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APPLICATION OF ARTIFICIAL INTELLIGENCE IN CIVIL AND MILITARY MEDICINE

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Abstract.

Artificial intelligence (AI) encompasses the advancement of computers and robots, enabling them to surpass human capabilities in various aspects. By utilizing AI, programs have the ability to autonomously analyze and interpret data, offering information and executing actions without any human involvement. The ongoing war in Ukraine showed various aspects of severe gunshot injuries because of previously unknown course of wounds after application of ballistic missiles, drones, etc., which is frequently applied by Russians. In such conditions, decision-making process by military medical doctors must be quick and rational; however in case of massive casualties, combined trauma (e.g. thoracoabdominal gunshot injury) MDs might have permanent challenges to apply appropriate care options and individualized approach. The aim of this study is to start the discussion about role and possible application of AI in management of gunshot injuries in combat patients or other individuals who received wounds relating to high-energy weapon. Conclusions. Gunshot wound is a clinical challenge in many cases among patients who were injured by high-energy weapons, requiring complex and quick decisions. AI might be applied as an additional tool for the decision-making process in case of severe trauma in deployed field hospitals, or in hospitals of higher Roles (3-4). This study is to start the research discussion about the utility of AI application for the management of the injured in the war associated with high-energy weapons.

Key words. Artificial intelligence, severe trauma, injuries, high-energy weapons.

Introduction.

Artificial intelligence (AI) encompasses the advancement of computers and robots, enabling them to surpass human capabilities in various aspects [1]. By utilizing AI, programs have the ability to autonomously analyze and interpret data, offering information and executing actions without any human involvement. Presently, there are techniques such as natural language processing and computer vision that facilitate task automation, expedite decision-making, and enable customer interaction through chatbots, presenting opportunities for enhanced communication. There are two approaches to automatic data sorting: AI and machine learning (ML). The consideration for application of AI for medical purposes is ongoing according to published reports. The AI is considered as an effective and promising tool in various fields of medicine including high medical education and routine clinical setting to help students and then medical doctors in data analyses and support decision for management of the patients [2,3]. Other possible applications for AI might be considered for the management of severe trauma, including injuries by high-energy weapon [2,4]. The ongoing war in Ukraine showed various aspects of severe gunshot injuries because of previously unknown course of wounds after application of ballistic missiles, drones, etc., which is frequently applied by Russians [5-14]. In such conditions, decision-making process by military medical doctors must be quick and rational, however in case of massive casualties, combined trauma (e.g. thoracoabdominal gunshot injury) MDs might have permanent challenges to apply appropriate care options and individualized approach. Another issue to be considered is pathologic changes in the human tissues within the area of gunshot wound and its canal as well as consequences to the patients outcomes.

The overall presentation of Artificial intelligence.

There are two approaches to automatic data sorting: artificial intelligence AI and ML. Both of these methods can be very effective in identifying relationships between available information for data classification. Although artificial intelligence and machine learning are often used interchangeably, machine learning is actually a subset of the broader category of artificial intelligence [1].

Machine learning, for its part, is a means of achieving artificial intelligence. Within the realm of artificial intelligence, machine learning employs algorithms to autonomously learn and detect patterns within a dataset, subsequently utilizing this acquired knowledge to make progressively precise decisions [1]. Deep learning, an advanced form of machine learning, takes this concept a step further. Deep learning models employ expansive neural networks that mimic the workings of the human brain to analyze intricate patterns and generate predictions autonomously, without relying solely on the input data [15]. The field of machine learning can be categorized into two primary divisions: supervised learning and unsupervised learning. In supervised learning, human experts assign labels to the data, designating them as either significant or insignificant, which is then used as input for an algorithm that constructs a model to categorize the data into distinct classes. Conversely, unsupervised learning eliminates the need for manual labeling or training data. Instead, the algorithm autonomously groups similar data together and classifies them based on the consistency within each class and
the distinctiveness between classes [16]. In order to achieve the primary goal, namely, the classification of large and complex data with great accuracy and the creation of a database for further use, it is appropriate to apply machine learning. If one considers the algorithms that can be used in the development of machine learning the following aspects might be seen: the k-nearest neighbor (k-NN) technique involves analyzing the Euclidean distance between data samples to determine classes for new data items. This allows easy classification of a new element based on its proximity to previously classified data elements [16]. The k-NN technique is an attractive choice for data classification because it can quickly learn and discover relationships between new and previously known information [16]. Currently, experts are investigating the application of k-NN for real-time data sorting [17]. This method has been used successfully to detect sorting data and is most effective when the data can be represented by a model that allows us to measure its distance to other data, such as a distribution or a Gaussian vector.

But in order to achieve truly precise and highly accurate data analysis, deep machine learning, also known as Deep Learning, is the ideal approach. Deep Learning is a specialized field within machine learning that mimics the learning process of humans by leveraging vast quantities of data. Within a “deep learning algorithm” or “deep neural network”, numerous intermediate layers exist between the input and output data, enhancing the complexity and sophistication of the analysis.

Artificial Neural Networks (ANNs) is a deep learning computing technology inspired by the functioning of neurons in the human brain that transmit and interpret information [18]. In ANNs, a neuron is represented as a mathematical formula that receives input data and produces a target output value that is then passed to the next neuron based on its value. The ANN algorithm continues to iterate until the output value is close enough to the target value that the neurons can learn and calibrate their weights by evaluating the discrepancy between the expected and previous output value. After completing this process, the algorithm provides a mathematical formula that generates a value that can be used to classify and sort the data [16]. A key advantage of artificial neural networks is their ability to adapt their mathematical models based on new data, unlike other mathematical models that may become outdated as new studies appear [16].

It is also necessary to understand that the construction of a database for artificial intelligence, especially for processing medical data on injuries, requires significant efforts due to their specificity, both visual and research. In such cases, using off-the-shelf AIs such as GPT chat may not be appropriate as they may not have sufficient expertise or skills to work with such data [19]. Therefore, it is important to consider the use of specialized models, developed taking into account the needs and characteristics of the medical field, having the appropriate experience and training to work with such data. Artificial intelligence obtained through the above methods will be specialized for medical use, focusing on treatment. It will be characterized by high accuracy, as it is based on machine learning and in particular deep learning technologies [19]. The final result of the examination of this artificial intelligence will be independent of human influence, which will ensure objectivity and reliability in the decision-making process.

The aim of this study is to start the discussion about the role and possible application of AI in management of gunshot injuries in combat patients or other individuals who received wounds relating to high-energy weapon.

Materials and methods.

We used the PubMed and Google Scholar search engine electronic database of publications, searching for abstracts using the following key words: artificial intelligence and wounds, artificial intelligence and gunshot wounds management, artificial intelligence, and healthcare. Based on the results of this search, 4,753 articles were identified and analyzed, followed by selection of the most important and appropriate to the scope of this research publications that meet modern scientific and practical standards as well as the current need for the AI application for medical purposes. The exact criteria for the selecting literature were relation to the gunshot injury or gunshot-related injury as well as trauma related to the combat casualties.

Current applications of AI for gunshot wounds.

Nederpelt et al. demonstrated application of artificial intelligence triage (information aware Dirichlet deep neural network) for prediction of shock and showed its utility for overall bleeding control procedures as well as in cases of massive blood transfusion in case of gunshot wounds. In this study, AI used various data about the anatomy locations and clinical data to predict shock course. By using AI, Nederpelt et al. developed a probability model to be used for prediction of shock [20]. Cheng et al performed research aimed to evaluate various specific features of entrance and exit gunshot wounds, which is frequently problematic for forensic doctors. This study used AI, evaluating clinical data from the forensic cohort, and resulted in identification specific protocol for the defining of entrance and exit holes. According to presented data, AI demonstrated utility for the correct classification of the abovementioned gunshot hole features (imprints, peripheral tears, stippling, bone beveling, border irregularity) and reported it as an image. The study is another evidence of excellent application of AI for medical purposes [21]. Other good example of AI application for the healthcare task is shown by Barakat-Johnson et al. This study evaluated patients with gunshot wounds in terms of the improvement of emergency care by using virtual medical aid. The AI was applied as a tool for remote patient monitoring, aiming to reduce patient transportation time to other levels of medical care in case of the worsening patient’s condition [22]. In line with others, Alser et al. developed a model with using of AI for prediction of patients with chest gunshot wounds as well as outcomes of their treatment. The study demonstrated the high utility of AI to solve mentioned tasks with a high accuracy, showing good results for the fast mobilization of appropriate resources as well as the improving of timing for doctors’ decisions. Overall, the results from this study showed significantly better outcomes for those patients who were managed with using such additional
It is also worth mentioning the study by Lee et al., who suggested to apply AI to create the model for prediction mortality in the Department of Emergency in order to identify high risk cases and reduce the mortality rate. The authors performed research on large nationwide data sets, resulting in a model and minimizing overfitting. We anticipate that our AI-based risk calculator tool will substantially aid health care providers, particularly regarding triage and early diagnosis for trauma patients [23]. The role of AI was also shown by Rippon et al. in their study of wound care. The study reported application of AI for assessment of acute and hard-to-heal wounds and possible role of AI for decisions in management of the patients with such clinical problems. It was shown that AI might be applied for the optimization of the protocols for wound care specifically in hard-to-heal wounds, which is in line with our hypothesis of possible AI application for the patients with gunshot wounds received due to high-energy weapon injury [24]. The further development of AI is also related to mobile application, considering their quick response in case of rapid clinical need. For example, Han et al. reported study of mobile application of AI for the critical patients in the intensive care unit with fractures in order to create a prediction for the early mortality among these individuals. The results from this study supported the conclusion of the utility of AI model (with the eXGBM algorithm), showing high performance in critical patients, allowing to predict 30 days mortality [25]. Still, the analyses of the published data lacking the information about the application of AI for the better understanding of wound healing process as well as understanding of wound healing process, and the possible features of the molecular stress and temporary and permanent cavity impacts on the healing process in the patients who received gunshot injury due to high-energy weapon, including combat patients wounded in the Russo-Ukrainian war.

**The overall challenges in wound management.**

Despite all the modern developments and research in the field of studying wounds caused by high-energy weapons, there is currently no comprehensive view of the entire set of consequences of wounds, not only from shrapnel wounds, but even from bullet wounds. According to published reports, the consequences of gunshot wounds were well described, in view of the changes in cell membranes in the area of the wound channel and the temporary pulsating cavity, as well as features of the microbial flora [14,26,27]. The basic research studies also showed ballistic features of gunshot wounds, including mathematical modeling of wounds in relation to the different types of bullets (explosive, ordinary) on animal models and ballistic plasticine or gel [11,14,28-30]. There are also multiple original publications, case reports, and patient series regarding the course of the wound process in various cases. However, the data often disagree with each other, sometimes having a paradoxical character, which ultimately led to the absence of a single effective protocol for the management of patients with severe gunshot wound based on the proven effectiveness of its use. The criterion of such a protocol should be reduction of patient’s’ disability time, shortening of treatment duration, and return to service. Also, in addition to the specified criteria, we did not find reliable morphological criteria for tissue damage when exposed to high-energy weapons, which can be relied on for analysis and prognosis. The role of microcirculation disturbance in the zones of the wound channel is not defined: the zone of primary necrosis, the zone of molecular shock, necrobiosis fields (areas of primary and secondary necrosis) [4,26,31,32]. According to the treatment criteria (classical non-inflammation wounds), both acute and chronic (diabetic foot syndrome) wounds are associated with the microcirculation disorders, playing a significant prognostic role in the healing process. It is possible to consider and compare wounds in the case of a diabetic foot, demonstrating changes of microcirculation that might be detected by determining the level of transcutaneous oxygen TcPO2, which also might be considered for penetrating gunshot wounds. Therefore, the existing zone of detection of non-viable tissues during tissue primary debridement and subsequent conservative treatment is excluded based on the experience and worldview of the doctor, which cannot give the predicted permanent effect. Due to the narrow specialization of medical doctors, there is often no exchange of modern methods of diagnosis and treatment, which are used in different fields of medicine. Therefore, the most productive method is the synthesis and summation of the experience of specialists from various fields who are experts in narrow fields that may not be directly related to wound treatment (geneticists, biochemists, biologists, etc.). The problem exists for tissue microcirculation detection and evaluation, and various methods have been suggested. One of these is related to the application of indocyanine green (ICG), which is a contrast fluorophore agent to detect areas of microcirculation disturbance in damaged tissue, and the correlation of these data to the histological study of these tissues over time of follow up. Determination of the ICG signal in the near-infrared area is known as fluorescence-guided surgery, especially for the endocrine surgeons during operations on the thyroid gland to identify and preserve the parathyroid glands as well as to detect their recurrent laryngeal nerve and other peripheral nerves using the ICG fluorophore angiography [33-37]. Oncologists and endocrinologists dealing with thyroid cancer use fluorescence-guided surgery method to determine the localization of metastatic lymph nodes and perform minimally traumatic surgery for breast cancer, a similar method is used in laparoscopic operations to determine the extent of metastatic damage to the peritoneum and pelvic organs in malignant gynecologic neoplasms and bowel formations. However, the use of such a technique is limited on the one hand by the technical parameters of spectrometers that are presented on the market of Ukraine, and on the other hand by unmotivated high prices from distributors, which often exceed similar prices, as well as bad planning in the healthcare sector [38]. The fluorescence-guided surgery with and without ICG application might be used for the prediction of the perfusion of the tissues and to be used as a possible tool for the evaluation of wound healing process, which is different for the gunshot wounds. The inclusion of fluorescence-guided surgery to the AI algorithms for the valuation of the gunshot combat injury might be considered in future studies. Therefore, at the final stage is the development and implementation of a new multispectral device that would
be effective in evaluating the ICG-induced signal in various tissues, and at various depths of biological tissues, including those after exposure to the high-energy weapon. Evaluation of the existing spectral analogues for detecting ICG signal showed that such devices are associated with narrow "specialization" and applicable only on certain biological tissues. The preliminary results of the application of the ICG angiography for tissue evaluation to inspire optimism and help to expand and supplement previously studied data on the course of the wound process that were obtained earlier. But given the vastness of the unrelated signals, there is no cause-and-effect relationship, and there are areas of gaps at both the basic and clinical research levels for the ICG application for evaluation of the gunshot wounds. It is also worth mentioning, that translational studies (a combination of basic research and clinical experiments in one study) also lack a systematic relationship with long-term outcomes of treatment of gunshot wounds. Therefore, a multidisciplinary research group turned to the experience of applying AI in this field. According to peer-reviewed literary sources, the absolute majority are based on an AI system such as ChatGPT and are descriptive in nature, without taking into account the interaction of numerous unrelated factors.

Conclusion.

Gunshot wounds are clinical challenge in many cases among patients who were injured by high-energy weapons, requiring complex and quick decisions. AI might be applied as an additional tool for the decision-making process in case of severe trauma in deployed field hospitals, or in hospitals of higher Roles. This study is to start the research discussion about the utility of AI application for the management of the injured in the war associated with high-energy weapon as well as for the application in the basic, translational, and clinical studies of the gunshot injury.

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