HEALTH RISK ANALYSIS RELATED TO ORGANIZATIONAL TASKS IN PUBLIC HEALTHCARE

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INFORMATION TECHNOLOGIES FOR DATA COLLECTION AND PROCESSING WHEN ESTABLISHING DETERMINANTS OF EPIDEMIC PROCESSES

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Providing biological safety of population is determined by a current situation with the state sanitary-epidemiologic system and its being ready to detect, localize and eliminate infective episodes. As threats of bioterrorism attacks against people are growing and infectious diseases are becoming more widely spread, it calls for greater efficiency of sanitary-epidemiologic examinations due to optimized collection and processing of data that are necessary for decision making related to revealing basic determinants of an epidemic process, as well as causes and conditions for infection occurrence and spread.

The paper dwells on a technology for automated data processing that helps to efficiently reveal all determinants of an epidemic process, and causes and conditions for infection occurrence and spread. The technology also allows automated checking of all proposed hypotheses basing on generalization of results obtained via independent research.

Proposed solutions are verified within a sanitary-epidemiologic examination that focused on dysentery episode in an organized team with its members staying on a closed territory and having their meals provided for them at a canteen. The authors compared an already existing system for collection and processing of statistical data (applied to reveal basic determinants of an epidemic process) and a proposed system for data collection and processing.

Obtained results supplement and develop existing theoretical and practical achievements as regards IT implementation into sanitary-epidemiologic examinations; they have considerable practical significance especially bearing in mind a future transition to electronic circulation of documents within public healthcare and medical provision. When applied, a proposed approach allows considerable reduction in time spent on generalization of data obtained via sanitary-epidemiologic examinations as well as a significant increase in validity of accomplished statistical calculations necessary to reveal factors that cause infectious agent transmission.

***Key words**: sanitary-epidemiologic examination, epidemiological analysis, health risks, infectious diseases risks, infection focus, determinant of en epidemic process, infectious agent, evidence-based medicine, medical information science, medical cybernetics.*

Biological terrorism is a grave problem related to providing biological safety nowadays as biological terroristic attacks on people are becoming more and more probable and there is a growing threat that infectious diseases will spread rapidly [1–3]. But it is much more probable to face a biological terroristic act that is not clearly obvious when it is too difficult to track cause-and-effect relations and determine an actual goal pursued by terrorists who applied biological agents [4–6].

State sanitary-epidemiologic surveillance should prevent occurrence and spread of hazardous infectious diseases that can cause mass outbreaks and epidemics. In this respect biological safety provision is determined by a system of state sanitary-epidemiologic surveillance being well-developed and well-prepared to detect, localize, and eliminate infective episodes [2, 7–9]. To work out efficient and timely activities aimed at minimizing consequences, localizing, and eliminating infective

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episodes, one should make sanitary-epidemiologic investigations as efficient as it's only possible [10, 11]. At present, as a number of sanitary-epidemiologic institutions is being gradually reduced but a number of object under surveillance, on the contrary, is growing, issues related to staff, material, and instrumental provision call for implementing information technologies (IT) that can support managerial decision-making [11–14].

Automated systems for control over various infectious nosologies are widely used in Western European countries and the USA [13–19]. The most widely used systems are Germ Alert, Germ Watcher, Gideon, RODS, and EpidInfo. Analysis revealed that Gideon and EpidInfo systems were the most efficient as regards finding solutions to outstanding tasks; these systems are aimed at monitoring morbidity with infectious diseases and analyzing monitoring data. However they can't be efficiently applied in Russian public healthcare as they are built taking into account organizational structures in public healthcare, reports and accounts, and peculiarities related to providing medical assistance to population in a specific country.

Domestic automated systems applied for control over morbidity with infectious diseases are aimed at keeping accounts and control over circulation of documents and at analyzing data including those on morbidity with infectious diseases as well as data on a sanitary-epidemiologic situation at objects under surveillance. However, none of such systems can provide automated collection, processing and analysis of data directly at foci where mass infective episodes occur; they don't allow revealing main determinants in epidemic processes and methods to eliminate basic ways and factors of contagion in organized teams. There are several problems related to creation of such systems; for example, there is a necessity to create algorithms for processing results obtained via clinical examinations and epidemiologic case histories; another problem is a necessity to formalize certain technological processes related to obtaining primary data on a disease from variable sources [20–23].

Sub-systems for monitoring over hazardous infectious diseases, analysis of data obtained via clinical and laboratory examinations of patients and reference data are basic components in automated systems that provide information support for decision-making when sanitary-anti-epidemic (preventive) activities take place [15–19]. It is also necessary to have a possibility to model epidemics scenarios depending on an infectious agent, preventive measures that were taken, and potential ability to eliminate an infectious focus [20–22].

Efficiency of anti-epidemic activities and medical aid for people who suffer from infectious diseases is determined by clinical and epidemiologic diagnostics being efficient and correct; these activities should also be timely and it to a great extent depends on how rapidly basic determinants of an epidemic process and causes for an infective episodes have been revealed [6–8, 10–13, 15, 17, 20]. When an epidemic is at its peak and patients with typical clinical symptoms are submitted to hospitals in great numbers, it is, as a rule, quite easy to determine a nosology, and causes for its occurrence and spread, especially in such cases when it concerns epidemic outbreaks that are well-known to physicians (shigellosis, flu, viral hepatitis, etc.). However, there may be infective episodes of diseases that are not so well-known, such as cholera, hemorrhagic fever with renal syndrome, malaria, contagious hemorrhagic viral fevers, etc.; they can occur both due to natural causes and biological terroristic acts when a clinical course of a disease can't be limited to only one nosology [10–27]. Therefore, to determine how an infectious agent is transferred in case of a mass infective episode, it is important to apply a principle of clinical-syndrome diagnostics (when major symptoms of a disease are revealed). Data taken from epidemiologic case histories and data obtained via operative epidemiologic analysis can be of critical importance for localizing and eliminating a focus of mass infectious diseases [1–10].

Our research can be considered vital due to Russian public healthcare being devoid of the above-mentioned sub-systems that are adapted to peculiarities of data collecting and processing when mass infections foci are localized and eliminated; such systems should take into account all the contemporary achievements in medical informatics.

It is vital to determine basic ways and factors that induce contagion; to do that, experts who perform sanitary-epidemiologic investigaions simultaneously detect infected people and those who were exposed to risks of contagion, question and examine them, process data and analyze obtained results [23–29]. Such examinations are based on questioning that, as a rule, is a primary tool for collecting complaints and symptoms of a disease that allow preliminary diagnosing and assuming how an infectious agent can spread and be caught; they also allow collecting data for epidemiologic case histories or data on consumed food products [30–34].

Our research goal was to increase efficiency of sanitary-epidemiologic investigations in mass infections foci due to streamlined collecting and processing data necessary to support decision-making related to revealing basic determinants in an epidemic process as well as causes and conditions for infection occurrence and spread.

Data and methods. Our research was simultaneously focused on detecting infected people and those who had been exposed to risks of contagion, questioning and examining them, data processing and analysis of obtained results. People who had been exposed to risks of contagion were detected via questioning, with its results being consequently processed.

As typical questionnaires for patients recommended to be applied in such investigations don't provide any possibility to automatically process questioning results, we developed new questionnaires to be applied for collecting and processing data in a mass infection focus (for acute enteric infections). Questionnaires included data on infected people and those who had been exposed to risks of contagion with a possibility to provide console or optical data input for consequent automated processing of results.

Questionnaires had a reference-identification block (personal data), and two basic parts; one of them had to be filled in by a patient, another one, by a doctor (medical assistant). Table 1 contains a part of such a questionnaire as an example.

Table 1

A questionnaire (a fragment)

To be filled in by a patient	
1. Complaints:	
– headache	□ – **no;** □ – **yes**
– overall weakness	□ – **no;** □ – **yes**
– fever	□ – **no;** □ – **yes**
…	□ – no; □ – yes
2. Participating in:	
– field exercises	□ – **no;** □ – **yes**
– constructing	□ – **no;** □ – **yes**
– agricultural work	□ – **no;** □ – **yes**
…	□ – **no;** □ – **yes**
3. Water consumption:	
– from non-centralized water supply sources	□ – **no;** □ – **yes**
– potable water	□ – **no;** □ – **yes**
– from open water reservoirs	□ – **no;** □ – **yes**
4. Contacts with infected people	□ – **no;** □ – **yes**
5. Mechanical damage to skin:	
– mosquito bites	□ – **no;** □ – **yes**
…	
– visit to a dentist	□ – **no;** □ – **yes**
– injections	□ – **no;** □ – **yes**
6. Data on nutrition	
1.Organized nutrition according to fixed rations:	
1 control day	
– cutlet	□ – **no;** □ – **yes**
– stewed meat	□ – **no;** □ – **yes**
– mashed potatoes	□ – **no;** □ – **yes**
– buckwheat cereal	□ – **no;** □ – **yes**
…	
2 control day	
…	□ – **no;** □ – **yes**
2. Additional list of products in non-organized rations	
– curds	□ – **no;** □ – **yes**
– sour cream	□ – **no;** □ – **yes**
– kefir	□ – **no;** □ – **yes**
…	
To be filled by a doctor	
Symptoms	
1. beginning of a disease	
– acute	□ – no; □ – yes

– sub-acute	□ – no; □ – yes
– slowly progressive	□ – no; □ – yes
2. Overall state a patient is in	
– satisfactory	□ – no; □ – yes
– average gravity	□ – no; □ – yes
– grave	□ – no; □ – yes
3. Body temperature	
– a drastic rise	□ – **no;** □ – **yes**
– up to 38 °C	□ – **no;** □ – **yes**
– 38 °C and more	□ – **no;** □ – **yes**
4. Skin and mucous tunics	
…	□ – no; □ – yes
5. coated tongue	
…	□ – **no;** □ – **yes**
6. State of the digestive organs	
…	□ – **no;** □ – **yes**
7. Tachycardia	□ – **no;** □ – **yes**
8. Bradycardia	□ – **no;** □ – **yes**
9. Low blood pressure	□ – **no;** □ – **yes**
11. High blood pressure	□ – **no;** □ – **yes**
10. Enlarged liver	□ – **no;** □ – **yes**
11. Enlarged spleen	□ – **no;** □ – **yes**
12. Decreased daily diuresis	□ – **no;** □ – **yes**

A part of the questionnaire that was to be filled by a patient (or, following his or her words, by a medical expert) involved filling in basic complaints and data for epidemiologic case history. The other part that was to be filled by a doctor enlisted basic symptoms acute enteric infections might have (primary clinical signs that were characteristics for certain acute enteric infections such as dysentery, viral hepatitis of A type, cholera, salmonellosis, and yersiniosis).

To avoid incorrect filling in questionnaires and to make analyzed data more valid, experts applied a system of predicates thus automatically checking whether questionnaires were filled correctly; this system allowed controlling data input and warning a doctor that there was probably a mistake in data input or certain data had been inputted incorrectly.

For example, high body temperature (T_1) can't go with normal (T_2) or low (T_3) temperature. Therefore, when a predicate $P(T)$ = *if* (T_1 = true and T_2= true) *or* (T_1 = true and T_3= true) *or* (T_2 = true and T_3 = true) *or* ($T_1 = T_2 = T_3$) has "ture" value, it means that data on complaints and symptoms of a diseases have been incorrectly filled in a questionnaire.

We worked out our algorithm for a sanitary-epidemiologic investigation aimed at determining basic ways and factors of contagion; this algorithm involved applying our developed questionnaires and could be considered a functional model for technological processes aimed at localizing and eliminating a mass infection focus; the model also included relevant information flows and was completed with Ross' notations (IDEF0), Gane – Sarson's notations (DFD), and Integrated Definition for Process Description (IDEF3) within All Fusion Process Modeler 4.1 data modeling system; its description can be found in [17, 19].

Data that were contained in questionnaires (complaints, symptoms, epidemiologic case histories, and data on consumed food products and drinks) were processed with a technology that allowed us to generalize results of independent research in order to check suggested hypotheses, or so called meta-analysis [11, 35–37]. Algorithms applied for data processing in meta-analysis procedures and interpreting its results are described in [35].

Research results. Suggested solutions were verified during an investigation that was aimed at revealing reasons for several mass infective episodes. We compared an existing system for collecting and processing data related to statistical parameters (the system was applied to detect basic determinants for epidemiologic processes related to those episodes) and a system for data collecting and processing based on all the suggested solutions.

As an example, we can consider results obtained during an investigation that focused on dysentery outbreak in an organized team; team members lived compactly on a closed territory and were provided with organized meals. 52 out of 160 team members caught dysentery (32.5%); 13 people fell sick on the first day; 16, on the second day; 11, on the third day; 7, on the fourth day; 3, on the fifth day; and 2, on the sixth day.

Our suggested approach involved filling in questionnaires both by those who had dysentery and those who ran a risk of contagion (control group); all the questionnaires were processed according to the following procedure.

On the first day when the disease was detected we input information into the database that included both data from questionnaires filled in by those who felt sick on that day and by those who didn't (the control group). On the second day we questioned only those who felt sick on that day and didn't question healthy people (as we already had data on them filled in on the first day) etc. Starting from the second day, we created an intermediate summary table with data both on those who fell sick and the control group.

For example: 13 people fell sick on the first day and the control group included 147 people; 16 people fell sick on the second day and the control group now included only 131 people, etc. On the second day the summary table contained data on 29 sick people and 118 healthy ones in the control group. The same summary tables were created for each following day during the outbreak until new patients ceased to be revealed. Accordingly, after all the data from filled questionnaires were fed and processed in a PC, the following reports were automatically created:

1. A number of people who fell sick as per dates and isolation, affection as per divisions in an organized team, summing up quantity of sick people as a progressive total, as well as a typical graph showing dynamics of the disease development (X axis showed dates of contagion; Y axis, a number of people who fell sick on a particular day).

2. Complaints and symptoms. Basic complaints that we received from people during the inspection were headache (71% sick people), thirst, dry mouth (85% and 98% respectively); colickly abdominal pains (65%). 65% and 100% sick people complained they had tenesmus and diarrhea. The results were presented both in tables and on graphs.

There were the following basic symptoms: acute onset of the disease involved drastic temperature rise up to 39 °C, patients were mostly in average gravity state, pains and spasms in the sigmoid section of the intestines were revealed in 77% patients; 67% and 46% patients had frequent liquid stool with mucus and blood respectively.

We analyzed the obtained results and revealed prevailing complaints and symptoms that were typical for damage to the gastrointestinal tract; it allowed a doctor to preliminary diagnose a disease and suggest a hypothesis that an infective episode was somehow related to contagion with food.

3. Data taken from epidemiologic case histories should include probable risk factors related to consuming water from non-centralized water supply systems, low quality food products, staying on geographically remote territories, possible contacts with infected people etc.

As all the sick people didn't attend any field activities during incubation, didn't take part in agricultural works, and didn't drink water from non-centralized water supply systems, contagion was the most likely caused by sanitary-epidemiologic rules being violated during cooking.

4. Reports on nutrition received by sick people and the control group were presented in the aggregate table. Dishes were selected from everyday menus by epidemiologists. In our examined case we took two menus, 2 and 3 days prior to the disease outbreak. We performed factor epidemiological analysis [24] to determine a specific product that was a possible factor causing contagion.

The aggregate table with data on nutrition contained results for each specific product that was included into menus; data included those on how many people (%) who consumed this or that product were affected and on the control group (people who didn't consume it), as well as significance of a zero hypothesis ("there are no discrepancies between sick people and the control group") calculated with Pearson's χ^2 test and the exact Fischer's test as per cross-tabulation tables created for each product [35].

We performed factor analysis to reveal what product was a contagion factor; to do that, we examined both groups: people who had consumed a certain product and the control group (people who hadn't done it). We revealed how many disease cases occurred in each group after a specific food product had been consumed 2 days prior to the day when sick people were first detected and in how many cases there was absence of the above effect.

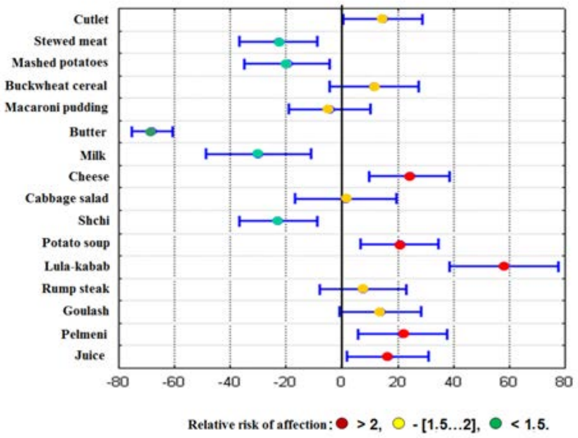

Figure 1. Visualized results of factor epidemiologic analysis (the first day of the inspection, a fragment)

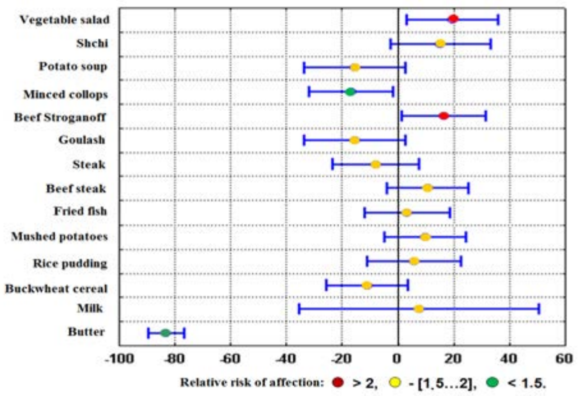

Figure 2. Visualized results of factor epidemiologic analysis (the second day of the inspection, a fragment)

Factor epidemiologic analysis aimed at determining a food product that was a contagion factor was performed in three stages: significance of a zero hypothesis was calculated; epidemiologic analysis results were visualized; absolute and relative risks were calculated.

Statistical properties related to authenticity of occurring effects caused by a specific product being consumed were calculated as per cross tabulation tables according to [11, 35]; the results are shown in Figures 1 and 2.

Y axis shows a list of consumed food products; X axis shows a difference between disease cases among people who were exposed to a risk of contagion and in the control group. Segments that connect three given points for each product characterize how apparent the disease occurrence is and how valid a suggested hypothesis is. The more to the right is a segment relative to the zero X axis, the more apparent is the disease and the higher its validity. And a product is considered to be a probable contagion factor if 95% confidence interval is located strictly to the right from the zero X axis.

Thus, according to the research results (Figures 1 and 2), we can conclude that on the first day the most apparent effects indicating a product could be a contagion factor were detected for lula-kabab, cheese, potato soup, and pelmeni; effects were not so apparent for cutlets, buckwheat cereal, macaroni pudding, salad, rump steak, and goulash; there were no effects detected for stewed meat, mashed potatoes, butter, milk, and shchi.

As for products consumed on the second day, the most apparent effects were detected for vegetable salad and beef Stroganoff. Effects were either vague or absent for all the other products consumed on that day.

To confirm the obtained results, we calculated absolute and relative risks of contagion caused by consumption of the listed products (Table 2). The highest absolute and relative risks were detected for lula-kabab and cheese.

On the second day the highest absolute and relative risks were detected for salad and beef Stroganoff. But significance of a zero hypothesis was $p = 0.09$ for vegetable salad and $p = 0.08$ for beef Stroganoff, that is, it was higher than its critical value being equal to 0.05.

Therefore, epidemiologic analysis as per risk factors based on analyzing cross tabulation tables and visualizing its results allowed us to reduce a list of products that could possibly cause contagion by 64% at the first two stages (determining significance of a zero hypothesis and visualizing research results); and by additional 30% at the third stage (calculating absolute and relative risks). We detected that only 4 out of total 28 products that could possibly be risk factors were the most probable causes of contagion (lula-kabab, cheese, potato soup, and pelmeni).

The obtained results were consistent with the data obtained via epidemiologic investigations on the infective episode and confirmed by laboratory research.

Table 2

Affection, absolute, and relative risks of contagion caused by consumption of food products included into menus 2 days prior to the day when the first disease cases were registered (a fragment)

A food product	Affection, %		Significance of a zero hypothesis	Absolute risk	Relative risk
	Among people who consumed a product	In the control group			
The 1st day					
Cutlet	38.71	23.88	0.07	14.83	1.62
Stewed meat	21.25	43.75	0.001	-22.5	0.49
Macaroni pudding	30.49	34.62	0.47	-4.13	0.88
Butter	32.08	100	0.019	-67.92	0.32
Milk	26.56	56.25	0.0006	-29.69	0.47
Cheese	**46.38**	**21.98**	**0.0019**	**24.4**	**2.11**
Lula-kabab	**85.71**	**27.4**	**0.0008**	**58.31**	**3.13**
Rump steak	37.5	29.81	0.42	7.69	1.26
Goulash	40.28	26.14	0.083	14.14	1.54
Pelmeni	47.17	25.23	0.009	21.94	1.87
The 2nd day					
Vegetable salad	35.56	16	0.09	19.56	2.22
Minced collops	20	36.67	0.03	-16.67	0.55
Beef Stroganoff	36.67	20	0.08	16.67	1.83
Goulash	29.03	44.44	0.05	-15.41	0.65
Steak	27.08	34.82	0.25	-7.74	0.78
Milk	32.69	25	0.82	7.69	1.31
Butter	16.92	100	0	-83.08	0.17

When necessary, this algorithm can be applied to test other hypotheses on probable causes for contagion.

Therefore, when questioning results are properly processed, it allows timely determining a probable contagion factor; it is truly vital for performing efficient sanitary-epidemiologic investigaitons.

Discussion. Our assessments revealed that an epidemiologist on average spent 20-30 minutes per 1 patient to collect data on clinical signs of a disease and other necessary data for epidemiologic case history. When an infective episode is massive and 15-25 people fall sick every day, it takes on average 2-3 hours to create analytical tables, generalize, and analyze available data.

Our research revealed that the suggested approach allowed a substantial reduction in amount of time spent on generalizing all the obtained data; this amount dropped by more than 60 times, from 3 hours to 3 minutes. It also allowed making statistical calculations much more valid due to simultaneous use of several complimentary statistical techniques. The most significant time gain was obtained via applying optical input of data from formalized questionnaires.

Results that we obtained expand and develop the existing theoretical and practical experience in IT implementation into sanitary-epidemiologic research; they have great practical significance, especially bearing in mind a future transition to electronic circulation of documents within providing medical assistance to population.

The suggested way to implement IT into support for decision-making processes during sanitary-epidemiologic investigations allows optimizing collection and processing of data that are necessary to detect basic determinants of an epidemiologic process as well as causes and conditions of infection occurrence and spread. The achieved effect is higher efficiency in preparing data for factor epidemiologic analysis; timely detection of factors that determine contagion risks and risks of morbidity; revealing primary ways of contagion; and validity of obtained results.

Conclusions. To provide timely epidemiologic analysis that supports decision-making when basic determinants of an epidemic process are revealed is a primary goal to be achieved via optimizing collection and processing of data during sanitary-epidemiologic investigations in mass infections foci.

A questionnaire applied to collect primary data on sick people and those who ran risks of contagion was adapted for further processing with IT; it is a basis for data structuring when an acute enteric infection is preliminary diagnosed. This questionnaire contains sufficient amount of primary data on sick people that allows assessing health of any patient objectively and obtaining generalized data on a group of examined people.

Questioning results are automatically processed due to implementing optical data input with automated primary test of its correctness based on a system of predicates and consequent visualization of results obtained via statistical data processing. It provides a significant time gain and increases validity of initial data that are necessary to support decision-making during sanitary-epidemiologic investigations.

Suggested IT for data collection and processing during sanitary-epidemiologic investigations allow achieving more efficient collection and processing of initial data; providing greater validity of data analysis when revealing basic determinants of an epidemic process (due to simultaneous use of several complimentary statistical techniques); reducing time that is necessary to make a decision on anti-epidemic protection of population and to eliminate consequences of bioterrorism.

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