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Original article

OPTIMIZATION OF COMPLEX DIAGNOSTICS OF NEUROTRAUMA DURING ELIMINATION OF MEDICAL AND SANITARY CONSEQUENCES OF EMERGENCY SITUATIONS

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Abstract. *The purpose of the study* is to analyze the use and determine the prospects for the development of computer tomography (CT) complexes, biomarkers, and test systems for rapid assessment of the functional state of the central nervous system as elements of a comprehensive diagnosis of neurotrauma in the elimination of medical and sanitary consequences of emergencies.
Materials and methods of research. The subject of the study is Russian and foreign experience in complex diagnostics of neurotrauma in emergency situation victims. Main research methods: logical, system analysis, field modeling and observation.
Research results and their analysis. The results of the study showed that promising elements of the system for complex diagnostics of neurotrauma in emergency situation victims are: mobile complex for CT; test systems for rapid assessment of the level of blood biomarkers that reflect the main pathological mechanisms of neurotrauma; test systems for rapid assessment of the functional state of the central nervous system.

Key words: *complex diagnostics, computed tomography, emergencies, neurotrauma, Service for Disaster Medicine of the Russian Defense Ministry*

Conflict of interest. The authors declare no conflict of interest

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Оригинальная статья

ОПТИМИЗАЦИЯ КОМПЛЕКСНОЙ ДИАГНОСТИКИ НЕЙРОТРАВМЫ ПРИ ЛИКВИДАЦИИ МЕДИКО-САНИТАРНЫХ ПОСЛЕДСТВИЙ ЧРЕЗВЫЧАЙНЫХ СИТУАЦИЙ

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Резюме. *Цель исследования* – анализ использования и определение перспектив разработки комплексов компьютерной томографии (КТ), биомаркеров, тест-систем экспресс-оценки функционального состояния центральной нервной системы как элементов комплексной диагностики нейротравмы при ликвидации медико-санитарных последствий чрезвычайных ситуаций (ЧС).
Материалы и методы исследования. Предмет исследования – российский и зарубежный опыт комплексной диагностики нейротравмы у пострадавших в ЧС. Основные методы исследования: логический, системный анализ, натурное моделирование и наблюдение.
Результаты исследования и их анализ. Результаты исследования показали, что перспективными элементами системы комплексной диагностики нейротравмы у пострадавших в ЧС являются: комплекс мобильный КТ; тест-системы для экспресс-оценки уровня биомаркеров крови, отражающих основные патологические механизмы нейротравмы; тест-системы экспресс-оценки функционального состояния центральной нервной системы.

Ключевые слова: *комплексная диагностика, компьютерная томография, нейротравма, Служба медицины катастроф Минобороны России, чрезвычайные ситуации*

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According to Russian sources data, in emergency situations (ES), including military conflicts, sanitary losses with neurosurgical trauma account for up to one third of all surgical losses: the proportion of trauma of the skull and brain is 12%; spine and spinal cord – up to 2.4; lesions of large nerve trunks – up to 11%. More than half of neurotraumas have multiple and combined character, which is due to the predominance of shrapnel wounds and mine-explosive injuries. Among spinal cord injuries, the prevailing mechanism is closed trauma, which accounts for 68% [1]. At the same time, it should be noted that the technical means of the Disaster Medicine Service (DMS) of the Russian Ministry of Defense do not allow timely diagnosis of neurotrauma.

Thus, the study of opportunities for further development of the neurodiagnostic system in the prehospital period remains an important task for military medicine.

In the armies of NATO countries, traumatic brain injury (TBI) is also an important problem, since it is the most recurrent cause of sanitary and irrecoverable losses. Thus, during the hostilities in Afghanistan and Iraq, head lesions were detected in 29.4% of cases [2]. Despite the fact that severe and penetrating BIs were detected in only 8% of all head injuries, the share of nervous system injuries in the overall structure of combat losses was 33%. The patients with mine-explosive wounds of the central nervous system (CNS) constituted the most numerous – over 60% – group of severe neurosurgical patients at the stage of specialized medical care [3].

The aim of the study was to analyze the use and to determine the prospects for the development of computed tomography (CT) complexes, biomarkers and test systems for rapid assessment of the functional state of the central nervous system as elements of a comprehensive diacrisis of neurotrauma in the prehospital period during the elimination of the emergencies' consequences.

Materials and research methods. The subject of the research is Russian and foreign experience of complex diacrisis of neurotrauma in those injured in emergencies. Based on the results of the study, a report "Neurodiagnostics-VM" was prepared [4].

Research materials: medical and technical characteristics of devices used to diagnose neurotrauma: a complex of mobile computed tomography; test systems for rapid assessment of the level of blood biomarkers, reflecting the main pathological mechanisms of neurotrauma; test systems for rapid assessment of the functional state of the central nervous system. Some means of craniography, echoencephaloscopy, radiography of the spine and other diagnostic methods used at the stage of rendering specialized medical care have been studied and analyzed.

Research results and their analysis. When eliminating the consequences of emergencies, including military conflicts, the main treatment and diagnostic work upon the provision of neurosurgical care is carried out during the hospital period, since the technical means for diagnosing trauma of the nervous system available at medical units and posts of the advanced echelon do not fully meet up-to-date requirements.

The means of radiation diagnostics of Russian Ministry of Defense DMS subdivisions, where the pre-assessment, diacrisis and pre-evacuation preparation of the wounded are carried out, include a foreign-made X-ray machine with a wired flat-panel detector, as well as an X-ray complex, consisting of a portable X-ray machine and a digital imaging system (available only in special operations medical unit – SOMU) – Figures 1, 2. The specified equipment has the design limitations that do not allow the radiologist to effectively perform the entire range of diagnostic measures to identify neurotrauma and to give a preliminary assessment of its severity.

That is why, in order to carry out the entire scope of necessary diagnostic measures within the subdivisions of the DMS of the Ministry of Defense of Russia, it is necessary to

Рис. 1. Портативный рентгеновский аппарат
Fig. 1. Portable X-ray apparatus

Рис. 2. Рентгенодиагностический комплекс (КРЦП)
Fig. 2. Diagnostic X-ray Complex

have a more advanced system of comprehensive diagnostics, which must first of all be equipped with CT unit.

Improving the field system for nervous system injuries diacrisis by introducing CT increases the general efficiency of providing neurosurgical care, since in this case the following features become possible:

- timely diagnosis of neurotrauma;
- objective assessment of its volume and severity;
- determining the scope of optimal therapy in the framework of pre-evacuation preparation;
- safe escort of the wounded during medical, including avia, evacuation.

In military mobile hospitals of foreign armies, CT is used to diagnose severe concomitant and multiple trauma (injury), including the implementation of the widely used whole-body CT protocol [5]. Such radiation diagnostics, being a modern highly informative method, gives a full overview of the state of the spine, skull, intrathecal spaces, wound canal, brain, which allows to draw conclusions about the presence and severity of edema, about the presence of contusion foci and about the displacement of the midline structures. Computed tomography also expands diagnostic capabilities in neurological pathology, most of which are CNS injuries – concussion and mild brain contusion, both isolated and combined, most characteristic of mine-explosive trauma. In this case, timely radiation diagnostics and monitoring of the effectiveness of medical measures are of particular relevance: with proper treatment, this category of wounded is a significant source of replenishment of the loss of personnel. In opposite case, such wounds result in disability.

As the experience of a number of countries has shown, CT is the leading method for diagnosing TBI and spinal cord injuries in the system of neurosurgical care provision. Therefore, within the provision of medical care in an emergency, it is necessary to introduce CT to the pre-hospital period of medical care.

As part of the DMS units of the Russian Ministry of Defense, mobile computer tomographs must be used in the form of a hospital module (container) – a CT room. It is proposed to use them in the daily work of diagnostics and treatment units, since this increases the operational efficiency of mobile CTs [5].

According to the results of research and testing of domestic and foreign medical and diagnostic equipment used to detect neurotrauma in the prehospital period, it was determined that the most optimal tool is the Mobile Medical Computed Tomography Complex (MMCTC), produced in the following versions:

- a mobile complex based on the chassis of KamAZ, MAN, Scania and others;
- a mobile complex based on a container body (Fig. 3);
–complex module.

The complex is placed in a container-body of a variable volume, which allows to organize a working area corresponding to the available examination room space in stationary medical institutions. The body of the mobile CT complex consists of isothermal panels placed on a welded frame base. To ensure radiation safety, the walls, doors, floor and ceiling of the examination room are covered with a 2-millimeter layer of lead, thanks to which the X-ray radiation is attenuated to a level at which the permissible dose limit will not be exceeded. The viewing window for patient observation has an X-ray protective glass.

CT mobile complexes are equipped with systems for heating, air conditioning, humidification and ventilation, which allow creating a comfortable indoor climate in all rooms. Utilities are located under the suspended ceiling, which has built-in ventilation grilles and lamps. The water supply system of the CT mobile complex consists of a reservoir for clean water, a water pump, a sink with a boiler, a hose and a reservoir for collecting contaminated water. Mobile complexes are connected to an external power source. If the power supply is not available, one can use a standard 130 kVA autonomous diesel-electric generator, which turns on automatically in the event of an external power failure. The deployment of the complex on site takes up to 35 minutes.

When eliminating medical and sanitary consequences of an emergency, it is proposed to include a study of the neurological status using a rapid assessment test system, consisting of 4 blocks, within the system of complex diagnostics of neurotrauma:

- 1st block – screening for concussion, allowing to describe the history of trauma, containing questions about loss of consciousness, its change and post-traumatic amnesia;
- 2nd block – cognitive exam, during which points are assigned to assess orientation, immediate memory, concentration and delayed feedback;
- 3rd block – neurological examination, including tests: for the pupil reaction to light, for fluency of speech and of word search, for grip strength, for pronator drift – an indicator of muscle weakness and compensation – and for balance;
- 4th block – screening of symptoms, including: headache, dizziness, memory problems, balance problems, nausea / vomiting, difficulty concentrating, irritability, visual disturbances and tinnitus.

This test, presented in the form of a ready-to-fill brochure (questionnaire), combined with a medical examination, al-

Рис. 3. Комплекс мобильный компьютерной томографии (КММПКТ)
Fig. 3. Mobile complex of computed tomography

lows to assess whether a soldier can return to his duties or further medical treatment and monitoring are required.

In the complex diagnostics system, the prospects for the use of biomarkers, which may contain important information on the pathological cascade connected to TBI, are explored.

A number of foreign companies have developed and implemented the analyzers for detecting the biomarkers of neurotrauma – Fig. 4 [6].

The use of separate classes of biomarkers, reflecting the main pathological mechanisms, makes it possible to identify and to assess the volume of primary damage to the nervous tissue and the dynamics of the development of secondary processes. It should be borne in mind that one biomarker does not have the necessary sensitivity and specificity to be sufficient for the diagnosis of TBI. The combination of biomarkers for the improvement of the diagnostic accuracy is a logical addition to tracking the dynamics and activity of pathological processes, to conducting molecular targeted therapy, and to monitoring the therapeutic response in TBI [7].

The diagnostic role of TBI biomarkers in clinical practice continues to be controversial issue due to the imperfection of criteria,to the lack of reliable data on the validity and clinical effectiveness of the indicators of damage to the nervous system.

At the stage of specialized medical care provision, the standard protocol for examining a patient with a wound or trauma of the head and spine is extended and includes craniography, echoencephaloscopy, spinal x-ray, neurological examination, which are promising for use in the prehospital period. At the same time, craniography in four projections – anteroposterior, posterior semi-axial, right and left lateral – complements the surgical and neurological examination of the wounded. Under these conditions, not only absolute radiological signs are assessed – such as a presence of a pathological shadow in the cranial cavity, but also indirect signs of a penetrating craniocerebral injury and other bone-traumatic changes – pneumocephalus, a presence of bone fragments, displacement of calcified structures – are analyzed in detail.

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Conclusions

1. Thus, the analysis of medical and technical characteristics of existing and projected neurodiagnostic tools, carried out in order to optimize the complex diagnosis of neurotrauma, indicates that the most promising tools for eliminating the consequences of emergencies are: a complex of mobile computed tomography; test systems for rapid assessment of the level of blood biomarkers, reflecting the main pathological mechanisms of neurotrauma; test systems for rapid assessment of the functional state of the central nervous system.

2. The use of complex diagnostics of neurotrauma in the prehospital period may increase the efficiency of medical assistance to those injured in emergencies.

3. The results of the study indicate the room for further improvement of diagnostic and treatment measures in the field.

Рис. 4. Компактный анализатор для определения уровня биомаркеров нейротравмы

Fig. 4. Compact analyzer for determining the level of biomarkers of neurotrauma

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