making on the need and possibility of vaccination against Covid'19 based on civil law (vaccination need/optionality).

TP = 49 *(correct operation)*	***TN = 13*** *(correct operation)*
FP = 0 *(incorrect operation)*	***FN = 0*** *(incorrect operation)*

Figure 12: Confusion matrix for information technology for supporting decision-making on the need and possibility of vaccination against Covid'19 based on civil law (vaccination possibility/contraindications).

4.2. Determining metrics and forming a conclusion about the quality of binary classifiers

Now, in accordance with steps 3-8 of the method for determining the quality and usefulness of information technologies for supporting medical decision-making based on civil law, based on the obtained values of *TP, TN, FP, FN* (Fig. 4-12) we will calculate the quality metrics of the analyzed binary classifiers a_1; a_2; a_3; a_4; a_5; a_6; a_7; a_8; a_9 – information technologies for supporting various medical decisions based on civil law, and summarize them in the form of Table 1.

Table 1

Results of the study of the quality of binary classifiers – information technologies for supporting the decision-making of various medical decisions based on civil law

	a_1	a_2	a_3	a_4	a_5	a_6	a_7	a_8	a_9
Accuracy	0,96	0,97	0,96	0,97	0,979	0,97	0,96	1	1
Precision	0,979	0,994	0,989	0,989	0,97	0,98	0,98	1	1
Recall	0,95	0,96	0,97	0,98	0,98	0,975	0,94	1	1
F1	0,965	0,975	0,98	0,985	0,975	0,98	0,96	1	1
Specificity	0,978	0,993	0,917	0,857	0,979	0,96	0,98	1	1
AUC	0,9642	0,9739	0,9417	0,9180	0,9786	0,9654	0,9603	1	1

The ROC-curves with the calculated AUC metrics plotted for 8 binary classifiers are shown in Figs. 13-20 (the ROC-curve for classifier a_9 is similar to the ROC-curve for the classifier a_8).

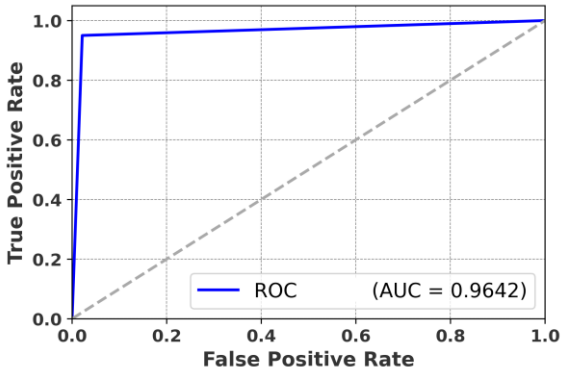

Figure 13: ROC-curve and *AUC* metric for the classifier a_1

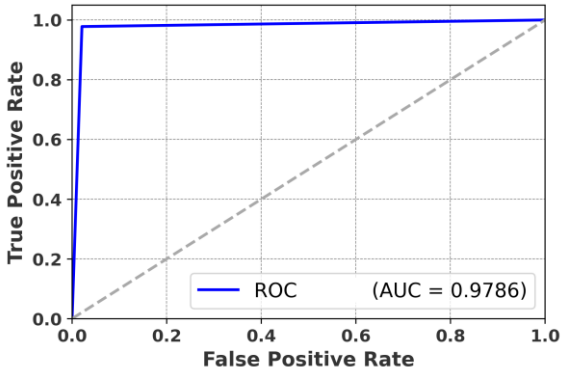

Figure 17: ROC-curve and *AUC* metric for the classifier a_5

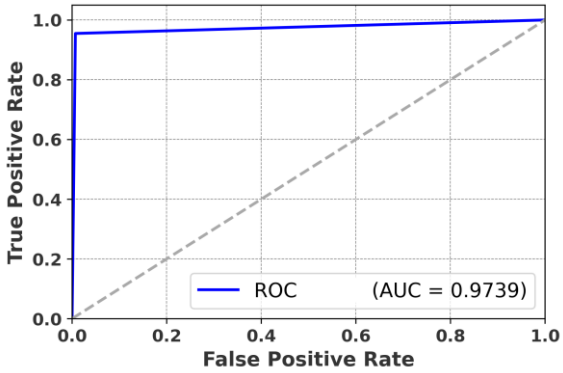

Figure 14: ROC-curve and *AUC* metric for the classifier a_2

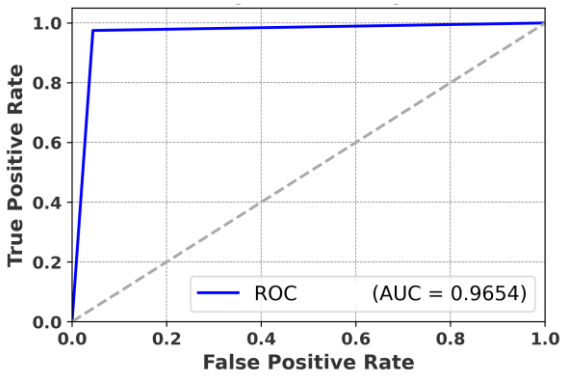

Figure 18: ROC-curve and *AUC* metric for the classifier a_6

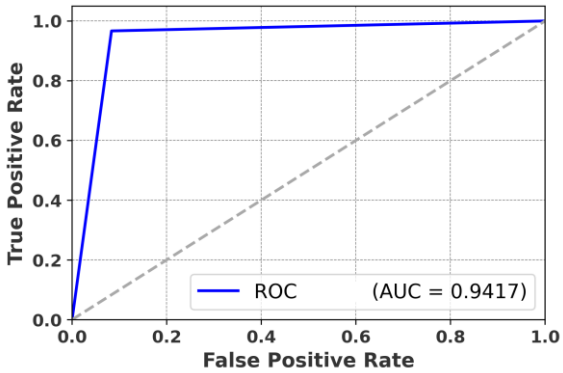

Figure 15: ROC-curve and *AUC* metric for the classifier a_3

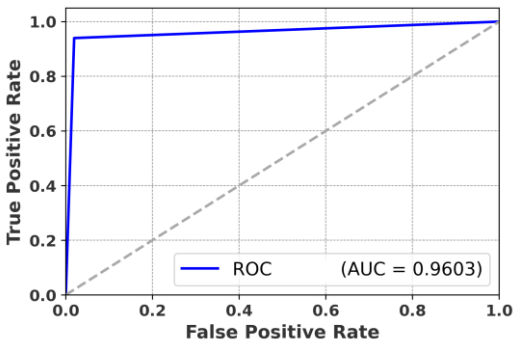

Figure 19: ROC-curve and *AUC* metric for the classifier a_7

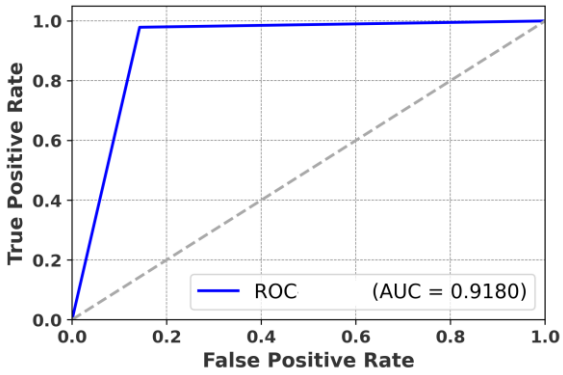

Figure 16: ROC-curve and *AUC* metric for the classifier a_4

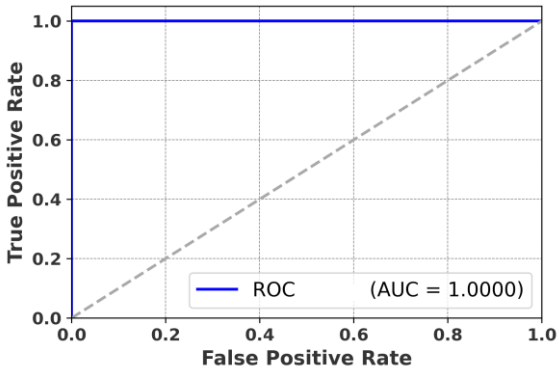

Figure 20: ROC-curve and *AUC* metric for the classifier a_8

In accordance with step 9 of the method for determining the quality and usefulness of information technologies for supporting medical decision-making based on civil law, we conclude on the quality of binary classifiers a_1-a_9. All the calculated values of the metrics *(Accuracy, Precision, Recall, F1, Specificity, AUC*), presented in Table 1, indicate the quality of all the developed binary classifiers a_1-a_9 – information technologies for supporting medical decision-making based on civil law.

4.3. Analysis of the causes of incorrect classification

Let's now analyze the reasons for the misclassification.

Thus, there is a situation where in 2 cases from the analyzed data set experts noted the impossibility of providing surrogacy, and in one case experts noted the impossibility of providing in vitro fertilization from the point of view of the current civil law, but the information technology for supporting decision-making on the possibility of using reproductive technologies based on the civil law (classifiers a_1, a_2 respectively) respectively), issued a conclusion on the possibility of surrogacy or in vitro fertilization, respectively. There is also a situation when in 5 cases from the analyzed data set experts noted the possibility of surrogacy, and in 8 cases experts noted the possibility of in vitro fertilization in terms of the current civil law, but the information technology issued a conclusion that surrogacy or in vitro fertilization was impossible, respectively.

There is a situation when in one case from the analyzed data set experts noted the impossibility of donation, and in one case experts noted the impossibility of transplantation from the point of view of the current legislation, but the information technology for supporting decision-making on the possibility of donation and transplantation based on the civil law (classifiers a_3, a_4 respectively) issued a conclusion on the possibility of donation or transplantation, respectively. There is also a situation where in 3 cases from the analyzed data set experts noted the possibility of donation, and in 2 cases experts noted the possibility of transplantation in terms of current legislation, but the studied information

technology issued a conclusion that donation or transplantation was impossible, respectively.

There is a situation when in 4 cases from the analyzed data set experts noted the impossibility of providing general medical services, in 13 cases experts noted the impossibility of providing therapeutic services, and in 5 cases experts noted the impossibility of providing dental services in terms of current legislation, but the information technology for supporting decision-making on the possibility of providing medical services, therapeutic services, dental services based on the civil law (classifiers a_5, a_6, a_7 respectively) issued a conclusion on the possibility of general medical services or therapeutic services, or dental services, respectively. There is also a situation when in 3 cases from the analyzed data set experts noted the possibility of providing a general medical service, in 20 cases experts noted the possibility of providing a therapeutic service, in 16 cases experts noted the possibility of providing a dental service in terms of the current legislation, but the studied information technology issued a conclusion about the impossibility of providing a general medical service or a therapeutic service or a dental service, respectively.

There are no incorrectly classified cases regarding the necessity/optionality of vaccination (classifier a_8), and the possibility/contraindications to vaccination (classifier a_9) by the information technology for supporting decision-making on the necessity and possibility of vaccination against Covid'19 based on the civil law.

The analysis of all 27 cases where experts noted the impossibility of providing a particular medical service in terms of the current legislation, but the information technology issued a conclusion about the possibility of providing such a service, showed that the information technology provided an erroneous conclusion due to errors in the data on potential patients and/or the contract for the provision of medical services submitted to it (for example, an erroneous space in a word; separately written words that should be written together; empty contract clauses, etc.).

The analysis of all 57 cases where experts noted the possibility of providing a particular medical service in terms of the current legislation, but the information technology issued a conclusion that such a service could not be provided, showed that the information technology also issued a false conclusion due to errors in the data on potential patients and/or the contract for the provision of medical services submitted to it (for example, missing letters in words; missing spaces between words; words written together that should be written separately; letters swapped, etc.).

Therefore, the reasons for misclassification are errors and inaccuracies in the patient data and/or contracts for the provision of medical services, submitted to the classifiers. Since the information technology for supporting decision-making on the need and possibility of vaccination against Covid'19 based on civil law (classifiers a8; a9) does not involve analysis of the patient's document or analysis of the contract, but works on the basis of clear "yes" or "no" answers to the questionnaires, there are no errors or inaccuracies in the data submitted as input, and therefore no incorrectly classified cases. Thus, the conclusions drawn from the analysis of incorrectly classified cases showed the following limitation of the information technology for supporting medical decision-making based on civil law as the dependence of its conclusions on the correctness of the formation and

writing of patient data and contracts for the provision of medical services submitted to it for further processing.

4.4. Determination of the usefulness of information technologies for supporting medical decision-making based on civil law

To determine the usefulness of the proposed information technology for supporting decision-making on the possibility of using reproductive technologies for reproductive medicine clinics, let's consider the cases analyzed by the information technology.

From 193 surrogacy cases analyzed by the information technology, in 91 cases it generated a correct decision on the impossibility of performing the surrogacy procedure. From 320 cases of in vitro fertilization analyzed by the same information technology, in 142 cases a correct decision was generated on the impossibility of performing the in vitro fertilization procedure. Thus, 91 surrogacy procedures (almost half of all reviewed cases) from 193 reviewed cases and 142 in vitro fertilization procedures from 320 reviewed cases were not allowed in terms of civil law regulation, as there was a failure to take into account or violation of certain civil law provisions, and this was revealed by the analyzed information technology (Fig. 21). Without the use of the proposed information technology for supporting decision-making on the possibility of using reproductive technologies based on civil law, the provision of surrogacy services in 91 cases (47.2%) and in vitro fertilization in 142 cases (44.4%) would have inevitably led to adverse legal consequences, lawsuits, and, given the nature of the surrogacy and in vitro fertilization procedures, to violations of moral and ethical standards.

Therefore, the usefulness of information technology for supporting decision-making on the possibility of using reproductive technologies for reproductive clinics is to ensure that it increases the legal correctness of medical decisions – by 47.2% for 193 reviewed cases of surrogacy and by 44.4% for 320 reviewed cases of in vitro fertilization.

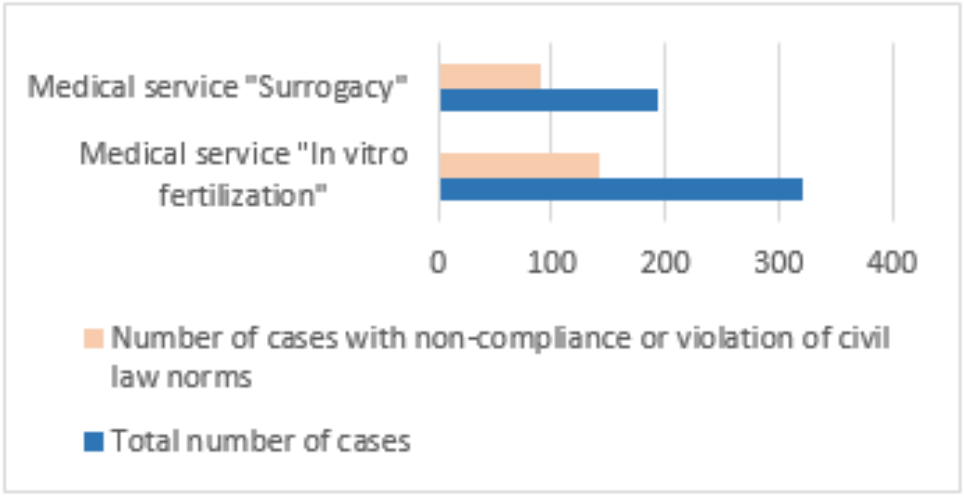

Figure 21: Usefulness of information technology for supporting decision-making regarding the possibility of using reproductive technologies for reproductive clinics.

To determine the usefulness of the proposed information technology for supporting decision-making regarding the possibility of donation and transplantation for surgical and transplant clinics and departments, let's consider the cases analyzed by information technology.

From 102 analyzed decisions on organ or tissue transplantation in Ukraine over the past 3 years, taken mainly from the UNOS (The United Network for Organ Sharing) database, in 11 cases a correct decision was generated about the impossibility of donation and in 6 cases a correct decision was generated about impossibility of transplantation. Therefore, 11 donation procedures and 6 transplantation operations from 102 considered cases of performed transplant operations were not allowed from the point of view of civil law regulation, because certain civil law norms were disregarded or violated, and this was revealed by the analyzed information technology (Fig. 22). Without the use of the proposed information technology, surgical and transplant clinics and departments may have adverse legal consequences, lawsuits, and, given the essence of the donation and transplantation procedure, also violations of moral and ethical norms.

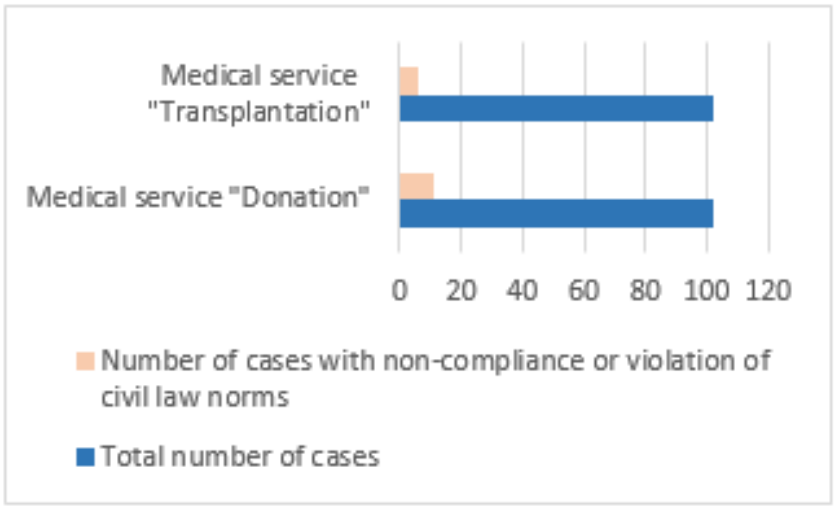

Figure 22: The usefulness of information technology for supporting decision-making regarding the possibility of donation and transplantation for surgical and transplant clinics and departments.

Therefore, the usefulness of information technology for supporting decision-making regarding the possibility of donation and transplantation for surgical and transplant clinics and departments is to ensure an increase in the legal correctness of the provided medical decisions – by 10.8% for 102 considered cases of donation and by 5.9% for 102 considered cases of transplantation.

To determine the usefulness of the proposed information technology for supporting decision-making regarding the possibility of providing medical services, therapeutic services, dental services for family medicine clinics, polyclinics and hospitals, let's consider the cases analyzed by information technology.

From 328 cases analyzed by information technology, in 188 cases (more than half of all considered cases), a correct decision was generated about the impossibility of providing a medical service. From 1090 cases analyzed by information technology, in 282 cases, a correct decision about the impossibility of providing a therapeutic service was generated. From 525 cases analyzed by information technology, in 254 cases, a correct decision about the impossibility of providing dental services was generated. Therefore, 188 procedures form 328 considered cases regarding the provision of general medical services, 282 procedures from 1090 considered cases regarding the provision of therapeutic services, 254 procedures from 525 considered cases regarding dental services were not allowed from the point of view of civil law regulation, because there was a failure to take into account or violation of certain civil law norms, and this was revealed by the analyzed information technology (Fig. 23). Without the use of the proposed information technology for supporting decision-making regarding the possibility of providing medical services, therapeutic services, dental services based on civil law, the provision of medical services in 188 cases (57.3%), the provision of therapeutic services in 282 cases (25.9%), the provision of dental services in 254 cases (48.4%) – a total of 724 cases from 1,943 reviewed cases (37.3%) – would certainly lead to adverse legal consequences and possibly lawsuits.

Therefore, the usefulness of information technology for supporting decision-making regarding the possibility of providing medical services, therapeutic services, dental services for family medicine clinics, polyclinics, and hospitals consists in ensuring that it increases the legal correctness of general medical decisions provided – by 57.3% for 328 reviewed cases for the provision of general medical services, by 25.9% for 1090 reviewed cases for the provision of therapeutic services, and by 48.4% for 525 reviewed cases for the provision of dental services – a total of 37.3% for 1943 reviewed cases.

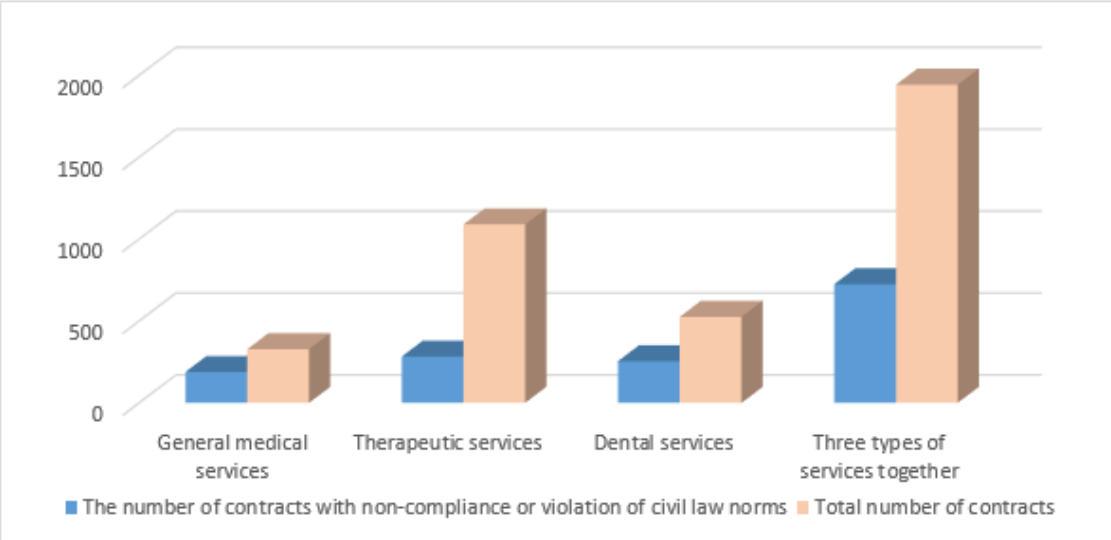

Figure 23: The usefulness of information technology for supporting decision-making regarding the possibility of providing medical services, therapeutic services, dental services for family medicine clinics, polyclinics, hospitals and dental clinics.

5. Conclusions

The development of cross-disciplinary information technologies (e.g., information technologies for supporting medical decision-making based on civil law) is currently an important, relevant, but complex and time-consuming problem, since, on the one hand, such technology ensures that the norms of current legislation are taken into account when making medical decisions, the correctness of the medical procedure from a legal point of view, protects the doctor and the patient from legal conflicts, and, on the other hand, requires taking into account the standards and principles of development of information technologies along with regulatory documents in the field of medical law.

The considered problem is to synthesize appropriate methods of binary classification az to solve the task of medical decision support (solved in [22-24]) and analyze the obtained binary classifier solutions, which is the purpose of this study.

The article develops a method for determining the quality and usefulness of information technologies for supporting medical decision-making based on civil law (binary classifiers $a_z: X_z \to Y_z$), which provides a conclusion on the quality and usefulness of these information technologies in terms of classifying decisions into possible and impossible ones.

All the calculated metrics' values (*Accuracy, Precision, Recall, F1, Specificity, AUC*) indicate the quality of the work of all the developed binary classifiers a_1-a_9 – information technologies for supporting various medical decisions based on civil law.

A limitation of information technologies for supporting medical decision-making based on civil law is that its conclusions depend on the correctness of the formation and spelling of patient data and contracts for the provision of medical services submitted for further processing. If the data and/or contracts contain spelling and/or punctuation errors (e.g., no spaces between words), the information technology for supporting medical decision-making based on civil law may issue an incorrect conclusion based on the incorrect classification of such words and phrases.

The conducted experiments and the obtained results showed that the usefulness of information technology for supporting decision-making on the possibility of using reproductive technologies for reproductive clinics is to ensure that it increases the legal correctness of the medical decisions provided – by 47.2% for 193 cases of surrogacy and by 44.4% for 320 cases of in vitro fertilization.

The usefulness of the information technology for supporting decision-making on the possibility of donation and transplantation for surgical and transplantation clinics and departments is to ensure that it increases the legal correctness of medical decisions – by 10.8% for 102 reviewed cases of donation and by 5.9% for 102 reviewed cases of transplantation.

The usefulness of the information technology for supporting decision-making on the possibility of providing medical services, therapeutic services, and dental services for family medicine outpatient clinics, clinics and hospitals is to ensure that it increases the legal correctness of the decisions made – by 37.3% for 1943 cases (including by 57.3% for 328 cases of general medical services, by 25.9% for 1090 cases of therapeutic services, and by 48.4% for 525 cases of dental services).

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