Development of an automaton recognizer of tissue pathologies caused by Chlamydia infection

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Abstract. Chlamydia belongs to such diseases, in which the blood-brain barrier permeability is disturbed leading to degenerative changes of brain cells and development of neurological symptoms in animals. Chlamydiae disrupt the barrier function of endothelium, which inside blood vessels forms a semipermeable barrier between the contents of vessels and surrounding tissues. As a result of this process, part of the endothelial cytes slough into the lumen of blood vessels and destroying, contributes to the generalization of infection in the body. Chlamydia infection affecting mammals and birds is caused by antigenically related microorganisms from the Chlamydiacea family. Under animal chlamydia a whole range of diseases is considered, which, due to their polymorphic nature, cannot be united by a specific symptom complex, and sometimes affect all systems and organs. Due to the lack of organotropism and host specificity in different representatives of chlamydiae, the clinic of chlamydiae is extremely diverse. As a diagnosis of this disease, as well as the accuracy of the results, the histological method of examination of pathological material is used. In the process of the conducted research qualitative and quantitative characteristics of pathomorphological changes of cellular structures were determined, with the identification of indicators. All pathological processes occurring in the cell of the organism we have divided into three main groups: cell membrane pathology, cell membrane pathology, and Mitochondria pathology. We developed a decision support module for preliminary diagnosis of pathologies. A truth table of the relationship between indicators and pathology groups was developed. Minimization of disjunctive normal form was carried out using finite automata theory.

1 Introduction

In the near future, a qualitative leap in the application of robotics is expected in numerous spheres of activity, including medicine and veterinary medicine [1-2]. Research is currently underway to develop expert systems for cancer diagnosis [3-4]. Many studies have been

devoted to the investigation of pathologies caused by Chlamydia infection, but not enough attention has been paid to automated systems [5-10].Approaches to the development of an automated histological analyzer system were described in [11]. This paper is devoted to the development of a module for pathology recognition based on the analysis of certain indicators. Three main groups of pathologies were identified during histologic analysis: Core pathology, Cell membrane and Mitochondria pathology; changes in the size, shape of cells, number of nuclei and nuclei were taken into account [12-13]. The appearance of various nuclear inclusions and changes in the nuclear envelope, followed by death of the nucleus, which is manifested by karyopyknosis, karyorrhexis and karyolysis. Disturbance of energy supply of cell vital activity, damage of membrane and enzyme system, ion and water balance, hereditary program of the cell, regulation of cell activity.

2 Materials and Methods

Methods of histological analysis, characteristics of systems with distributed parameters, methods of continuum mechanics, theory of automatic control, methods of mathematical and simulation modeling were used to substantiate methods and algorithms of control of histological process.

The research work was carried out on laboratory rats. The pathogen Chl. Psittaci, strain "Lori" was used for infection of rats. The rat cerebellum was presented as an object of study for the description of morphological features. Biomaterial for the study was subjected to fixation in 10% formalin, then wired in alcohols of increasing strength. For histologic studies, the material was fixed in 4% formaldehyde solution and embedded in paraffin. Histological sections were stained with hematoxylin and eosin. Hematoxylin stained in blue-violet tones the shell of cell nuclei, chromatin. Eosin stained cytoplasm and some structures (fibers) in pink-red-orange tones. Slices up to 5 microns thick were made from the prepared blocks on a sledge microtome. The obtained preparations were studied with a Zeiss microscope (Axioskop 40) at the magnification of the eyepiece x10, with lenses x4, x10. The structural organization of the cerebellar cortex (gray and white matter) of the control rat is shown in Figure 1 (Hematoxylin-eosin x 10).

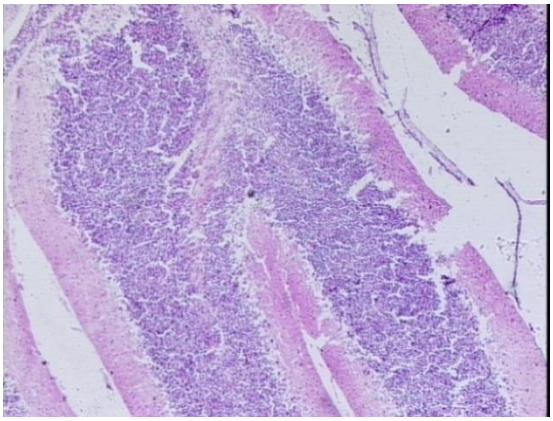

Fig. 1. Structural organization of the cerebellar cortex (gray and white matter) of the control rat. Hematoxylin-eosin.x 10

Karnaughmaps were used to find the minimum disjunctive form. The program for the industrial controller is written according to and IEC 61131-3. The software is written using Software CX-ONE.

3 Results of the study

3.1 Laboratory experiments

Laboratory experiments were performed using the following equipment: technical and analytical scales, pH-meter, microtome, cryostat, water bath, table for melting paraffin sections, thermostat, refrigerator, microscope, wiring machine. When examining the cerebellum, sharply expressed edema and tissue swelling were observed. Three cell layers - molecular, ganglionic and granular - were traced in the cerebellar gray matter (Figure 2). The most severe changes were noted in Purkinje cells. Individual cells that retained their shape increased in size (Figure3). Their cytoplasm was stained weakly eosinophilic, heterogeneously, nuclei had indistinct contours. The processes of Purkinje cell death were also detected. Big changes were expressed in the vascular bed of gray and white brain matter, including capillaries, small arteries and veins (Figures 4,5). Thus, the gray and white matter and the soft cerebellar medulla of the cerebellum showed changes of dyscirculatory character with vascular channel lesions.

The aim of which was to determine indicators of three major cell pathologies: Cell membrane, Core pathology and Mitochondria pathology. Experiments were performed on 158 samples with a specific type of pathologies and subpathologies shown in Table 1.

Table 1. Preparation of samples for research

N	Pathology		Number of samples
1.1	Cell membrane	Violation of energy supply to cell activity (y_{11})	15
1.2		Damage to the cell membrane and enzyme system (y_{12})	12
1.3		disturbance of ion and water balance (y_{13})	17
2.1	Core pathology	karyopyknosis(y_{21})	20
2.2		Carirexis (y_{22})	25
2.3		Karyolysis (y_{23})	27
3.1	Mitochondria pathology	Mitochondriaswelling (y_{31})	12
3.2		Crystal structure change (y_{32})	14
3.3		Crystal death (y_{33})	16

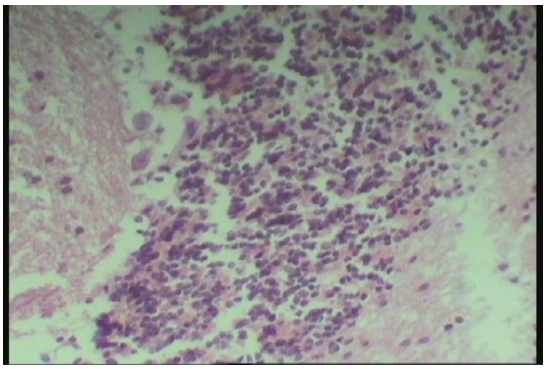

Fig. 2. Gray cerebral substance of the cerebellum. Preservation of the structural organization of the cortex against the background of pronounced edema. Hematoxylin-eosin. x 40

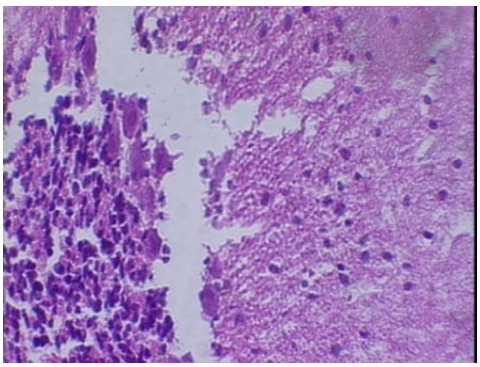

Fig. 3. Dystrophic changes in cells. Hematoxylin-eosin. x 40

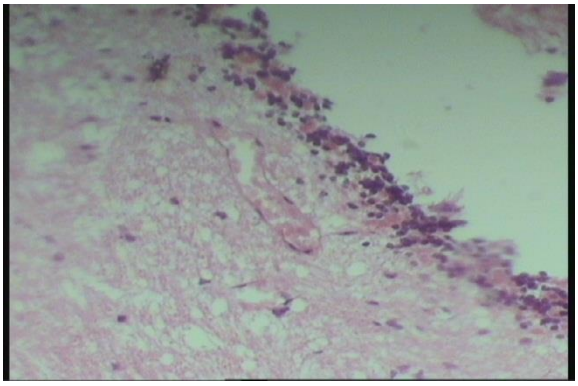

Fig. 4. Enlargement of the vessel lumen with disconnection of endotheliocytes. Hematoxylin-eosin. x 40

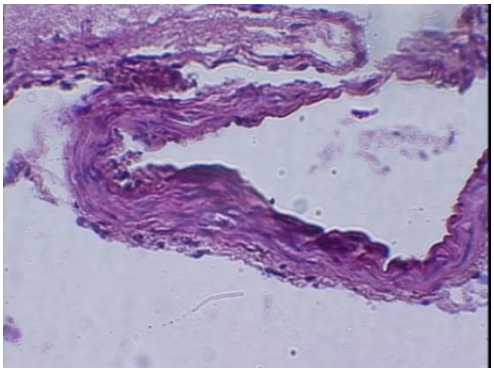

Fig. 5. Edema, plasma saturation of the arterial walls. Hypertrophy of myocytes. Hematoxylin-eosin. x40

3.2 Synthesis of logical equations

By associating indicators with pathologies, a truth table was obtained (Table 2).

Table 2. Construction of the truth table

a	*b*	*c*	*d*	Cell membrane			Core pathology			Mitochondria pathology		
				y_{11}	y_{12}	y_{13}	y_{21}	y_{22}	y_{23}	y_{31}	y_{32}	y_{33}
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	0	1	0	0	1	0	0
0	0	1	1	0	0	0	1	0	1	1	0	0
0	1	0	0	1	0	0	0	0	1	0	0	0
0	1	0	1	1	0	0	1	1	0	0	0	0
0	1	1	0	1	1	0	1	1	1	1	1	0
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1	0	0	0	1	1	0	1	1	1	1	0	0
1	0	0	1	1	0	0	1	1	1	0	1	0
1	0	1	0	1	0	1	1	0	1	1	1	1
1	0	1	1	1	0	0	0	1	1	1	0	0
1	1	0	0	1	1	0	1	1	1	1	0	0
1	1	0	1	1	1	1	0	1	1	1	0	0
1	1	1	0	1	1	0	0	0	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1

By performing disjunctive normal form minimization, the following logical expressions were obtained (Table 3).

Table 3. Logical equations

Y	Logical equations
y_{11}	$a \vee b$
y_{12}	$a\bar{c}\bar{d} \vee bc \vee ab$
y_{13}	$abd \vee bcd \vee a\bar{b}\bar{d}$
y_{21}	$\bar{a}c \vee \bar{a}b\bar{d} \vee a\bar{b}\bar{d} \vee a\bar{b}\bar{c} \vee a\bar{c}\bar{d}$
y_{22}	$a\bar{b}\bar{d} \vee \bar{a}bc \vee bd \vee ac \vee a\bar{c}$
y_{23}	$a \vee b\bar{d} \vee \bar{b}cd$
y_{31}	$ab \vee c \vee a\bar{d}$
y_{32}	$adc \vee ac\bar{d}$
y_{33}	$adc \vee ac\bar{d}$

Based on the logic equations, ladder diagrams were constructed to program the industrial controller (Figure 6).

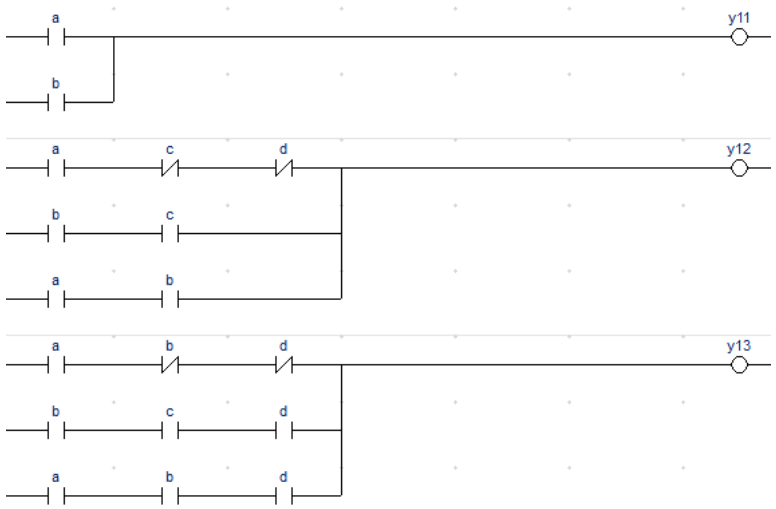

Fig. 6. Ladder diagram fragment

The operator screen is designed using the CX-Designer module (Figure 7) [14]. The screen includes a pathology display and a test block of indicators.

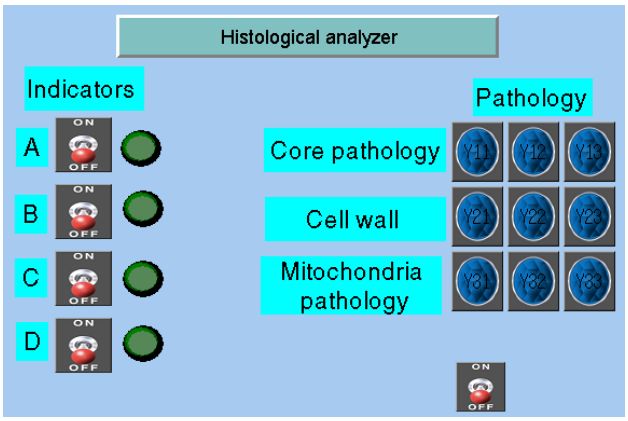

Fig. 7. Histologist operator panel

3.3 Simulation of program operation

To verify the correctness of pathology detection, simulation of the program operation was carried out (Figure 8).

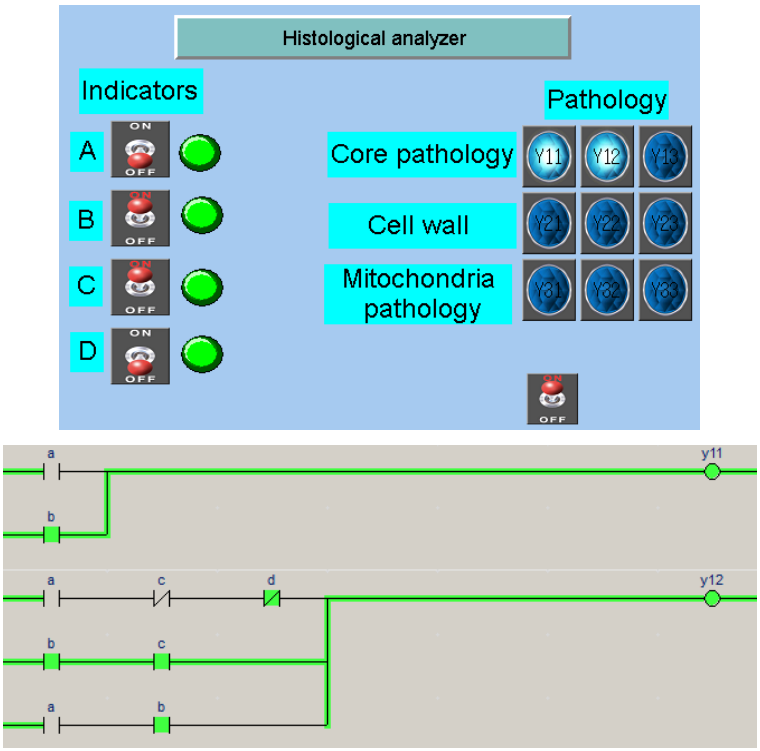

Fig. 8. Program simulation

When a certain set of indicators is detected, the lamp on the operator panel lights up. The program was tested in all modes and worked according to the specified algorithm.

4 Conclusion

Thus, in the gray and white matter and the soft cerebellar cortex there were observed, first of all, changes of a dyscirculatory character with lesions of the vascular channel. The developed ladder diagrams can be used to build an automaton recognizer of morphostructural changes in tissues during chlamydial inrfection. The recognizer module under development is part of the projected histology robot. In the future, it is planned to train the recognizer module for other pathologies and also to study morpho-structural changes in tissues. Currently, experiments have also been conducted on the use of neural networks in pattern recognition, and the results have shown a recognition rate of up to 80%.

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