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Application of Electrical Engineering in Ukrainian Military Medicine in the First Decade of the Russian-Ukrainian War (2014–2024). Selected Cases

Abstract

Historical experience demonstrates that periods of conflict often stimulate significant advancements in various fields of science and technology. The ongoing Russian-Ukrainian War is no exception.

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Drawing upon open sources, the authors of the article trace the development and implementation of Ukrainian and foreign equipment in military medicine within the Ukrainian Defence Forces during the first decade of this war. The article evaluates and summarizes the initial experience of their battlefield application, analyzes challenges encountered by equipment developers and military personnel in implementing scientific and technical advancements, and proposes ways to address these issues. The primary focus is on developments related to electrical engineering.

Specifically, the article highlights the equipment in medical electrical engineering and telemedicine screening, the creation of mobile hospitals equipped with modern electrical devices, and various models of evacuation drones and electric stretchers operating on principles of automation and telemechanics, including robotic systems for medical evacuation. Examples of new organisational forms for conducting research and implementing promising projects related to the scientific synthesis of the medical science experience and practice in wartime are given. This underscores the significant and diverse contributions of Ukrainian scientists, engineers, technicians, entrepreneurs, investors, and military personnel.

The authors conclude that the development of electrical engineering for military medicine in Ukraine holds international significance. This is particularly relevant given the increasing number of 'hot spots' globally. Electrical engineering for the needs of war is developing dynamically and very rapidly. Ukrainian developments provide a powerful impetus to this process. Based on the experience of the ongoing Russian-Ukrainian War, several areas of electrical engineering in Ukrainian military medicine are poised to make a significant impact on the history of science and technology. This includes remote diagnostics based on telemedicine, robotic systems for evacuating the wounded (evacuation drones), and mobile hospitals equipped with advanced electrical equipment. Ukrainian medical electrical engineering, stimulated by the ongoing war, offers an invaluable impetus to the development of both the theory and practice of civilian medicine.

Keywords: *automation, automatic devices, electrical measuring devices, electrical engineering, electrical equipment, history of science and technology, methods of electrical measurements, computer technology, military medicine, telemechanics*

Zastosowanie inżynierii elektrycznej w ukraińskiej medycynie wojskowej w pierwszej dekadzie wojny rosyjsko-ukraińskiej (2014–2024). Wybrane przypadki

Abstrakt

Doświadczenia historyczne pokazują, że okresy konfliktów często stymulują znaczące postępy w różnych dziedzinach nauki i technologii. Trwająca wojna rosyjsko-ukraińska nie jest wyjątkiem. Opierając się na otwartych źródłach, autorzy artykułu prześledzili rozwój i wdrożenie ukraińskiego i zagranicznego sprzętu w medycynie wojskowej w ukraińskich siłach obronnych w pierwszej dekadzie tej wojny. Artykuł ocenia i podsumowuje początkowe doświadczenia z ich zastosowaniem na polu walki, analizuje wyzwania napotkane przez twórców sprzętu i personel wojskowy we wdrażaniu udoskonaleń naukowych i technicznych oraz proponuje sposoby rozwiązania tych problemów. Główny nacisk położono na rozwój związany z inżynierią elektryczną.

W artykule zwrócono szczególną uwagę na urządzenia w inżynierii medycznej i telemedycynie, tworzenie mobilnych szpitali, wyposażonych w nowoczesne urządzenia elektryczne, oraz różne modele dronów ewakuacyjnych i noszy elektrycznych, działających w oparciu o zasady automatyki i telemechaniki, w tym robotyczne systemy ewakuacji medycznej. Podano przykłady nowych form organizacyjnych prowadzenia badań i wdrażania dobrze rokujących projektów związanych z naukową syntezą doświadczeń i praktyki medycznej w czasie wojny. Wszystko to wskazuje na znaczący i różnorodny wkład ukraińskich naukowców, inżynierów, techników, przedsiębiorców, inwestorów i personelu wojskowego.

Autorzy dochodzą do wniosku, że rozwój inżynierii elektrycznej dla potrzeb medycyny wojskowej na Ukrainie ma znaczenie międzynarodowe. Jest to szczególnie istotne, biorąc pod uwagę rosnącą liczbę „punktów zapalnych" na świecie. Inżynieria elektryczna na potrzeby wojny rozwija się dynamicznie i bardzo szybko. Ukraińskie osiągnięcia stanowią silny impuls dla tego procesu. Bazując na doświadczeniach trwającej wojny rosyjsko-ukraińskiej, kilka obszarów inżynierii elektrycznej w ukraińskiej medycynie wojskowej

ma szansę wywrzeć znaczący wpływ na historię nauki i technologii. Chodzi o zdalną diagnostykę opartą na telemedycynie, zrobotyzowane systemy ewakuacji rannych (drony ewakuacyjne) czy mobilne szpitale wyposażone w zaawansowany sprzęt elektryczny. Ukraińska inżynieria medyczna, stymulowana trwającą wojną, stanowi nieoceniony impuls do rozwoju zarówno teorii, jak i praktyki medycyny cywilnej.

Słowa kluczowe: *automatyka, urządzenia automatyczne, elektryczne urządzenia pomiarowe, elektrotechnika, urządzenia elektryczne, historia nauki i techniki, metody pomiarów elektrycznych, technika komputerowa, medycyna wojskowa, telemechanika*

1. Introduction

Global processes demonstrate that periods of turmoil and upheaval often catalyze some of the most significant leaps forward in the development of various areas of science and technology. War, similar to epidemics or natural disasters, acts as a powerful catalyst for inventions and rationalizations. By mobilizing all forces, humanity invents, tests, and implements innovations. Interdisciplinary inventions at the intersection of medicine and electrical engineering have proven particularly fruitful for military practice. This interdisciplinary approach enables a fresh perspective on contemporary demands and needs, facilitating the creation of fundamentally new products in electrical engineering, automation, telemechanics, and medicine. What were cutting-edge inventions yesterday have rapidly become significant milestones in the history of science and technology today. The ongoing Russian-Ukrainian war is no exception in this regard.

In the present study, the authors aim to evaluate and summarize the experience of military medical equipment within the context of interdisciplinary scientific research related to electrical engineering over the past decade, during which the Russian-Ukrainian war has been ongoing in Ukraine. By such equipment, the authors refer to scientific and technical developments for pre-hospital medical care, aimed at eliminating preventable causes of death. These developments are based on principles that account for the threats posed by hostilities, mainly on the battlefield. The authors do not aim to analyse and evaluate them from a technical point of view, as they are not technical specialists. The study focuses on the process of inventions' development and implementation, and summarise it in this publication. Historical and medical approach allows us to explore this

topic and demonstrate the significant and diverse work of Ukrainian scientists, engineers, technicians, entrepreneurs, and military personnel, etc. The systematisation and generalisation of the process of introducing electrical engineering developments was carried out by the authors under challenging conditions of constant enemy fire. While this inevitably influenced the study, it is hoped that it did not impede the achievement of its goal.

The methodological approaches are based on the interdisciplinary nature of the study and the use of new vectors. Traditionally, the authors utilized general scientific methods of analysis and synthesis, induction, and deduction, which enabled the collection and qualitative processing of available data. The historical method was applied to consider the subject of research across all its stages – from the creation of electrical engineering equipment to its implementation in medical practice. The classification method enabled the identification of electrical inventions developed for various stages of medical care for the wounded. The researchers also employed specific scientific methods. The chronological method was used for presenting events. The synchronous method allowed for considering the introduced developments not only as a purely medical process but also within the context of social and political changes in Ukrainian society. The comparative historical and retrospective methods were useful in comparing the level of electrical invention implementation at the initial stage of the war and after the full-scale invasion. The historical-systemic method with decomposition allowed for distinguishing electrical developments from the broader range of new introductions and conducting their structural analysis. Among the related methods employed were quantitative approaches, including statistical method, mathematical analysis, and sociological research. The research is based primarily on the use of specific historical methodology, which allows to study the process of development and implementation of inventions from the perspective of historical and medical knowledge. Methods inherent in purely technical sciences were not used for the reasons. Firstly, the authors are professional historians and do not have the appropriate expertise to use them. Secondly, the purpose of the article is to study the process of applying military medical developments in the Russian-Ukrainian war, not to evaluate them technically. The applied methodological apparatus completely allows conducting the research and obtaining the results presented in the publication.

The study used available open sources, including the official website of the Ministry of Defence of Ukraine, regulatory acts and guiding state

documents on the organisation of medical support for the Armed Forces of Ukraine, materials from scientific institutions, patents, materials from the official websites of NGOs and charitable foundations, thereby providing valuable scientific information on the topic.

2. Medical developments during Russian-Ukrainian war

The introduction of new developments has consistently been of interest to the Ukrainian public, medical professionals, and researchers in various fields. This topic gained particular relevance with the commencement of the Anti-Terrorist Operation / Joint Forces Operation (ATO/JFO), when wartime inventions began to be reported in newspapers, scientific journals, and online publications. To prepare the article, the authors utilized available Internet resources, articles from scientific journals, university bulletins, collections of scientific papers of the Ukrainian Military Medical Academy, encyclopaedic editions, scientific and educational works and textbooks, etc.

The Russian-Ukrainian war, which commenced in 2014, and the aggressor's full-scale invasion in 2022 have posed a series of complex but extremely important tasks for Ukrainian society, foremost among them the development of military medical equipment to provide battlefield assistance. Indeed, in the early years of the war, when it was localised, the numbers of human losses were already alarming. Thus, between 14.04.2014 and 31.12.2019, the number of victims reached approximately 41–44 thousand people, including 13–13.2 thousand killed and 29–31 thousand wounded.[1]

As a key factor for the future of the national economy, Ukraine's research and innovation sector faced significant challenges during those years and continues to do so. These challenges stem from inadequate funding, corruption, outflow of qualified personnel, high risk, insufficient public attention to this area and other factors, the most serious of which is the Russian military aggression against Ukraine. One of the key indicators of the state's innovation policy effectiveness is its place in global rankings. Ukraine is represented in numerous international rankings that assess its innovation potential, innovation capacity, and the effectiveness

[1] N.N. 2020.

of its innovation policy. Specifically, the following rankings offer a comprehensive description:

- The Global Innovation Index – GII;
- The Global Sustainable Competitiveness Index – GSCI;
- The Global Talent Competitiveness Index – GTCI;
- The Summary Innovation Index – SII;
- The Human Development Index – HDI.

The dynamics of Ukraine's ratings according to the four most popular approaches to assessing innovation capacity in 2015–2022 – GII, GSCI, GTCI, and SII – demonstrates that the country ranks rather low, although in recent years there has been a tendency to improve some positions.[2]

Following the initiation of the anti-terrorist operation in eastern Ukraine, an audit of departmental medical services was conducted, revealing significant problems of both a purely medical and technical nature. In particular, military personnel lacked personal medical protection equipment, and existing equipment was not properly utilised. Military units lacked armoured vehicles for transporting the wounded from the battlefield. Medical equipment, numerous automatic devices, and electrical equipment were outdated and technologically insufficient, and medical teams lacked adequate life support means. Simultaneously, even medical personnel were unaware of the specific characteristics of combat pathologies, employed incorrect treatment tactics, and faced diagnostic challenges, which subsequently complicated matters for rear specialists and led to patient complications.[3] The situation regarding the procurement of medical equipment in accordance with international protocols also warrants attention. Since old ineffective equipment with an unlimited shelf life was still stored in warehouses, its decommissioning was not possible, thus hindering the procurement of new, advanced electrical equipment.

In alignment with the doctrine, and based on the Law of Ukraine "On Scientific and Scientific-Technical Activities," a freelance department of military medical science was established at the National Academy of Medical Sciences of Ukraine by Resolution No. 8/3 of November 22, 2018, titled "On the Establishment of a Freelance Department of Military Medical Science at the Presidium of the National Academy of Medical Sciences of Ukraine." It was headed by Major General of the Medical Service, Ihor

[2] Pisarenko et al. 2023, p. 7.
[3] Žahovskiy, Lìvìnskiy 2015.

Lurin. The department's purpose is to create conditions for organizing and coordinating joint scientific activities and implementing collaborative projects related to the scientific generalization of medical science and practice experience during the ATO/JFO at the national level. The department's tasks include:

- coordinating scientific research in the medical field aimed at improving national security and defence capabilities of the state;
- coordinating relations pertaining to the implementation of collaborative research projects;
- developing proposals for long-term planning of scientific activities;
- accounting, analysis and control over the implementation of research and development;
- coordinating international cooperation with NATO member states in military medical science, particularly with the NATO Science and Technology Organisation – Human Factors in Medicine (HFM).[4]

Thus, supporting medical inventions, particularly those implemented by domestic scientists, has gained paramount legislative importance. Medical developments in military medicine were anticipated by all, especially by those directly exposed to various combat injuries – medical professionals and their patients across different areas, both on the battlefield and in the rear.

A powerful activity has been launched at all levels, including higher education institutions and research institutes, etc. It is also noteworthy that the shared adversity has spurred societal self-organisation. This includes the sphere of medical developments. In 2020, in Lutsk, Ukraine, the non-governmental organization, the Centre for Medical Innovation Technology Park, was established to serve as a creative space for medical institutions, authorities, business representatives, and investors.[5] The organisation's main goal is to support promising technological start-ups by talented scientists.

Medical developments can be examined using various approaches and classifications. Specifically, scientists distinguish military surgery, dentistry, and military pharmacy as separate areas. Wartime psychiatry is considered independently. One approach to classification is by type of medical care: organisational, sanitary and hygienic, therapeutic and preventive,

[4] AMSU 2019.
[5] Technopark 2024.

anti-epidemic, etc. Numerous classifications of medical care types based on various criteria complicate the analysis of medical developments and impede their systematic evaluation. The authors chose to focus on inventions in electrical engineering applicable at the first (pre-hospital) of the four levels of medical care. The second, third, and fourth levels are considered promising areas for further research.[6]

At the first level, it should be noted that the purpose of medical personnel in this segment is to provide emergency medical care and treatment to patients for up to 2 days, as well as care for the wounded on the battlefield or in a war zone. Effective medical care on the battlefield is achieved through a high level of theoretical and practical training for medical personnel.[7] The rapid initiation of pre-hospital care in combat is identified as a key factor that significantly increases the chances of survival and functional recovery for the wounded. That is why the concept of the 'golden hour' exists – the critical first hour after an injury during which qualified medical care should be initiated.

3. Medical electrical engineering and telemedicine screening

Domestic medical electrical equipment is now actively used for civilian needs as well as possesses strong potential for military medical treatment. Automatic devices are increasingly replacing manual instruments. Electrical blood pressure measuring equipment, which is much more convenient for emergency use, is not the only example. Numerous other examples exist.

A notable Ukrainian device is a low-frequency electrotherapy apparatus developed and improved through new methods by Radmir with the participation and scientific support of the National Technical University "Kharkiv Polytechnic Institute" (NTU "KhPI").[8] The constant electric current of low strength used in galvanization technique has a positive effect on the human body, exhibiting anti-inflammatory, lymphatic drainage, hypoallergenic, and sedative effects. An additional feature of this electrical equipment is the ability to change the polarity of the electrodes

[6] Strafun et al. 2021; Ostapenko, Kornìlova, Samčuk (eds.) 2021, pp. 18, 21.
[7] Gur'êv, Škatula, Pechyborshch 2017, p. 42.
[8] Kìpenskiy et al. 2019; Kipenskiy, Kulichenko, Babkova 2023.

from the control panel. The device generates seven types of currents and can be utilised for diadynamicphoresis, amplipulse therapy, fluctuorisation, and short-pulse electro analgesia. The introduction of new electrical equipment enables significant improvements in human health, accelerating recovery and rehabilitation.

Odesa and Kharkiv scientists have provided a new impetus to ozone therapy and LED therapy. Today, medicine actively utilises the method of intravenous administration of ozone saline, which exhibits immunomodulatory, anti-inflammatory, bactericidal, fungicidal, and analgesic effects. The BOZON-MOF apparatus, a portable modernised module, demonstrates normalisation of the body's oxidant and antioxidant system parameters after patient use.[9] LED therapy also received a boost in Kharkiv with the development of advanced laser devices possessing innovative characteristics at the Research and Production Medical and Biological Corporation «Laser and Health» of V.N. Karazin Kharkiv National University.[10] Electrical engineering can be applied in various fields of medicine, including phthisiology, treatment of viral infections, gynecology, dermatology, dentistry, pulmonology, and cardiology. However, from our perspective, particularly noteworthy is the potential for utilising laser power to irradiate sutures, suture material, and implants in traumatology, orthopedics, and sanatorium treatment, which is especially crucial for military personnel.

The issue of early diagnosis is crucial across all areas of medicine. It is well known that treatment speed and quality are dependent on it. In the context of military operations, where access to experienced physicians and specialised consultants is challenging, remote technologies, including telemedicine, can provide significant assistance. Scientists from the National Technical University "Kharkiv Polytechnic Institute" (NTU "KhPI"), namely Y.I. Sokol (Doctor of Technical Sciences), A.V. Kipensky (Doctor of Technical Sciences), M.A. Shyshkin (Candidate of Technical Sciences), and K.K. Kolisnyk (Candidate of Technical Sciences), have explored possibilities for improving mobile telemedicine systems.[11] They proposed a new method of electrical measurements utilising the GSM/GPRS radio channel to collect patient information – including blood pressure, body temperature, saturation level, and automated ECG data – with the introduction

[9] Gluhen'kaâ, Kipenskiy, Nazarov, Korol' 2017.
[10] Kipenskiy (ed.) 2024, p. 31.
[11] Kolesnik, Šiškin, Kipenskiy, Sokol 2014.

of a modified averaging algorithm based on a differentiated approach to various parts of the biological signal. This enables effective filtering at the initial stage of preparation for transmission.

The study of telemedicine issues underwent a qualitative shift in 2020, when the whole world was engulfed by the SARS epidemic caused by a new type of COVID-19 virus. The laboratory of biomedical electronics at NTU "KhPI", founded in 1998, has become a significant base for studying its certain aspects.[12] For Ukraine, COVID-19 resulted not only in morbidity and mortality among the civilian population but also in losses among military personnel. For obvious reasons, the course of corona virus infection was exacerbated: combat conditions hindered timely patient isolation, led to medicine shortages, and resulted in diagnostic errors due to outdated or absent electrical equipment – all significantly complicating the situation. Ukrainian scientists Y. Sokol, K. Kolisnyk, S. Lapta, S. Koval, and O. Avrunin noted that in addressing such problems, the capabilities of telemedicine systems (telemedicine screening, telediagnosis, and telemonitoring) should be used as widely as possible,[13] because it is impossible to conduct a complete and high-quality examination in risk areas. The complex for telemedicine diagnostics of epidemics and pandemics should provide rapid and high-quality diagnostics for geographically separated patients from diverse social groups who are in individual or group isolation. A recent example is the situation of servicemen who are isolated within their units having lack the same opportunities as civilians to visit a family doctor, undergo laboratory tests, or monitor their health status effectively.

The complex for telemedicine diagnostics of epidemics and pandemics includes a telecommunications network for collecting, processing, and transmitting biometric digital information and video images, combining various mobile and remote diagnostic tools with a central control point. The central control point of the complex is a specialised medical institution, comprising the necessary medical specialists for analytical research and processing of received biometric information using modern computing technology as well as a central server and relevant databases that allow for the accumulation and systematisation of the information received. It is equipped with the necessary telecommunication facilities

[12] Sokol, Kipenskiy, Korol' 2015, p. 40.
[13] Sokol et al. 2020.

to ensure communication with regional and central authorities, as well as geographically distributed medical institutions directly involved in pandemic response.

4. Mobile hospital

The performance of medical teams on the battlefield is critically important for the correctness and timeliness of medical care. However, even in this context, medics face limitations if they cannot transport patients to the rear as quickly as possible. The time elapsed between the first aid and treatment in a hospital or a military hospital in the rear is equally critical and poses significant risks for a soldier with serious injuries. Consequently, Ukrainian scientists and medical practitioners have undertaken the challenge and provided the Medical Command of the Ukrainian Armed Forces with an unprecedented national development – a twelve-meter Mercedes-Benz bus, which is essentially a mobile hospital equipped with advanced electrical equipment. This medical development operates in close proximity to the combat zone, where aid for wounded soldiers is most urgently required.

The idea to create such a mobile unit originated with Yaroslav Kashuba, the head of the Innovation Fund organisation from Lviv. It was brought to fruition and designed by Vitaliy Bagirov, a Ukrainian by birth who has long resided in Germany but immediately responded to the needs of the Ukrainian army. He studied NATO standards and the needs of the Ukrainian army, subsequently designing what is considered the first such mobile hospital globally.[14]

The modern techniques and electrical equipment within the mobile hospital are impressive, including two surgical chairs, five resuscitation stations for the wounded, seven vital activity monitors, seven perfusers, coalescers, fluid suckers, and ultrasound and ventilator devices. It even includes a dental chair for maxillofacial interventions, and a powerful Wi-Fi hotspot for telemedicine. A team of three doctors and nurses can operate here. The bus motor provides uninterrupted power via an inverter. The cost of this equipment is 150 thousand euro, with each mobile hospital being funded entirely by donations from concerned individuals. The funds were primarily donated by Ukrainians residing in Germany, as well as by

[14] MOD 2022.

Germans themselves. It is anticipated that the state will express interest in this development, leading to the deployment of more such mobile hospitals in the army.

5. Evacuation drones

A mobile hospital represents an excellent development for situations where an injured soldier can be evacuated from the battlefield with the assistance of paramedics or fellow soldiers, or if an individual administers self-aid and then exits the combat zone to a safe location for qualified treatment. However, these are not the only scenarios encountered. If a soldier is left alone and unable to reach a safe location, a new development by Ukrainian engineers – an evacuation drone – can provide assistance. As is often stated, the current war is characterised as a war of drones. However, these telemechanical devices can not only be used to neutralize the enemy but also to save the lives of Ukrainian soldiers.

Ukrainian engineers have developed a special type of ground drone for rescuing such military personnel, which, similar to flying models, is controlled remotely. The initiators of this invention were fighters from the 'Da Vinci Wolves' unit. The device is equipped with cameras for terrain tracking, can carry a weight of two hundred kilograms, and can penetrate one and a half kilometres into the danger zone for a video signal and up to 2.5 kilometres for a remote-control signal. The drone is unique in its silent movement, undetectability in grass, and successful traversal of diverse landscapes thanks to its caterpillar tracks. Batteries serve as the power source for this automated device. The drone operator can observe the surrounding environment via cameras with a 120-degree viewing angle.[15]

Despite its appearance, which might resemble a child's toy or a garage start-up, the device has proven highly effective at the front and is already saving lives. The height of the drone is designed so that even with a limb injury, an individual can self-load onto the platform, which includes special straps for torso stabilisation. The first drone was developed in Kharkiv using Chinese spare parts, but domestic parts are now being utilised. Its use for over six months on the front line demonstrated not only the effectiveness of the automated device but also highlighted the challenge of manufacturing such drones, as thousands are required for frontline operations.

[15] Freedom 2024.

The developers plan to establish mass production, enabling automation in manufacturing to assist those currently assembling the drone manually, thereby transitioning these rescue machines into large-scale production. Indeed, today the drone has become even more powerful and in demand at the frontline. The design was upgraded by volunteers from Rivne region, who carefully studied the operating principle of the first drone, used by the 'Da Vinci Wolves' and created a more powerful automated device – the 'Zhyvchyk' model – for the 10th Separate Mountain Assault Brigade 'Edelweiss'. The payload has been increased to 250 kg, the speed to 10 km/h, and the drone's range to approximately 13 km. The battery capacity has also increased. The development cost is 240,000 UAH, with funds for the drone being raised by volunteer organisations.[16]

In November 2023, engineers in Bucha developed a comparable drone, but this electrical device boasts a range of up to 3.5 kilometers and is driven by six all-wheel-drive wheels. The drone's speed is 20 km per hour, and its capacity is designed to transport a soldier with a full set of ammunition.[17] This automated device has already been deployed to the 'zero line' (battlefront) and saved the lives of Ukrainian soldiers.

The ground drone was designed by the engineer Ruslan Zatorsky, who has upgraded the telemechanical device three times to date. The innovation originated in Poltava, where it was affectionately named 'Wozik' ("a cart" in Ukrainian language). The drone was tested in various terrain and weather conditions. This automated electronic device can be controlled by a drone operator, enabling sustained communication even under difficult conditions of heavy shelling. Twelve of these drones are already operating at the front; some are returned for repair and then redeployed. The developers emphasize that any telemechanical technology that saves the lives of soldiers is extremely necessary and important in the current situation.

Not only professional engineers but also students of Kyiv Polytechnic Institute are involved in the production of evacuation drones. They have been providing assistance since the first day of Russian full-scale invasion, including assembling electric stretchers for evacuation. This represents a new model of electrotechnical equipment for evacuation, featuring the same remote control as a drone, but with a significantly lighter design.

[16] Klimčuk, Gruntkìvs'ka 2024.
[17] Morozova, Proskurov 2024.

The development team was headed by Viktor Pasichnyk, PhD, Professor, and Vice-Rector for Research at Igor Sikorsky Kyiv Polytechnic Institute. The electric stretcher is a mobile automated unit that can be quickly folded and unfolded manually. The electric stretcher can be equipped with tracks depending on the terrain requirements. This design features a load capacity of 120 kg, a range of 5 km, and a comparable speed.[18]

The designer of the electric stretcher is Dmytro Mamonov, an internally displaced person (IDP) from Sloviansk, Donetsk region, who, at the end of 2022, conceived a solution for transporting wounded soldiers from the war zone. He was initially interested in the Estonian-made THeMIS multi-purpose robotic platform (300,000 euros) that Ukraine received, but began working on finding his own telemechanical solution to significantly reduce the design cost, as the frontline requires a large number of such automated devices. After designing the first stretcher at the turn of 2022–2023, he consulted with soldiers and doctors, incorporated their feedback, updated the project, and presented it anew to companies which, unfortunately, showed no interest. Dmytro Mamonov's stretcher cost only 70,000 UAH.[19] Fortunately, representatives of the Igor Sikorsky Kyiv Polytechnic Institute supported the designer's initiative and began assembling this crucial device for soldiers. Today, the developers are planning to improve the design of these electrical devices, and the first electric stretchers are already being deployed to the front.

Numerous instances exist where medical developments were proposed even before the full-scale invasion, but progressive developments did not secure financial support and were not implemented in public healthcare. Despite the challenging circumstances caused by the war, Ukrainian scientists continue to work in the field of electrical engineering, but they critically require support and long-term investment to remain productive. There is no time for delay; it is imperative to accelerate innovative development based on public-private partnerships, introduce grant-based funding for institutions, personalise funding for breakthrough research teams, develop standards, and intensify international partnerships, etc.

Robotic systems for medical evacuation have been tested in Ukraine. On World Emergency Medical Day in May 2024, nine test models from seven Ukrainian manufacturers demonstrated their inventions to draw

[18] NTUU "KPI" 2024.
[19] Čiricâ 2024.

attention to domestic developments in electrical engineering and telemechanics.[20]

> Such equipment is needed at the frontline; it saves the lives of both the wounded and military medics. Our manufacturers are capable of producing quality products, but additional funds are required for their procurement. Therefore, we presented these equipment samples to representatives of partner countries to solicit assistance in procuring these vehicles for the army,

stated Deputy Minister for Strategic Industries Anna Hvozdyar.[21]

Fundraising is also being conducted on Ukrainian platforms. For example, the 'Brave Inventors' charity fund has been established, allowing every inventor to post their innovation to attract donors and receive funds for its implementation or procurement for the frontline. The website of the RoboForce engineering group already features the multifunctional platform 'Gnome', a small self-propelled remote-controlled tracked cart that serves three purposes: logistics, sapper operations and evacuation.[22] The development is ready, waiting for funding.

The issue of production and supply of evacuation drones in 2024 has finally been addressed by officials. Yaroslav Oliynyk, Advisor to the Minister for Strategic Industries, has already tested electrical models and consulted with medical professionals and military personnel.[23] These telemechanic systems have demonstrated excellent tactical and technical characteristics, and if they pass electronic warfare tests, there is hope that such products will be adopted by the country's leading enterprises, given that domestically produced evacuation drones are significantly cheaper than foreign counterparts.

6. Conclusion

Nowadays Ukrainian electrical engineering developments in military medicine have demonstrated their significance and proved their compet-

[20] Mukhin 2024.
[21] *Ibid*.
[22] BraveInventors 2023.
[23] Dedeĭ 2024.

itiveness with global counterparts. They are successfully utilised in both field and rear operations, highlighting that Ukrainian electrical inventions are on par with foreign ones. Now, it is incumbent upon the government to regulate this area at the legislative level and provide financial support.

The development of electrical engineering is of great importance for military medicine not only in terms of the Russian-Ukrainian war, but also in the context of other current events in the world. The relevance of these developments for science and technology will not diminish, as there are many 'hot spots' in the world today and there are real prospects for their increase. Tensions are escalating in the Middle East, in the Chinese-Taiwanese and Korean regions. Electrical engineering for the needs of medical professionals at war is developing dynamically and very rapidly. Every day it is moving towards new discoveries and improvements of existing equipment. Now, based on the experience of the current Russian-Ukrainian war, we can already point out certain areas of electrical engineering for Ukrainian military medicine that will go down in the history of science and technology. This is remote diagnostics, which has not been widely used in risky conditions before.

Telemedicine brings a specialist from the rear to a wounded person in a combat zone. A military medic can get professional advice from a narrow specialist, and the rear doctor can monitor the patient's condition in real time via a GSM/GPRS radio channel, helping with diagnosis and treatment. Robotic systems for evacuating the wounded (evacuation drones), which avoid human intervention in a number of processes, saving the lives of soldiers at the front, and mobile hospitals with wider capabilities than before, have become a powerful step forward. Ukrainian medical electrical engineering, stimulated by the war, is also making an invaluable contribution to the development of peacetime medicine and healthcare. It is changing not only the ways of treatment and diagnosis, but also expanding the possibilities of scientific research and technical development. These developments are setting new standards in healthcare and fostering interdisciplinary fields such as bioengineering and neurotechnology.

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