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Intelligent Information System of Diagnosis and Monitoring Application in the Emergency Medical Aid for Poisonings by Toxic Substances

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Abstract

According to statistical data, a considerable increase in the number of acute carbon monoxide poisonings has been observed in Azerbaijan in the last few years. The difficulty of diagnosis is caused by the fact that the same symptoms and even syndromes may be seen in case of poisonings by different toxic substances. For this reason, the problem of necessity of performing differential diagnosis becomes urgent. The danger of poisonings is that they can be the causes of serious pathologies with the passage of time. This article is proposing development of a system carrying out differential diagnosis and monitoring, based on up-to-date methods of evidence medicine.

Keywords: Differential diagnosis; Monitoring; Evidence medicine; Carbon monoxide; Frame; Production rule; Intelligent system; Neuronal networks

Introduction

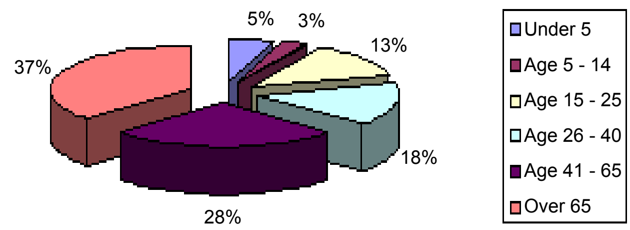
Modern scientific-technical period is characterized by the creation of big industrial centers, because of the functioning of which happened intensive pollution of environment, especially atmospheric air. When we say about atmospheric pollution, it means throw out mixtures human activity. 31.9% of common mixtures formed by the functioning of industrial centers are carbon monoxide. According to the carbon monoxide poisoning statistic information, every year in USA 15,000 calls are entered to ambulance and 500 death events are registered [1,2].

Most of poisoning events are observed and in the state of Nebraska in January month [1,2]. In 2000-2009, 68,316 of carbon monoxide poisoning patients; 30,798 (45.1%) were provided on-site aid, and 36,691 (53.7%) patients were treated in hospitals. 34,386 of poisoning patients are women, 30,257 are men. Most of poisoning events are related to the living conditions, and here, special places have women, children less than 17 years old, and persons between 18 and 44. In spite of these quantity of poisoning persons has decreased: in 2006-0.31%, in 2009-0.24%. In 2000-2009, 16,447 death events are registered [3,4]. In Great Britain, there have been 1,537 deaths in 1990, 666 in 1999 year and 318 deaths were in 2000-2010 from carbon monoxide poisoning. 5% events of patients are under 5 little children, 3%- between 5 and 14, 13%-between 15 and 25, 16%-between 26 and 40, 26%-between 41 and 65, 37%-persons over 65 [5,6] (Figure 1).

In 2009-2010, 250 persons and in 2010-2011, 55 persons were poisoned in France. As of information in 2010-2011, 87% of events happened in mode of life, 65-related to professions, 7%-in social places, in cars and etc. Accordingly in 2009-2010, 86% events happened in mode of life, 7%-related by professions, 8%-in social places, in cars, and etc. 60 of events were corresponded to 14 December 2009, 79 events-03.01.2010, 8 events-14.02.2010, 80 events-27.10.2010, 03.12.2010. Most events were observed in Paris and Northern regions (190-175 events in 2009-2010, 194-150 events in 2010-2011). 100,70,63,61 poisoning events are registered in 2010-2011 in Rhône-Alpes, Provence-Alpes-Côte d'Azur, Pays-de-la-Loire regions. (In 2009-2010–102,74,65,26) [3,6].

Statement of the problem

In this research, we have studied the cases of poisonings by the following toxic substances: carbon monoxide, aniline, atropine, barbiturates, dichlorethane, codeine, pachycarpin, tubaside, phosphor organic substances, ethyl alcohol, ethylene glycol, tranquilizers,



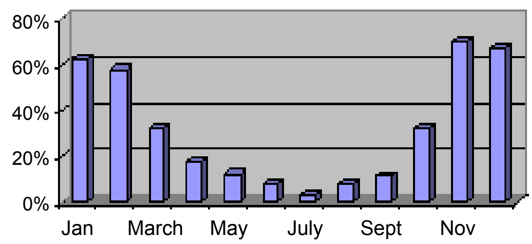


Figure 1: Age categories of poisoning victims and their change depending on seasons in Great Britain.

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No.	Districts of Baku	2006	2007	2008	2009	2010	2011	2012
1	*Narimanov*	41	38	38	48	69	121	127
2	*Khatai*	77	159	154	82	106	135	192
3	*Sabaiyl*	47	26	36	41	42	85	109
4	*Yasamal*	57	64	88	83	118	137	151
5	*Nasimi*	20	103	186	122	129	221	237
6	*Nizami*	-	40	63	54	64	123	171
7	*Binagady*	53	70	217	129	190	316	395
8	*Khazar*			9	9	17	26	36
9	*Surakhany*	34	33	59	62	70	141	141
10	*Sabunchu*	30	43	111	72	107	147	221
11	*Karadag*	42	83	83	86	98	115	232
12	**TOTAL:**	**401**	**659**	**1044**	**788**	**1010**	**1567**	**2012**

Table 1: Information on poisonings within Baku during 2006-2012.

antihistamines, salicylates, cyanides. The justification for selecting precisely these substances becomes the fact that acute poisonings by carbon monoxide and the enumerated toxic substances have similar symptoms. According to statistical data, a considerable increase in the number of acute poisonings by carbon monoxide has been observed in Azerbaijan. Information on poisonings within Baku during 2006-2010 is given in table 1 [7,8].

The difficulty of diagnosis is explained by the fact that the same symptoms and even syndromes may be witnessed in cases of poisonings by different toxic substances. Naturally, this calls for the performance of differential diagnosis. The nature of poisoning depends on carbon monoxide concentration in the air (WA-20 mg/sq.m.), duration of exposure and individual sensitivity of a person [9]. Acute and chronic carbon monoxide poisonings are distinguished. In industrial production conditions, pollution of atmospheric air with small doses of carbon monoxide is possible, prolonged effect of which on human organism leads to chronic poisoning. If chronic intoxication is of reversible nature, acute poisoning often causes lethal outcome or severe complications, which can manifest them for quite a long time after poisoning.

Parkinsonism cases have been observed, which had developed some weeks after carbon monoxide poisoning [10]. Also have been reported cases of human deaths from poisoning consequences, after two or three weeks of the event of poisoning. More than that, as was discovered by scientists from the Heart Institute in Minneapolis in 2006 [8], acute carbon monoxide poisoning can continue affecting adversely people's health down to lethal outcome in the course of the nearest few years after poisoning, as a result of damage caused to cardiac muscle by carbon monoxide. It becomes evident from the above said that people who were poisoned by some or other dose of toxic substances need monitoring for sufficiently prolonged period. Here, peculiarities of clinical pattern of certain intoxication and results of laboratory toxicological investigation are of major significance. For example, such peculiarities of clinical pattern during carbon monoxide poisoning are as follows:

1. At first, pink coloring of mucous membranes and marked hyperemia of skin integuments are usually observed in comatose patients. The HbCO (carboxyhemoglobin) concentration in blood reaches toxical value (60-80%), only within an hour after CO inhalation. Further on a comatose state may continue at a considerably lesser HbCO (carboxyhemoglobin) content in blood, which is due to developing brain anoxia [10,11].

2. Convulsive states running with symptoms of brain edema and hypoxia during CO Poisonings are frequently complicated by hyperthermia syndrome, which must be distinctly differentiated from febrile states caused by pneumonia [10,11].

The efficacy of rendering qualified aid in case of acute CO Poisonings depends on the time from the start of treatment since the moment of intoxication, as the development of critical states with symptoms of respiratory disturbance, as well as disturbance of cardiovascular activity and cerebral circulation is possible, which can result in lethal outcome.

From all the above said, it becomes obvious that medical equipment and training of medical personnel in the ambulance conditions are such a burning problem, as they have never been before. For solving this problem, one of the most useful assistants and consultants can be modern information technologies possessing huge knowledge and potential. An invaluable assistance in solving the mentioned problem will be provided by attracting methods of artificial intelligence, possibilities of soft computations, creating databases, knowledge bases and data banks using methods of evidence-based medicine. The solution of the stated problem we see in the elaboration of an intelligent information system of differential diagnosis and monitoring for poisonings by carbon monoxide and toxic substances, which have kindred symptoms and clinical patterns.

In doing so the following objectives are pursued:

• Collection and systematization of data in application domain

• Preparation of necessary data for conducting differential diagnosis

• Elaboration of database and knowledge base for the system

• Organization of monitoring satisfying the requirements of evidence-based medicine

• Elaboration of data banks on the abovementioned poisonings

• Creation of teaching program for students of medical educational institutions and medical personnel of ambulance.

Solution

A situation of clinical pattern of comatose states during the most frequently observed poisonings in the ambulance conditions is studied. A physician mainly accumulates information on the following clinical symptoms: characteristics of pupils, nervous muscular sphere, skin, pulse and breathing. A list is made of clinical symptoms (there are 19 of them), which are actually seen in the conditions of emergency aid when anamnesis, functional and laboratory data are absent.

Database (DB): On the basis of expert knowledge, table 2 is made, where the «+» sign means the presence of symptom in a supposed hypothesis, «0» means the absence, «~»-insignificant presence bringing an element of uncertainty in diagnosis. With the use of table 2, a database is created, which is based on network and relational models. A network model arranged in the form of a connected graph is very handy for teaching program. For diagnosis, a relational model is employed the use of which is justified by its mathematical rigor and practical simplicity.

Knowledge base (KB): The Statistics of the table were made in accordance with production rules of the type: If "prerequisites"-Then "actions":

The first step-Rigid differentiation

№	Clinical symptoms	Anilin	Atropin	Barbitu-rates	Dichlor-ethane	Codein	Pachycarpin	Tubaside	Phosphor organic substances	Ethyl alcohol	Ethylene glycol	Carbon monoxide	Tranquilizers	Antihista-mines.	Salicylates	Cyanides
1	Miosis	0	0	±	±	+	0	±	+	±	±	±	+	±	±	±
2	Mydriasie	+	+	±	±	0	+	±	0	±	±	+	±	+	+	+
3	“Play of pupils”	0	0	+	±	0	0	±	0	+	±	±	±	±	±	±
4	Synchronous myofibrillations	0	0	0	±	0	0	0	0	+	±	±	±	±	±	±
5	Asynchronous myofibrillations	0	0	0	0	0	+	0	+	0	0	±	±	±	±	±
6	Hyperkinesis of choreoid type	+	+	0	0	0	0	0	+	±	0	±	±	+	+	±
7	Rigidity of occiput muscles	0	0	0	±	0	0	±	±	±	+	+	±	±	±	±
8	Asynchronous convulsions	+	±	0	±	±	±	0	±	±	+	+	±	±	±	+
9	Epileptiform convulsive status	±	0	0	0	0	0	+	±	0	±	±	±	±	±	±
10	Perspiration of skin	±	0	0	±	±	±	±	+	±	±	±	±	±	±	±
11	Dryness of skin	±	+	±	±	±	±	±	0	±	±	±	+	±	+	±
12	Drastic cyanosis of skin	+	±	±	±	±	±	±	±	±	±	±	±	±	±	±
13	Hyperemia of skin	0	+	±	±	±	0	±	±	±	+	±	±	±	±	+
14	“Marble” appearance of skin	±	±	±	+	±	+	±	±	±	±	±	±	±	±	±
15	Bradycardia	0	0	±	0	0	±	±	+	±	±	±	±	±	±	±
16	Tachycardia	+	+	±	+	+	±	±	±	±	±	±	±	±	+	±
17	Respiratory paralysis with retained reflexes	±	±	±	±	+	+	0	±	0	±	+	±	±	±	±
18	Respiratory paralysis only against the background of areflexia	+	+	+	+	±	±	+	±	+	±	±	+	±	±	±
19	Bronchoreia	±	0	±	±	±	±	±	+	±	±	±	±	±	±	±

Table 2: Differential diagnosis of comatose states during poisonings by different toxic substances.

$$\begin{array}{ll} if & \exists x_i \in X \Rightarrow x_i \in y_j, \\ then & x_i \notin y_1, y_2, \ldots, y_{j-1}, y_{j+1}, \ldots, y_m \\ i = 1,2,\ldots,19; & j = 1,2,\ldots,15 \end{array}$$

The second step- Non-rigid differentiation

$$\begin{array}{ll} if & \exists x_i \in X \Rightarrow \exists y_j \in Y \\ then & x_i \in y_j \\ i = 1,2,\ldots,19 & 1 < j < 15 \end{array}$$

The third step- Indeterminate differentiation

$$\begin{array}{ll} if & \exists x_i \in X \\ then & \Rightarrow \left\{x_i \in y_j\right\} \vee \left\{x_i \notin y_j\right\} \\ i = 1,2,\ldots,19 & 1 < j < 15 \end{array}$$

where $\{x_1, x_2, \ldots, x_i, \ldots, x_n\}$-clinical symptoms of a patient; yi-possible hypotheses from Y (a frame is constructed for each hypothesis), X-set of states. Knowledge in KB is represented as a three-step structure, where the first step-knowledge of rigid differentiation of symptoms («0» in our designations). «0» means the required absence of a sign in a given hypothesis; the understanding of the probability of some event as a certain assessment, which is ascribed to it by a person, and which may change after obtaining additional information. The selection of Bayes's method of decision-making is explained by the fact that the method has mathematical substantiation, and is applicable for solving problems of diagnosis and knowledge testing, which corresponds to the stated problem. Bayes's theorem serves as the mathematical basis of Bayes's method.

The theorem: Let H1, H2,…,Hn be a set of pair wise incompatible events, which is complete in the sense that one of the events invariably happens and S is an event with the probability of P (S)>0. Then the probability of Hi provided that S has happened [12]. Can be computed from the following formula:

$$P(H_i/S_i) = \frac{P(S/H_i)P(H_i)}{\sum_{j=1}^{n} P(S/H_j)P(H_j)} \tag{1}$$

The accepted terminology is as follows: events are termed hypotheses, $P(H_i)$-a posterior probabilities of hypotheses, $P(H_i/S)$-a posterior probabilities of hypotheses, event S is termed “a symptom”, $P(S/H_i)$-probabilities of confirming H_j hypotheses by the symptom S [12,13].

Assume that H is a hypothesis and S a symptom. Let us study the events H and ~H. They are incompatible and complete. The symptom

S may take place or be absent, i.e. ~ S may take place. Then according to Bayes's theorem:

$$P(S/H)=\frac{P(S/H)P(H)}{P(S/H)P(H)+P(S/\sim H)P(\sim H)} \tag{2}$$

$$P(H/\sim S)=\frac{P(\sim S/H)P(H)}{P(\sim S/H)P(H)+P(\sim S/\sim H)P(\sim H)} \tag{3}$$

Let us take designations $P^{+}=P(S/H)$, $P^{-}=P(S/\sim H)$, and considering that

$$P(\sim H)=1-P(H), \tag{4}$$

$$P(\sim S/H)=1-P(S/H), P(\sim S/\sim H)=1-P(S/\sim H), \tag{5}$$

we have

$$P(H/S)=\frac{P^{+}P(H)}{P^{+}P(H)+P^{-}(1-P(H))}, \tag{6}$$

$$P(H/\sim S)=\frac{(1-P^{+})P(H)}{1-P^{+}P(H)-P^{-}(1-P(H))} \tag{7}$$

In our designations, $P^{+}=P(S/H)$, $P^{-}=P(S/\sim H)$ mean the confirmation of the hypothesis by the symptom and refutation of it by the symptom. The first estimate is close to an expert in the sense and logics of his mentality, and due to this, its value is close to the true one. The second estimate is very subjective, it is dictated more by experience and intuition of a doctor, and for the most part, is corrected on testing examples.

If we assume that the answers-alternatives "Yes-No" are allowable to a symptom, then there are 2k sequences of answers predetermined by different trajectories of computations. If the answers always tend towards an increase (a decrease) in the probability, then we will obtain a trajectory leading to the maximally (minimally) feasible probability $P_{max}(H)$ ($P_{min}(H)$) of the said hypothesis.

On the basis of the maximum and minimum probabilities, we will establish values of the upper and lower thresholds for each hypothesis. A hypothesis will be considered accepted if a trajectory of computations gives a value of its probability exceeding that of the upper threshold, and discarded if a value of its probability is less than values of the lower threshold. Thus, all trajectories of computations are broken into three classes of trajectories leading to the acceptance, rejection and indetermination of a hypothesis [13,14]. If the answers always tend towards an increase (a decrease) in the probability, then a trajectory will be obtained which leads to the maximally (minimally) feasible probability $P_{max}(H)$ ($P_{min}(H)$).

For visualization purpose, the trajectories of 4 hypotheses are shown in figure 2 where:

Row 1-the hypothesis has reached the lower threshold, hence, expertise has discarded this hypothesis.

Rows 2,3-the hypothesis remains topical, there are no data for making the final decision.

Row 4-the hypothesis has reached the upper threshold, hence, expertise has confirmed it.

On the strength of the above stated frame representations of all hypotheses are elaborated. Two such frames are demonstrated in table 3. It is seen from table that zero moments do not participate in Bayes's method, and this can be responsible for the ambiguity of diagnosis. An example of successful diagnosis of situation by Bayes's method is demonstrated in figures 3 and 4 shows the situation when diagnosis is unclear and indeterminate. In these cases, it is expedient to use

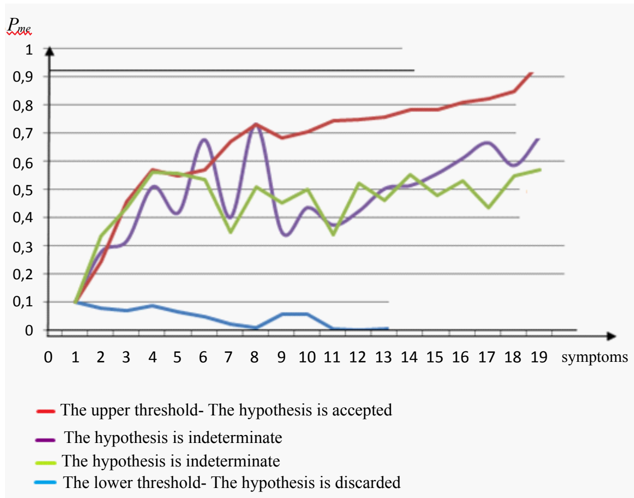

Figure 2: Types of decision-making trajectories.

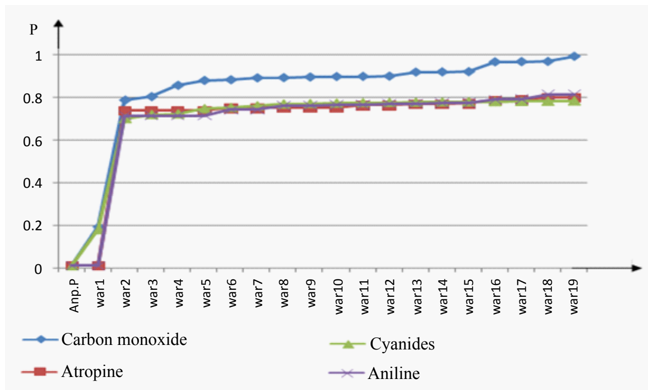

Figure 3: Successful diagnosis of situation by Bayes's method is demonstrated.

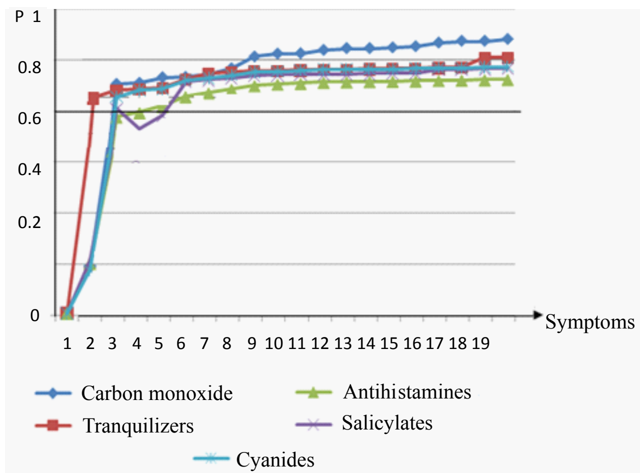

Figure 4: Shows the situation when diagnosis is unclear and indeterminate.

№	Symptoms	Carbon monoxide			Anilin		
		Symbols	P⁺	P-	Symbols	P⁺	P-
1	Miosis	*y/n*	0,3443	0,3548	0		
2	Mydriasie	+	0,9821	0,4229	+	0,9208	0,3209
3	“Play of pupils”	*y/n*	0,5002	0,4976	0		
4	Synchronous myofibrillations	*y/n*	0,5017	0,5004	0		
5	Asynchronous myofibrillations	*y/n*	0,4992	0,4899	0		
6	Hyperkineses of choreoid type	*y/n*	0,5034	0,4938	+	0,8877	0,2977
7	Rigidity of occiput muscles	+	0,9777	0,2338	0		
8	Asynchronous convulsions	+	0,9678	0,5246	+	0,8979	0,0432
9	Epileptiform convulsive status	*y/n*	0,4887	0,4902	*y/n*	0,5008	0,4989
10	Perspiration of skin	*y/n*	0,4910	0,5006	*y/n*	0,5037	0,5005
11	Dryness of skin	*y/n*	0,5028	0,5009	*y/n*	0,4927	0,4870
12	Drastic cyanosis of skin	*y/n*	0,4881	0,5000	*y/n*	0,0,9833	0,0141
13	Hyperemia of skin	*y/n*	0,4929	0,4899	0		
14	“Marble” appearance of skin	*y/n*	0,5101	0,5027	*y/n*	0,5011	0,5003
15	Bradycardia	*y/n*	0,4990	0,4809	0		
16	Tachycardia	*y/n*	0,5012	0,5100	*y/n*	0,7868	0,3565
17	Respiratory paralysis with retained reflexes	+	0,9769	0,2558	0		
18	Respiratory paralysis only against the background of areflexia	*y/n*	0,4876	0,4709	+	0,7668	0,3727
19	Bronchoreia	*y/n*	0,5031	0,4900	*y/n*	0,5000	0,4989

Table 3: A fragment of frame representation of “Carbon monoxide” and “Aniline” hypotheses.

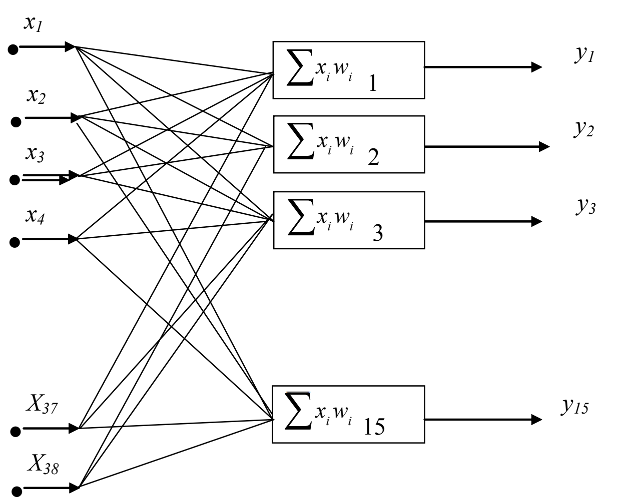

Figure 5: 19 clinical symptoms are declared by 38 entries.

neuronal networks. Neuronal networks theory allows to take into consideration all situations, i.e. the presence, absence of a symptom, as well as the presence and absence of non-dominant low-significant symptoms [15,16]. In this case, there is no loss of information. Owing to this, each symptom is represented in the net by two entries, i.e. 19 clinical symptoms are declared by 38 entries, as in figure 5 all situations, i.e. the presence, absence of a symptom as well as the presence and absence of non-dominant low-significant symptoms. In this cas,e there is no loss of information. Owing to this, each symptom is represented in the net by two entries, i.e. 19 clinical symptoms are declared by 38 entries, as in figure 5.

Then, any situation from table 2 will look like:

$$y_j = \sum_{i=m,k,...l}^{38} x_i^+ + \sum_{i=t,s,...p}^{38} x_i^- + \alpha(\sum_{i=e,r,...,v}^{38} x_i^{yes/no}) \qquad (8)$$

No	Toxic substances	Impact on the effect of toxic substances
1	**2**	**3**
1	Anilin	Psychotropic, neurotoxin, hemotoxic (met hemoglobin), hepatotoxic
2	Atropin	Psychotropic, neurotoxic
3	Barbiturates	Psychotropic (narcotic)
4	Dichlorethane	Toxic,Psychotropic, (narcotic), neurotoxic, hepatotoxic, nefrotoxic
5	Codein	Psychotropic, neurotoxic (narcotic)
6	Pachicarpin	Neurotoxic
7	Tubaside	Neurotoxic (cramp)
8	Phosphor organic substances	Psychotropic, neurotoxic
9	Ethyl alcohol	Psychotropic (narcotic)
10	Ethylene glycol,	Psychotropic (narcotic), nefrotoxic, hepatotoxic
11	Carbon monoxide	Neurotoxic (hipotoxic), hemotoxic
12	Tranquilizers	Psychotropic
13	Antihistamines	Neurotoxic, Psychotropic (narcotic)
14	Salisilates	Psychotropic, hemotoxic
15	Cyanides	Toxic (neurotoxic)

Table 4: Specific (antidote) therapy in acute poisoning.

Here x_i^+ -required presence of a parameter in an appropriate hypothesis;

x_i^- - required absence of a parameter in an appropriate hypothesis;

$x_i^{yes/no}$ –presence of a non-existent symptom x_i in an appropriate hypothesis;

α means the presence starting from one representative in the sum up to all kinds of combinations;

y_j–hypotheses (j=1,2,...,15);

x_i–parameter (i=1,2,...,19).

If the first two sums in (1) are taken to be zero state confirming the presence of hypothesis, then all kinds of variations $\alpha(\sum_{i=e,r,...,v}^{38} x_i^{yes/no})$ of (1) will perform two functions:

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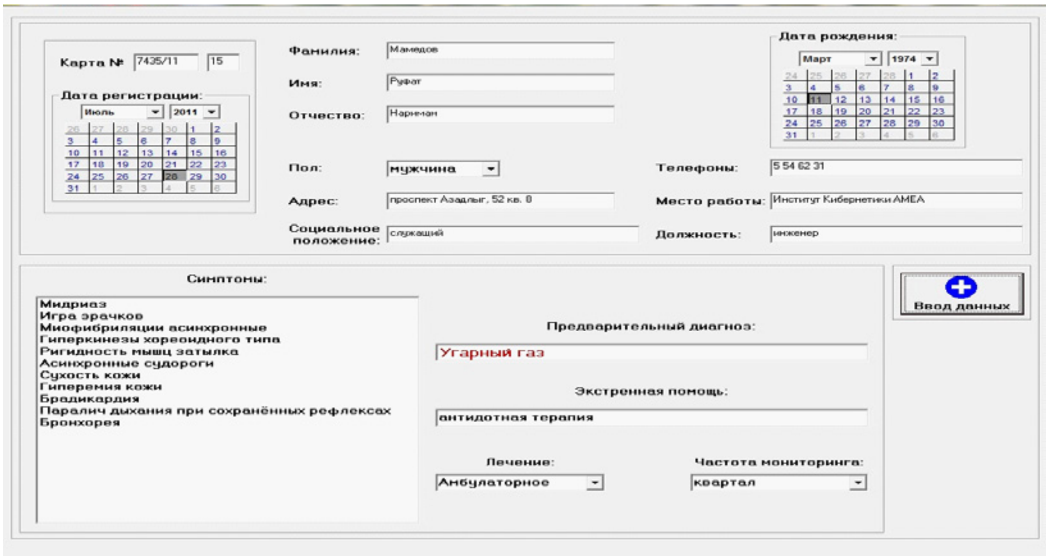

Figure 6: A patient's electronic medical card.

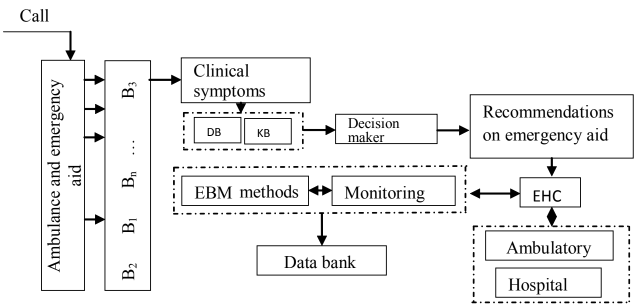

Figure 7: Structure of the intelligent information system.

at all α≠0 confirmation of a hypothesis;

α is a training set of neuronal network, its dimension equals to (2^n-1), where n is the number of symptoms of "yes/no" type [13,17].

So, the following package of programs is proposed for differential diagnosis:

• Diagnosis by Bayes's method.

• Diagnosis with the use of a two-layer neuronal network.

The process of decision-making is completed after joint solution of equations (6,7,8), when the only decision is made; this means that a hypothesis is confirmed. Then, a recommendation block proposes a suitable antidote therapy [18] (Table 4). Clinical symptoms, initial diagnosis and actions (treatment) related to a suitable antidote therapy are collected in a patient's electronic medical card. A fragment of this card is shown in figure 6.

Monitoring: Considering specificity of poisonings as was shown above, this category of patients' needs obligatory long-term observation of their health condition. A monitoring module performs systematic (periodical) collection and processing of information, which is used during decision-making. This process is indispensable, as in the course of monitoring, it is possible to reveal the state of critical parameters, or those being changed in a patient who had once been affected by some or other dose of toxin. Information processing is made using methods of evidence-based medicine, i.e. medicine which is based on evidence. As this takes place, decisions concerning the performance of preventive, diagnostic and therapeutic procedures are made on the strength of ready proofs of their safety and affectivity, and such proofs are subjected to search, comparison, generalization and wide spreading for using them in the interests of patients [17]. An information processing package comprises 4 biostatistic methods: Mentzel-Hansel, regression logical analysis, non-parametrical criterion of Mann-Witney [8], after which concordance coefficient is computed [15], for determination of agreement during decision-making. (Figure 7) proposes a structure of the intelligent information system for poisonings by carbon monoxide and 14 toxic substances which have similar symptoms, where B1, B2,…Bn-ambulance teams, DB-data base, KB-knowledge base, EBM-evidence-based medicine, EHC-electronic health card.

Conclusion

Pre-laboratory clinical symptoms of carbon monoxide poisoning are revealed and the necessity of differential diagnosis of carbon monoxide poisoning from poisonings by toxic substances with similar symptoms is substantiated; two approaches of diagnosis are proposed–by Bayes's method and by neuronal networks, which excludes any indetermination of diagnosis; an architecture of the intelligent information system is proposed and the software product is developed, which had been tested on real medical cards of patients over the period of 2006-2012 at the Central First and Emergency Aid Station of the city of Baku; operation of the system does not require special knowledge in the field of information technologies.

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