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METHOD AND DEVICE FOR SHOCK WAVE MODELING (LITERATURE REVIEW)

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The widespread use of explosive devices in military conflicts leads to an increase in blast injuries to organs, which differ from classic mechanical injuries by the mechanism of damage and clinical signs. The special attention of both clinicians and theoreticians is attracted by blast brain traumatic injury, since its course is distinguished by the appearance of cognitive-behavioral disorders in an acute period and the development of neurodegeneration in the remote period. However, the pathogenesis is currently largely undisclosed, and all experimental studies differ in modeling methods. So, we made an analysis of modern literature in order to establish the differences between devices for creating an explosive wave and, taking into account the advantages and disadvantages, we proposed our own device, which is safe and guaranteed to generate an explosive wave of the pressure necessary for damage.

Key words: blast injury, device, experiment, brain.

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МЕТОД І ПРИСТРІЙ ДЛЯ МОДЕЛЮВАННЯ УДАРНОЇ ХВИЛІ (ОГЛЯД ЛІТЕРАТУРИ)
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Широке застосування вибухових пристроїв у військових конфліктах призводить до збільшення вибухових ушкоджень органів, які за механізмом пошкодження та клінічними ознаками відрізняються від класичних механічних травм. Особливу увагу як клініцистів, так і теоретиків привертає вибухова черепно-мозкова травма, оскільки її перебіг відрізняється появою когнітивно-поведінкових розладів у гострому періоді та розвитком нейродегенерації у віддаленому періоді. Проте патогенез наразі більшою мірою не розкритий, а всі експериментальні дослідження відрізняються способами моделювання. Тож ми провели аналіз сучасної літератури з метою встановлення відмінностей пристроїв для створення вибухової хвилі і, враховуючи переваги і недоліки, запропонували власний пристрій, що є безпечним і гарантовано генерує вибухову хвилю необхідного для ураження тиску.

Ключові слова: вибухова травма, пристрій, експеримент, головний мозок.

Introduction. Widespread use of explosive devices in military conflicts leads to an increase of blast-induced injuries of the organs, which differ in the mechanism of damage and clinical signs from classical mechanical injuries. The special attention of both clinicians and theoreticians is attracted by explosive blast brain traumatic injury, since its course is distinguished by the appearance of cognitive-behavioral disorders in an acute period and the development of neurodegeneration in the remote period [1]. The pathogenesis of bTBI is currently being actively investigated, but separate links have been established, and modeling methods differ. Therefore, this question requires meticulous research, in particular experimental, which needs the development of a simulation model of bTBI. Analysis of selected scientific sources showed that explosion-induced trauma studies have different methodologies which differ in the way the blast or shock wave simulation, the devices used for it, the location of the experimental animal at the time of exposure, the range of excess pressure, etc. [2; 3; 4].

We suppose that a detailed study of the bTBI experimental modeling features will contribute to the establishment of the injury pathogenesis depending on the distance, position and other factors. This, in turn, helps in the development of treatment and prevention of complications, as well as in improving the safety of those at risk of such an injury. Including, taking into account the results of research, more effective protective elements can be developed for the military, workers in certain industries where explosions may occur [5].

Methods. Analysis and evaluation of experimental models of blast-induced injury by scientific publications, monographs and invention obtained in stages patent information search in the library collection of the Dnipro State Medical University, a retrospective search of the literature database PubMed.

Results and discussion. By method of explosive or shock wave experimental modeling there are two ways. The first method is simulated by detonating explosives in both open landfill [6; 7] and special devices, an explosive chamber or a shock tube. The advantages of the first method include the fact that the circumstances are more close to the real situation, in which there is an impact of harmful factors of the explosion, as well as in these conditions it is possible to use a large group of animals with different distances from the epicenter.

But conducting research in open space (landfill) has significant disadvantages due to the fact that biological objects have several impressive factors of explosion (simultaneous effect of explosive wave, thermal, chemical, mechanical and other factors), which hinder the study of the impact of the explosive wave in the dynamics of the post-traumatic period on individual organs, such as the brain. Also, the disadvantages should be added to the fact that the explosion affects the whole body of the subject, which leads to high lethality of animals due to pulmonary barotrauma and this prevents further trace, in particular, reactive changes in the central nervous system in different terms of the post-traumatic period. The limitations, which also significantly hinder the widespread use of this method, are that explosives are used during the experiment, requiring special equipment for researchers and special permits of the relevant services [8; 9].

The second way of a shock wave generating is the diaphragm destruction. Function of this diaphragm is separation the gas or air mixture with high pressure from the biological object. This method allows to eliminate the remaining shortcomings by changing the methodology of simulation the model state by destroying the diaphragm in a special device with a high pressure gas or air mixture and local impact on the corresponding part of the body. The absence of these disadvantages in the method has many supporters among researchers of the impact of an explosive or shock wave on biological objects. Nevertheless, to use of explosive substances in laboratory shock tube is not only expensive, but also dangerous for the investigators [10; 11].

Shock tubes, regardless of design, can be horizontally or vertically oriented, with an open or closed muzzle. With a closed end shock tubes were used to study the thermodynamic characteristics of the blast wave. At the same time, the shock tube with an open end has a wider range of characteristics to study the air shock wave in the experiment [10].

We reckon the most successful is an experimental device which consists the impressive factors of the explosion and means of experimental animals placing in the zone of the impressive factors influence of the explosion [11; 12; 13]. The device for simulating the pathogenic factors of an explosion includes a shock tube, which consists of a high- and low-pressure chamber separated by a destructive diaphragm. Means of animals placing in the zone of the impact factors action include a grid cell, which is located in a low-pressure chamber. The placement of animals inside the device (in a low-pressure chamber) prevents obtaining a model state (local impact of an air shock wave on the corresponding part of the body, dynamic changes in the formation of the parameters of the air shock wave, the speed of the impact), which makes it impossible to further study the influence of the air shock wave in dynamics, because a shock wave acts on the experimental animal in general, on the whole body, affecting all organs and systems of causes. Considering the above-mentioned disadvantages, placing animals outside the shock tube is the most suitable method for studying, for example, the mechanism of development of primary damage to a specific organ, in particular the brain, and can be taken as the standard position of a biological object in the study of blast wave action [14; 15]. Using the results of the analysis, we modified and proposed a device for experimental simulation of blast-induced brain trauma, which solves the following tasks: the possibility of regulating the excess output pressure in wide areas, high speed of the experiment conducting, safety during the experiment, conducting the research in laboratory conditions without any additional restrictions, the possibility of local action of the formation factor, reduction of animal mortality rate. The expected technical result is achieved by modernizing the design by installing an electromagnetic valve between the two chambers, pumping the air mixture to the specified pressure using a compressor for 10 seconds, creating the corresponding excess pressure by breaking the rubber diaphragm fixed to the muzzle of the output chamber from the direction of the compressed air mixture on an animal, the use of a standard electrical network to power the solenoid valve and the compressor with the corresponding overall dimensions of the shock tube [16].

Conclusion. Thus, the distinctive features of the proposed method of experimental simulation of a blast-induced injury (an electromagnetic valve built into the model body, fixation of a destructive membrane on the muzzle of the exhaust cylinder, an external device for the fixing of animals), in combination with the general features of previous models provide the possibility of modeling an air shock wave and studying the results of its local action in dynamics without damaging of other organs.

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