A MODEL OF DYNAMIC PLANNING OF MEDICAL SUPPORT FOR COMBAT TROOPS. A NEW PERSPECTIVE ON THE REQUIREMENTS AND CAPABILITIES OF THE MEDICAL COMPONENT

Model dynamicznego planowania zabezpieczenia medycznego wojsk walczących. Nowe spojrzenie na wymagania i zdolności komponentu medycznego

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Abstract

Introduction and objective: The experience of the war in Ukraine has shown that success in the field of medical protection of the population can only be ensured by a complete service, tailored to the nature of operational activities, utilizing solutions that allow the use of the latest organizational and technological achievements in healthcare. The aim of the study was to develop a new method for dynamic planning of medical support for combat troops by modeling battlefield medical care processes to increase the effectiveness and efficiency of healthcare system resource management and improve the operational capabilities of combat troops. **Materials and methods:** The modeling of battlefield medical care processes was based on commonly recognized operational factors – force, time, and area, expanding this group with an additional parameter – safety, which is important from the point of view of organizing the work of medical field units. **Results:** A calculation model was developed on the basis of which an analytical tool was compiled that allows for flexible adjustment and combination of the goals and needs of medical care – regulated mainly by the scale and structure of sanitary losses, with progress in the course of the military operation. **Conclusions:** The proposed model for estimating medical needs in the part related to securing military operations is a methodologically advanced and, at the same time, easy-to-use decision-making support tool for planning and organizing medical care. It integrates knowledge on the occurrence and distribution of the key factors determining the conditions and possibilities of providing medical support as well as the needs and expectations resulting from tactical and operational intentions. It optimizes the process of securing battlefield medical resources and reduces the risk of errors in the most sensitive areas that are crucial to the success of a military operation. It also strengthens the healthcare system's resistance to hybrid and military operations by providing key information on the current needs for its organization and functioning in connection with tactical and operational plans and the state's defense strategy. The concentration and coordination of medical resources carried out using the model, both native – assigned to the combat group, and those located in the operational space, creates an environment ensuring high effectiveness and efficiency of the assistance provided.

Streszczenie

Wprowadzenie i cel: Doświadczenia wojny w Ukrainie pokazują, że sukces w dziedzinie zabezpieczenia medycznego ludności może zapewnić jedynie służba kompletna, dopasowana do charakteru działań operacyjnych, korzystająca z rozwiązań pozwalających wykorzystać najnowsze osiągnięcia organizacyjne i technologiczne z obszaru zdrowia oraz opieki. Celem badania było opracowanie nowej metody dynamicznego planowania zabezpieczenia medycznego wojsk walczących poprzez modelowanie procesów opieki medycznej pola walki, służącej zwiększeniu skuteczności i efektywności zarządzania zasobami systemu ochrony zdrowia oraz poprawie zdolności operacyjnych wojsk walczących. **Materiał i metody:** Modelowanie procesów opieki medycznej pola walki oparto na powszechnie uznanych czynnikach operacyjnych – sile, czasie i obszarze, rozszerzając tę grupę o dodatkowy, istotny z punktu widzenia organizacji pracy medycznych jednostek polowych parametr – bezpieczeństwo, przypisując jednocześnie wszystkim zmiennym właściwą, odpowiadającą przedmiotowi zagadnienia charakterystykę i interpretację. **Wyniki:** Opracowano propozycję modelu kalkulacyjnego, na bazie którego skompilowano narzędzie analityczne pozwalające elastycznie dostosowywać oraz łączyć cele i potrzeby opieki medycznej – regulowane skalą i strukturą strat sanitarnych – z postępami w przebiegu operacji wojskowej w części zależnej od jej dynamiki oraz zdolności do prowadzenia manewru. **Wnioski:** Proponowany model szacowania potrzeb medycznych w części dotyczącej zabezpieczenia operacji wojskowych jest zaawansowanym metodycznie i równocześnie łatwym w użyciu narzędziem wspomagania decyzji w zakresie planowania oraz organizacji opieki. Integruje wiedzę na temat występowania oraz rozpowszechnienia najważniejszych czynników określających warunki i możliwości prowadzenia pomocy medycznej oraz potrzeby i oczekiwania wynikające z zamierzeń taktycznych i operacyjnych. Optymalizuje procesy zabezpieczenia medycznego pola walki. Ogranicza ryzyko błędów w najbardziej wrażliwych, kluczowych dla powodzenia operacji wojskowej obszarach. Wzmacnia odporność systemu ochrony

zdrowia na działania hybrydowe i militarne, dostarczając kluczowych informacji dotyczących bieżących potrzeb w zakresie jego organizacji i funkcjonowania w powiązaniu z planami taktycznymi, operacyjnymi oraz strategią obrony państwa. Prowadzona za jego pomocą koncentracja i koordynacja zasobów medycznych, zarówno natywnych, przypisanych do ugrupowania bojowego, jak i znajdujących się w przestrzeni operacyjnej, tworzy środowisko zapewniające wysoką skuteczność i efektywność udzielanej pomocy.

Keywords: operational planning, military health service, armed forces, war in Ukraine

Słowa kluczowe: planowanie operacyjne, wojskowa służba zdrowia, siły zbrojne, wojna w Ukrainie

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Introduction

From the point of view of the tasks related to the need to meet medical needs of armed forces and the obligations to protect and defend population against the consequences of kinetic actions in the course of an armed conflict, the Military Health Service (MHS) enters the stage of implementing an urgent operational need, the most important objective of which is to acquire competence and capacity to provide effective medical care during military actions on home territory.

The implementation of this goal requires a carefully planned and well thought-out consolidation and coordination of the resources generated and accumulated in the MHS system, with additional support derived from the competencies of services and authorities responsible for national security. It also requires the application of solutions that allow the use of the latest organizational and technological achievements in the field of healthcare – their proper selection based on the needs of a modern military operation, concentration and coordination. Finally, it requires novel thinking and acting strategies, with exclusion of elements of the previous strategy of organizing medical delivery for the troops implemented in dispersion, in isolation from the structures that make up the national healthcare system.

The experience of the war in Ukraine has shown that successful securing of medical resources for the population can only be achieved by a complete service, tailored to the nature of operational activities, taking into account the needs and conditions of securing resources arising from the realities imposed by the type, scale and scope of the military operation and, at the same time, rejecting practices based on reproducing the way of thinking about medical needs known from peacetime experience and practice and transferring it directly to the state of war.

Characteristics of modern armed conflict on the example of the war in Ukraine based on war theory

The course of events accompanying the war in Ukraine has shown that modern technologies, their creative adaptation to the needs of war, can disperse military power among millions of people, which means that the scope of military action goes far beyond the physical battlefield and allows citizens, civilian companies and institutions to have their contribution in the fight. This also highlights the blurring of boundaries between the civilian and military domains, and the fact that the entire society should participate in the preparation for combat. Victory may be determined by adaptability, as a highly creative response to environmental changes, innovation, but also by public involvement, i.e. combining available civilian and military technologies to reinforce one's own capabilities.

Military force is made up of people and reflects the society's character and values, therefore, as Clausewitz said [1]: "War is a trial of moral and physical forces through the medium of the latter." Although equipment, doctrine, training, and leadership are crucial attributes of any military force, the essence of its combat power stems from what the nation represents, as well as the short- and long-term resilience of the state structures to the effects of military actions [2]. No less important are also the state's resources, especially the part that the state can and is firmly willing to allocate to the army. Inspired by the German experience of the Great War, Ludendorff [3] wrote: "The army is rooted in the homeland. It lives in the country and draws its strength from it. What it needs, it can only receive, not create – and fight only with what the country lends from its spiritual, material, and physical strengths." The reality of military operation, as experienced by Clausewitz – the success of military endeavor in which both state and nation are engaged, requires mature and responsible political leadership – "War is not merely an act of policy but a true political instrument, a continuation of political intercourse carried on with other means" [1].

Military experts largely assumed that "revolution in military affairs" would enable one of the parties to gain such an advantage that the military conflict would practically be reduced to delivering one decisive blow. Such technological asymmetry was expected to result in shorter conflicts, which meant diminishing prospect of an armed confrontation to the point of exhaustion. This was however

questioned by the war in Ukraine, which confirmed a fact that has been known for more than 100 years, that war is essentially a contest of new constantly implemented technologies, especially in terms of firepower. Quantity, when considering both equipment and personnel, begins to matter once again. The potential of states involved in warfare is not solely determined by their gross domestic product, especially if it is primarily derived from services. It rather hinges on their capabilities in the production of ammunition and military equipment, the speed of their mobilization, armament, preparation, and utilization in combat, all while using cutting-edge latest technology tools for reconnaissance, surveillance, intelligence, and communication, i.e. everything that contributes to situational awareness [4].

According to Biddle [5], it is not technology that matters most, but the tactical and operational changes, namely how the combat forces utilize new capabilities. Approaches to target designation, the dispersal of forces, the pace of operations, as well as camouflage and supply systems change in response to new technologies.

Views on how large and armed formations will best work in the realities of the modern battlefield, at what depth operations should be conducted, what capabilities should be utilized and how to coordinate multi-domain activities are evolving. In this sense, modern warfare constitutes a constant arena of innovation and change, as well as adjustment of perspectives and existing approaches. However, it is not, as many incorrigible optimists who believe in the proximity of Hegel's "end of history" would like to see it, merely a straightforward, brutal clash of physical potentials and forces, detached from threats to the fundamental, most valuable resources of the states and societies involved in the conflict. According to Clausewitz, war "belongs not to the Arts and Sciences, but to social life [...] it can better be compared to commerce, which is also a conflict of human interests and activities [...] it has its own grammar, but not its own logic, no way of thinking properly. Accordingly, war can never be separated from political intercourse, and if, in the consideration of the matter, this is done in any way, all the threads of the different relations are, to a certain extent, broken, and we have before us a senseless thing without an object." [1]. Therefore, seeking peace and preparing for war, it is imperative to conduct a mature, forward-looking, and coherent state policy across all domains that could theoretically become areas of kinetic and non-kinetic adversary actions, thereby mitigating their adverse effects on society and the state, its political and economic stability, as well as the ability to defend one's own ambitions, aspirations, and interests.

The great Prussian war theorist also wrote: "…The military genius, that it is not one single quality bearing upon War, as, for instance, courage, while other qualities of mind and soul are wanting or have a direction which is unserviceable for War" [1]. Instead, "that it is a harmonious association of powers, in which one or other may predominate, but none must be in opposition" [1]. If, therefore, we are not witnessing revolutionary changes in military technologies or a breakthrough in the effectiveness of new technologies in destroying enemy's potential, then traditional, incremental updates of ideas and equipment are insufficient, and a more radical solution is needed. It is therefore evident that victory is rarely determined by weaponry (unless there is an extreme asymmetry in this regard), but rather by how its is utilized and how quickly we can adapt to new challenges.

If both conflicting sides adapt to rapidly changing realities, the advantage lies with the side that adapts more quickly. Therefore, the primary focus should be on new modes of warfare, novel operational concepts, including new medical supply doctrine. German experiences from the 1930s related to the organization of armored forces confirm that the manner in which combat effectors are employed (integration of different types of weapons, communication, as well as the speed and efficiency of command) is a decisive factor in military success [6]. Such innovative approaches, changes stemming from the ability to learn, and the fullest possible utilization of possessed capabilities, possibilities, and competencies, including their inherent benefits derived from the synergy effect, are the true source of victory. This equally applies to the tactics of deploying elements of medical support system during war [7].

Considerations on ways and methods for securing medical resources in the battlefield

Successful 21st century warfare tactics are based on the pursuit of multiplying operational capability of a soldier on the battlefield. Saturation of the battlefield with weapons, missiles, and bombs is no longer a prerequisite for gaining an advantage or victory. Instead, the key to success lies in precision, range, and speed – indicators and measures that are directly linked to access to modern technologies, as well as the skills of soldiers utilizing these technologies in contemporary battlefield – specialists with competence to operate complex weaponry, available in fewer numbers than before.

Therefore, the changes in methods of warfare that we are witnessing today necessitate the development and implementation of novel approaches for providing combat troops with medical support. The power, precision, and range of weapons on one hand, and modern protection systems (survival on the battlefield and maintaining maximum availability) minimizing the attrition of high-quality soldiers on the other, radically change the perspective on the organization of medical support. The priority is no longer given to the forms of military healthcare that have been in place for the past 200 years, whose main goal was to provide mass access to medical service at the expense of its scope and complexity. New means of transportation, evacuation and, to an even greater extent, the progress made in the field of medical knowledge and technology, unleash previously unknown capabilities for delivering highly specialized medical care in a timeframe that guarantees not only survival, but also minimization of the immediate and distant consequences of injuries suffered [8].

Under these circumstances, the task of the military medical component is to create conditions that allow for the organization and maintenance of medical support as close to the front lines as possible, during both defensive

and offensive operations. Hence, the MHS, given today's needs of armed forces, should be set on the foundation of procedural and product innovations that break through the previously established organizational standards, solutions that correspond to modern methods of warfare, which consider modern possibilities arising from advances in knowledge and technology in practical use. A secure and efficient logistic network of drones, based on modern unmanned platforms delivering medications and medical supplies to the frontline and resistance nests; autonomous casualty evacuation platforms ensuring quick access of the injured to medical units capable of providing first aid; modular, mobile dressing stations distinguished by their ability to easily expand the scope of medical assistance provided to a degree corresponding to the type and scale of sanitary losses, interconnected via medical evacuation vehicles with level III and IV hospitals are a few examples of implementations that could significantly change the way military medical services are organized and operate. Illustrating the capabilities and methods of their practical application to establish new solutions for the provision of medical assistance for the military.

The profile of the units that make up the national network of hospitals of the state security system should include entities that are ready to provide comprehensive multispecialty medical care, with particular emphasis on the management of battlefield injuries. The knowledge and experience of medical personnel and the available material resources will constitute a distinguishing factor for the aforementioned entities in the healthcare market. The list of facilities should be opened by military hospitals, to which civilian entities such as multi-specialty hospitals and trauma centers will be added based on locally defined needs. These units, with minimal effort and resources, will be able to meet the personnel, material, and organizational requirements in the field of medical support for armed conflict.

Implementation of a new approach to aspects related to tactics, command and training of medical personnel is another issue. These should be seen not as an imposed, dogmatic norm, but rather as knowledge grounded in experience, and a detailed and thorough analysis of issues related to battlefield medical support. A provisional solution, necessitating continuous learning, including understanding the enemy's behaviors, improving treatment methods, as well as resource organization and management, subordinating them to the principle of integration of available forces and resources, and adapting the scale and scope of activities to evolving conditions. Finally, the ability to provide medical assistance in the face of dynamically remodeled battlefield needs.

The war in the East. Lessons from past experience

The conflict in Ukraine is a unique opportunity to update issues related to tactics, training, but also the strategy of organizing healthcare systems in conditions of conflict with near-peer opponents – adversarial nations with equivalent military force. The well-known peculiarity of this type of conflict is the use of weapons with greater force of destruction and range, which directly translates into an increased scale of injuries and fatalities As a result, the management of the injured becomes a significantly greater challenge for medical services than previously estimated, with changes in the organization of battlefield medical support involving such key issues as the location of levels (stages) of care.

The types of weaponry utilized, as well as its velocity and precision, account for changes in the severity and nature of injuries that have not been seen before in armed conflicts. Polarization in the area of sanitary loss registry adopting a simplified structure – mild, severe, and very severe injuries – means in the medical service practice that there is a need for advanced methods for stabilizing the condition of the wounded already at the early stage of treatment.

It is estimated that 5–10% of Ukrainian soldiers deployed to the theater of operations were either wounded or killed in action. Multiple cases of casualties with symptoms of hemorrhagic shock or burns, penetrating or multiorgan injuries and barotrauma, which are mainly the result of artillery or missile fire, constitute a new, unprecedented characteristic of sanitary losses, which require medical (often specialized) care provided in close proximity to the enemy.

Given the goal of ensuring the effective implementation of the healthcare system's tasks, efficient, targeted medical evacuation, ensuring conditions for prolonged care in the field, including an expanded volume of medications and medical supplies, and the ability to perform extensive surgeries to limit the consequences of sustained injuries are essential [9]. It is estimated that the capabilities of "leader" surgical teams should be measured, among other things, by their readiness to perform at least 10 rescue procedures, including laparo- and thoracotomies, with simultaneous intensive care for 15 patients for at least 48 hours, without the need to replenish supplies. Expanding the medical competence of these teams, resulting from the need to save the health and life of those wounded, limits their mobility, which is responsible for creating an organizational disharmony between the need for greater medical capabilities and the capacity for rapid relocation, which is difficult to reconcile with the principles of military maneuvers. This implies that raising the level of medical support may have a negative impact on one of the operational indicators (mobility), hence the decision should be considered each time during the planning and implementation of medical support for military operations, being the resultant of expected tactical and operational goals pursued under constraints imposed by the magnitude and structure of sanitary losses, which delineate the competency framework of medical care, setting the limit on achievable military objectives at a given stage.

In addition to the level of medical support, medical evacuation is another factor requiring special attention in terms of maintaining the proper operational efficiency of home troops, especially when it comes to the transportation of those wounded. Conclusions from analyses of armed conflicts occurring in the past decade clearly indicate that securing evacuation routes by operational forces, for instance, through achieving air dominance (medical evacuation, MEDEVAC), should always be re-

garded as a factor enhancing operational capabilities and mitigating the impact of constraints associated with the level of medical support.

The communications system, both its technological and organizational layers, is also an integral, high-priority utility element of medical support according to the new design. In addition to coordinating interaction at the level of autonomous medical structures, as well as between these structures and operational units, the key task of the communication network is to coordinate the flow of the stream of wounded – to optimize the management of the resources at hand, to adapt care processes to the current needs defined by the scale and structure of sanitary losses. The experience from the ongoing military conflict behind our eastern border shows that success in battlefield logistics and medical care can only be ensured by a service that is strictly oriented to securing specific medical needs of the army, as well as the operational objectives that the organizational units of the armed forces are required to implement.

According to the Ukrainian Crisis Media Center, more than 1,300 health care facilities, including 200 hospitals, have been completely destroyed due to Russian military actions. Therefore, temporary medical facilities, such as field hospitals, may need to be placed underground. This may mean that significant investment is needed in high-speed tunnelling and earthmoving equipment, which currently cannot be placed on the battlefield. Despite the current practice of surrounding structures with concrete walls and barriers, these facilities are still exposed to vertical attacks. Hence, point defense elements similar to those used in Israel's Iron Dome should be an essential element in protecting critical military medical infrastructure, guaranteeing the safety of both those wounded and medical personnel.

All this should be kept in line with the previously mentioned principles of civil-military cooperation (colocation), a variant of public-private partnership, and aided by the ability to create an open network for collecting and processing information on medical needs related to the effects of military kinetic actions based on detailed data on the size and type of sanitary losses, with the widest possible use of novel technologies to support decision-making processes at subsequent stages of care. This approach contributes to improved situational awareness and allows for more rapid responses tailored to current needs. The organizational and functional integration of the military and civilian segments of the state healthcare system in the context of the needs emerging during the conflict in Ukraine is currently the best possible approach to issues related to medical support in times of crisis such as war. This solution guarantees measures against the effects of using means of warfare against soldiers and civilians that are coherent in terms of place and time, and involve the entire potential of the state. It is also a method that increases the effectiveness and efficiency of the actions carried out in two dimensions: short-term – the professional capacity and availability of medical assistance, and the long-term – the resilience of society and the state to the exhaustion of capabilities and resources in the course of a prolonged conflict.

A proposal for a universal formal principle codifying a new method for organizing medical support for a military operation

Planning the medical supply system for armed forces and the state requires acceptance and recognition of the importance as well as tactical, operational and strategic significance of the events that have taken place and continue to take place during the armed conflict in Ukraine, a war that has no equivalent in European history since the hecatomb, i.e. World War II, given the scale, extent, dynamics, spectrum of weapons and technology used.

The clash of states of equivalent military force, based on political and economic polarization, accompanied by extreme cultural and ethical differences regarding the rules and principles of armed conflict, imposes an obligation to have a critical infrastructure that provides the highest level of security in the area of civil protection. This means that the schemes for organizing medical supply developed for the previous war are not and will not be useful or effective in countering the effects of future conflicts. Likewise, the specifics of current military operations, which are most strongly influenced by the already mentioned velocity, range and precision, make it possible to consider it necessary to depart from the previous practice of countering the effects of military operations based mainly on a universal (generic), and thus not taking into account the distinctiveness of needs, model of organizational solutions for military health protection. The starting point for thinking and acting in this regard should be the well-established truth, known for over three centuries, that if armed forces are expected to deal with any challenge and any conflict, such an army will not be able to cope with any of them.

The scale and structure of sanitary losses recorded during the war in Ukraine have shown that a modern full-scale military operation has its own specific needs and conditions in terms of medical supply, and that they cannot be met in any other way than by combining all existing resources, capabilities, as well as organizational and technical solutions, including novel technologies present on the health market to support diagnostic and therapeutic as well as decision-making processes that are related, for example, to improving evacuation of the wounded.

Both today and in the foreseeable future, the framework for the composition of such action should be guided by a new model for the organization and planning of the medical support system. This model should prioritize the definition of services that meet the current requirements and needs of the military and the state. The vector of the proposed action should be directed first and foremost to services that guarantee the connection between the current, and this should be emphasized, dynamically changing wartime objectives, and the best possible utilization of available competencies and resources.

The role and importance of operational factors in the planning and organization of medical support for a modern military operation

The dynamics and maneuverability of a military operation, as well as the different ways and conditions of warfare

require new capabilities and skills for the flexible management of healthcare system resources. The starting point for their development is situational awareness based on knowledge of the type and purpose of the military operation, the planned use of combat assets and the associated scale and type of expected sanitary losses. Equally important is the advanced ability to rapidly estimate medical needs and replenish them to a degree and extent appropriate to the current tactical and operational situation, supported by a number of interrelated innovative technological solutions – decision support algorithms.

The implementation of the aforementioned intentions necessitates a change from the current organization of medical support based on norms and completing requirements, endowing it a new dynamism and flexibility, drawing on full subordination, and thereby, effective use of the available resources. It also necessitates closely linking the medical system, appropriate for a given level of support, with the operational activities performed by the combat troops, which in practice means a full departure from the commonly used formal principle, due to which medical system units that are part of the operational troops are inadequate in terms of the specificity and nature, as well as the conditions, mode and dynamics of the troops receiving medical support.

Reference to the specificity of operational units is justified if it stems, for example, from the conviction supported by experiences from the war in Ukraine, which relatively precisely delineate the norms and rules defining the needs regarding the level of medical support for combat troops. There is no doubt that the forecasted scale and structure of sanitary losses is the main variable determining the capabilities of the medical component designated to support a unit or tactical formation. However, considering the scale and the dynamics of events that make up the picture of modern battlefield, the approach presented seems highly insufficient and operationally imperfect. Indeed, the expectations placed on competent, expert medical capabilities required in combat by mobile forces (high maneuverability shifts the level of medical care as close to the line of contact with the enemy as possible) are different from those required by the subunits of light infantry engaged in position defense on their own territory, supported by the national healthcare system. Examples of treating the medical support needs of the battlefield within the polarized framework illustrate the extent to which the current practice of organizing healthcare (universalization of military healthcare) remains imperfect, having been applied in its unchanged form for several decades. It deviates significantly from the actual needs of operational forces, which are normalized by new combat systems and their methods of use.

Just as guns and airplanes of different types are constructed depending on their combat tasks, medical support, whose role is to ensure the full protection of the health and lives of soldiers, maintain combat spirit, and moral strength necessary to overcome one's own instinct for self-preservation, should be tailored to the common goal, which is victory. This implies an urgent need for changes in planning and organizing military medical support, with a recommendation to employ the method of overlaying operational plans of combat and medical forces. Additionally, there is a need to develop new decision-supporting tools utilizing tangential vectors and data resources, would, to the widest possible extent, take into account both common areas and differences – a key characteristic for operational planning of the simultaneous use of types of troops subordinated to a common goal.

Assessing the feasibility of using operational factors in planning battlefield medical support

The proposal of a new organizational model for MHS operational actions as a prelude to the concept of dynamic planning for the medical support of combat forces requires meticulous preparation of a cognitive map to ensure conceptual clarity of the proposed assumptions. For the purposes of the present study, this task was based on transcribing source terms describing operational factors to a conceptual level corresponding to organizational issues within the healthcare system, as well as on linking new organizational and functional proposals with the practice of tactical and operational military operations.

The premise of this reasoning was the assumption that conclusions derived from the analysis of operational factors serve as the basis for thinking and planning. They make it possible to assess the conditions for achieving the intended goal, and their interrelations support, with an appropriate degree of freedom of action, decisions on the choice of the appropriate mode of action, remaining in close correlation with the operational situation of the home troops. They serve as utilitarian and simultaneously pragmatic methodologies in terms of managing the battlefield, expanding and complementing the previously presented aspects of warfare theory.

Conducting war is a reality, not a theory; therefore, the fundamental objective of developing and effectively implementing a new method of dynamic planning of medical support for combat troops through modeling battlefield medical care processes is to pursuit rationalization and automation of the actions taken as:

- Support of planning decisions on the preparation and implementation of tasks related to the organization of medical support for military operations. Effective utilization of allocated resources – type, quantity, as well as the time and place of their utilization.
- Optimization of integration processes in the field of available forces and resources and adaptation of the scale and scope of activity of the universal healthcare system, including the possibility of providing medical support in the realities of the dynamically changing needs of the battlefield.
- Determining the role and importance of operational factors as determinants of the validity of actions taken in planning and organizing medical support for military operations.
- Improvements in both planning and organizing battlefield medical support, including integration with the goals of operational troops, while maintaining their dynamics and maneuverability to effectively and quickly achieve the pre-set goals.

Methods

Military medical modeling is based on widely recognized operational factors, i.e. force, time, and area, with this

group expanded to include an additional parameter – safety, which is important from the perspective of the organization of medical work of field units. Simultaneously, all variables are assigned appropriate characteristics and interpretation corresponding to the subject matter [10].

A mathematical model for planning battlefield medical support

Dependent variable:

- **Force (expected capabilities)** – properly organized and equipped medical units that should be at the disposal of the component commander as part of the preset tasks

Independent variables:

- **Medical needs** – the scale and extent of sanitary losses forecasted in the area covered by the medical support unit in connection with the implementation of the assigned operational task.
- **Time (dynamics) –** the time required for the preparation of the operation, estimated in terms of forming the necessary forces, their transfer to the area of operation and integration within the other structures, while ensuring the level of maneuvering activities appropriate to the operational situation.
- **Area (space)** – the characteristics of the place where the operation will be conducted, mainly in the context of forces and resources involved, as well as the state of the healthcare infrastructure available for use within the military-civilian colocation system.
- **Safety (protection)** – the level of achievable protection of medical support sites in the area of operation.

The meaning and etymology of the terms used indicate that, in the practice of battlefield, the method of planning medical support for military operations will seek to overlap the intentions of the operational troops and the medical component envisaged for implementation in place and time, which states that the structure – the strength and vector of the impact of each of the above-mentioned operational factors – will draw from both domains to the extent appropriate to the realities of the tactical and operational environment.

Structure, complexity, resources, definitions

Operational structure (O):

O – combat grouping: brigade, division, corps, army, front, etc.

d_S – the dynamics of activities corresponding to the proportional structure of O mobility, with frontline assigned a value of 1

p_S – number of troops

l_S – number of doctors in the structure completion

spm_S – number of medium-sized medical personnel in complete structure

lo_S – number of medical beds in complete structure.

- Medical structure (Sm):

  n_i – number of units for the level (i), i – I, II, III, IV – according to the level of medical support

  d_m – the dynamics of medical structure activities proportional to the structure's personnel mobility, with a value of 5 for level IV and a value of 100 for level I

  l_m – number of doctors in complete medical structure

  spm_m – number of medium medical personnel in complete medical structure

  lo_m – number of medical beds in complete medical structure

  b_m – safety indicator that defines the minimum requirements for the protection of medical structures involved in countering the effects of military action.

- Medical structure in the theater of operations (Sm_t) – medical structure located in the area of operations as a resource that can be used as a whole or in part during the implementation of medical support tasks.

- Medical support resources (Z):

  zm_Z– medical resource: doctors, mid-level health providers, hospital beds

  wz_Z – rate of utilization of the resource in relation to sanitary losses

  wr_Z – rate of concurrent losses requiring medical attention.

According to the preset operation, the parameters for its implementation have been defined:

d_o – dynamics of operations defining the expected minimum rate of movement of the medical structure during the provision of medical support for combat group

b_o – safety factor for an operation implemented by a combat group, equivalent to the impact of the conditions of the operation on sanitary losses

ss_o – the coefficient of estimated sanitary losses following the operation, with an assumed safety factor (b_o).

Under the predefined conditions, the decisions of the medical commander will involve quantitative and generic selection of medical structures (Sm) as resources, so as to be able to maintain the ability to conduct operational activities despite the sanitary losses incurred. A direct consequence of this situation is, among other things, the need for allocating appropriate number of medical resources for the size of losses (tab.).

Accordingly, the following has been estimated:

Table. Characteristics of the structure and dynamics of the levels of medical support in the medical security system.

Medical structure	Dynamics	Physicians (*n*)	Nursing and emergency personnel (*n*)	Beds (*n*)
Level 1	100	0	12	10
Level 2	85	8	25	20
Level 3	35	50	200	300
Level 4	5	700	1200	600
n –number				

- The magnitude of sanitary losses as a derivative of the loss rate (ss_O), the number of personnel (p_S), b_O, assuming that the lower the b_O, the greater the sanitary losses.

$$wss = \sum_{i=1}^{n_i} 1 + (1 - b_{O_i}) \times ss_{O_i} \times p_{S_i}$$

- The potential of home combat group (O) as the size of the medical resource available within the O, without involving the resources of the medical component.
- Potential of Sm_t as the size of a medical resource with a number (t), providing support in the area of the operation being carried out.

$$p_{sm_t}(zm_z, wz_z, wr_z) = \sum_{i=1}^{t}(zm_{z_i}, wz_{z_i}, wr_{z_i})$$

- The size of the medical support resource (Z) resulting from the adopted values – wr_Z, zm_Z, size of sanitary losses.
- The magnitude of medical structure deficit as the difference between available and necessary resources.

$$D_{zm_z} = (p_O + p_{s_{m_t}} + p_{s_m}) - p_{pss}$$

where:

p_O – native medical potential of the combat grouping

$p_{s_{m_t}}$ – medical potential of the medical resource providing support in the area of the operation

p_{s_m} –potential of the medical structure in the theater of operations

p_{wss} – necessary potential, resulting from estimated sanitary losses.

Knowing the magnitude of limitations in terms of the available medical resources and the number and type of medical structures (Sm) at the disposal of the medical commander, the decision on the organization of medical support for operational activities will be based on such a constellation of forces and resources that will reduce the level of the perceived deficit to the greatest extent possible.

$$D_{zm_z opt} = D_{zm_{z_i}}, i = 1$$

such that

$$D_{zm_{z_i}} > 0 \text{ i } D_{zm_z} = \min(D_{zm_{z_i}}) \; i = 1 \ldots N$$

At the same time, it should be kept in mind that any task of this type will be neither simple nor easy. For only one level IV unit, five level III units, 15 level II units and 100 level I units, the number of possible combinations to be evaluated is 7,500 and it grows according to the following relation:

$$N = \prod_{i=1}^{IV} n_i$$

Considering the above, a calculation model was developed according to the algorithm (fig. 1).

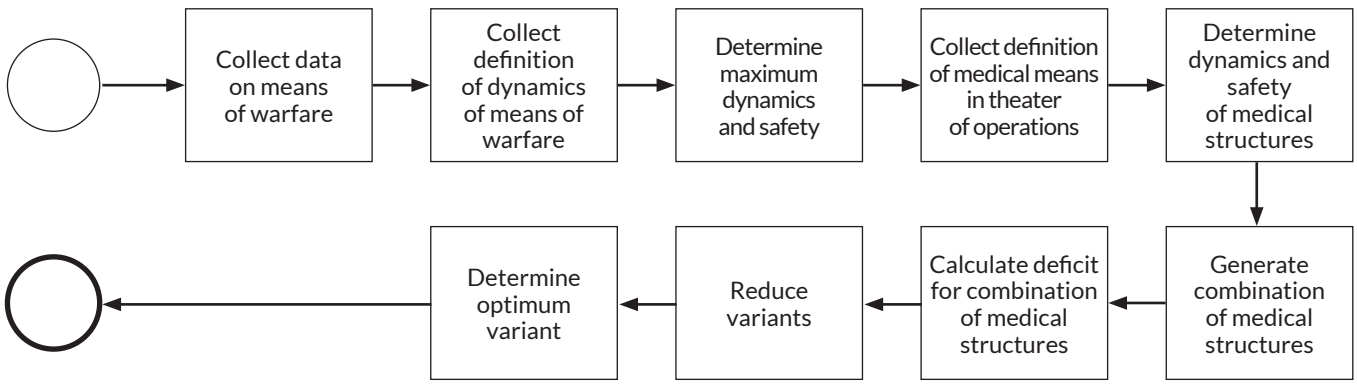

Figure 1. Algorithm for calculating medical supply variant

By setting the model parameters as follows:
- combat grouping: brigade
- dynamics: 5
- estimated losses: 30%
- operational safety: 60%
- spare medical resources in the theater of operations (operational space): none

the estimated deficit in medical resources will be:
- physicians: 173 persons
- mid-level medical personnel: 347 persons
- number of beds: 158.

By setting the decision space at the level of reduced combinations, assuming minimum medical safety appropriate to the level of security determined by the results of the situational analysis, the medical commander will in fact have a narrowed field of choice resulting from the differences between the dynamics of operational activities and the priorities of care processes implemented by medical structures. Additionally, constraints on key command decisions may be faced due to the frequent cognitive dissonance between the need to maintain the conditions for purposeful medical care that meets the current needs and providing support for the implementation of operational tasks, following the principles of tactical operations (fig. 2).

It should be noted that the dynamics of medical troops in terms with the mode of operation according to the pattern: reaching the target – infrastructure deployment – action – infrastructure redeployment, including unevacuable patients, will always limit the mobility of operational activities. Therefore, it is crucial to possess capabilities enabling flexible adjustment through operational planning tools, to integrate the goals and needs of medical care (modulated mainly by the scale and structure of sanitary losses) with advancements in the course of military operations, dependent upon their dynamics and maneuvering capabilities, and to precisely determine and adjust the planning for the utilization of the designated medical component's capabilities in terms of both location and timing to support military operations.

The model also shows that the ability to utilize properly arranged and organized medical structures located in the theater of operations (operational space) clearly reduces the requirements associated with the need to engage reserves located in the retreat (fig. 3 and 4). This outcome is a result of the engagement of medical resources situated either at the location or along the direction of operational military activities. While mobile medical structures can follow the army, level III and higher level hospitals may be considered mobile from an operational perspective only in terms of personnel, not infrastructure. This implies that with a defined level of medical security, the medical commander can effectively fulfill tasks using a large number of lower-level medical structures, with the potential for their support through military-civilian collocation with

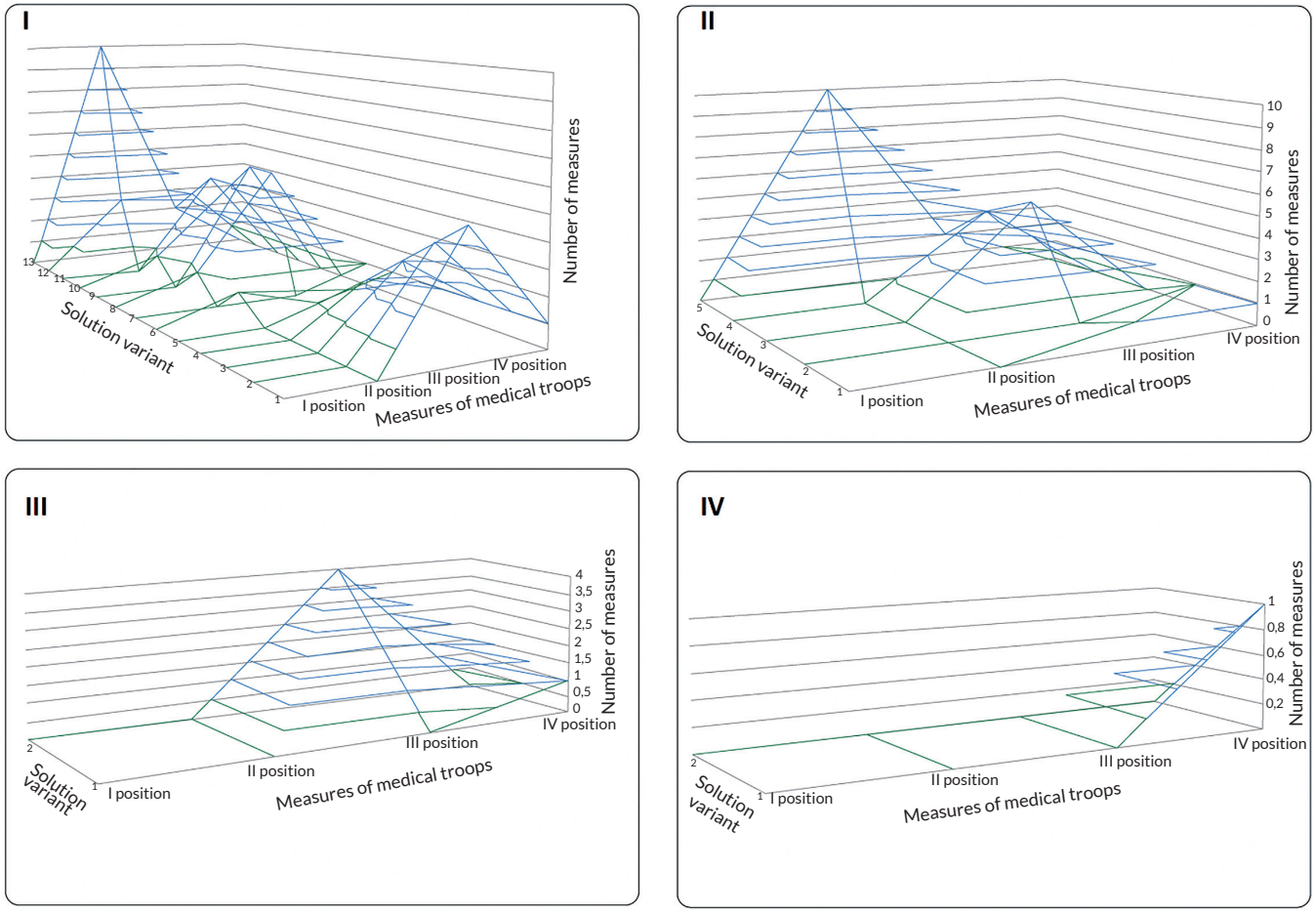

Figure 2. Decision space under conditions of maintaining minimum security at successive (I–IV) levels of medical support

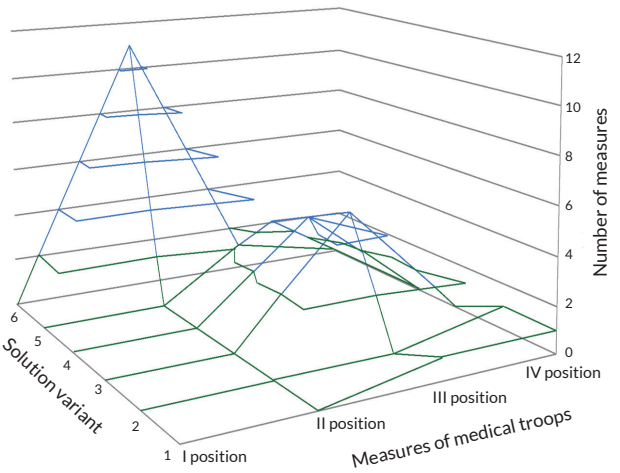

Figure 3. Decision space of the medical commander in the context of medical structures in the theater of operations using a single level-III unit

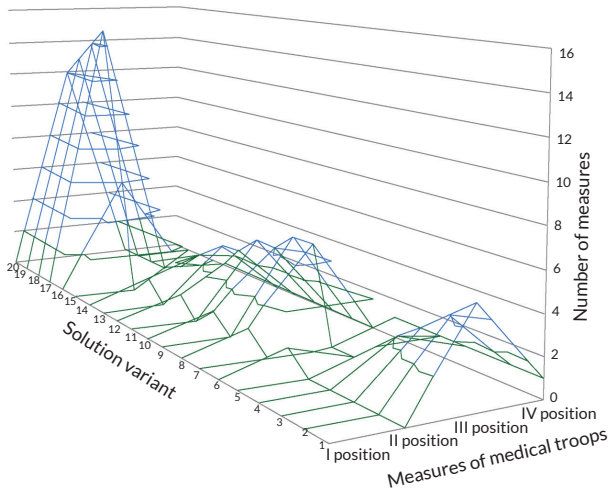

Figure 4. Decision space of the medical commander in the context of medical structures in the theater of operations using two level-III units

medical teams deployed in the theater of operations, possessing advanced care capabilities, thereby minimizing limitations on the mobility of these units.

Discussion

From the point of view of tasks related to the protection and defense of the population against the effects of crisis events, the Polish health care system is currently at the stage of transformation, the most important goal of which is to acquire the ability to deliver effective medical care during an armed conflict taking place on its own territory. This necessitates a thoroughly planned, well-thought-out consolidation and utilization of the resources gathered within the system, reinforced by the competencies of services and authorities responsible for state security.

The current threats to Poland's security clearly show that selected operational competencies, which until now have been the almost exclusive domain of the military, should also become part of the "civilian" segments of socio-economic life. Maintaining the conditions for the nation's health security is equally the responsibility of the civilian and military segments of the healthcare market, participating in the development of a crisis-proof health system. Hence, it is so important to organizationally and functionally link the two components of the system, determine the scope of needs and conditions of cooperation, in which having a planning tool that integrates data on the system resources and the current needs for their use provides invaluable support as it sets the framework for a new option, a standard for greater effectiveness and efficiency of the management of civil protection operations, giving priority to the principle according to which basing activities on a primary common operational plan ensures better, more coherent, comprehensive preparation in the field of medical support, optimizes integration processes in the field of available forces and resources, and adaptation of the scale and scope of the activity of the national health protection system, including the possibility of providing medical assistance in the realities of the dynamically changing needs in the battlefield.

Both the concept of development and the confirmed results of the assessment of the proposed analytical method are rooted in the viewpoint formulated by von Bülow [11] over 200 years ago, according to which employing mathematics facilitates the planning and execution of all operations with geometric precision. An opposite view was presented by Clausewitz [1], who saw war precisely as an art rather than science based on geometric diagrams. However, the conclusions resulting from the use of the new planning tool show that, contrary to the first impression, the two views cited, although categorical, are neither contradictory nor mutually exclusive. This is because the more strongly military operations are linked to the need for advanced planning (simultaneous management of multiple situations and resources) the more they correspond to the tactical and operational objectives of the battle, the more room they have for mathematical calculations, shaping the space for developed and oriented decision support related to task implementation. On the contrary, the more they are part of politics and the achievement of its goals through military means, the more they correspond to the rules of art expressed through strategy.

Conclusions from the practical use of the presented proposal for a model of dynamic planning of medical support for military operations further indicate that the effective utilization of such tools is possible when ensuring the organization of the medical component of the structure corresponding to the type of troops. If programming of medical support on the battlefield is expected to guarantee the possibility of using the potential of planning military operations taking into account operational factors, then it must ensure rapid and full access to the resources at its disposal and grant formal and legal conditions, and thereby the possibility of flexible management. A military medical component is responsible for preparing conditions that will allow for

organizing and maintaining medical support as close to the battlefront as possible – both during defensive and offensive operations. The actions undertaken should also take into account operational priorities, including those relating to the dynamics and maneuverability of own forces. The application of the new planning model eliminates previous limitations caused by the subjectivity of assessments and the decisions formulated based on them, improving the pace and efficiency of achieving key goals and objectives.

At the same time, conducting a military operation on one's own territory requires the definition of norms and principles for managing the processes of co-location of civilian and military health market resources. Given the estimated needs, it is most expedient to create a network of hospitals on the home territory, the distribution, number and competence and capabilities of which will correspond to the projected size of sanitary losses associated with a potential conflict [12]. Accurate knowledge of the number and type (strength and complexity) of medical support units required for use during a military operation is the basis for conducting effective calculations during the planning process and, subsequently, for the effective use of the resources at hand.

The application of the developed planning tool also clarifies the view on the role and importance of level III hospitals. Under the conditions of a defense operation conducted in an area with a developed network of highly specialized inpatient treatment units, the main task of the above-mentioned units will be to provide support to local medical entities, as well as to serve as a mobile backup of lower-level military hospitals. Hence the conclusion that the potential of level III hospitals can be fully utilized mainly during hostilities conducted in an area devoid of medical infrastructure or operations outside the country, which together should contribute to the knowledge of the operational planning area on the real material and equipment needs in terms of the number and type of field hospitals needed to provide support for military groupings involved in combat.

This also underscores the importance of decisions on the location of medical structures, especially in the field of highly specialized (hospital) treatment, given the anticipated directions of hostilities, as well as initiatives such as military-civilian co-location – arranging for the cooperation of civilian resources intended to support medical care during an armed conflict. The scale of predicted medical needs in this regard, applying the classification included in the system of basic hospital provision of healthcare services, allows us to assume that level I–III facilities, which are multispecialty hospitals (level VI), responsible for ensuring the availability of selected, highly specialized procedures resulting from the needs of the battlefield, will play the key role in meeting these needs.

A state that is strong in the face of threats, safe from the perspective of the needs of society, requires directional, variant plans of action that will allow to reproduce in some areas, or to build from scratch in others the capabilities and competencies necessary for an effective response – neutralizing the effects of all threats related to the occurrence of a crisis situation, including those having the nature of an armed conflict. Therefore, the widespread awareness and resulting responsibility, an unyielding determination and an understanding, supported by empirical evidence, that departure from the postulated changes that complement and strengthen the existing capabilities of the state security system, including the armed forces, will mean accepting the risk of losing the national fabric should be the measure of Poland's and Poles' commitment to build a safe future for the state and the nation. Given the experience of the war in Ukraine, the scale of the aforementioned phenomenon will be incomparably greater than the tragic demographic consequences caused by the pandemic crisis, which are considered tragic today.

Conclusions

The proposed model for estimating medical needs concerning the support of military operations is methodologically advanced and simultaneously user-friendly as a decision support tool for planning and organizing healthcare. It mitigates associated dilemmas and uncertainties, integrating knowledge about the occurrence and prevalence of key factors determining the conditions and possibilities for providing medical assistance, as well as the needs and expectations arising from tactical and operational intentions. It optimizes battlefield medical support processes, reduces the risk of errors in the most sensitive areas crucial to the success of a military operation – both on the side of method and conditions of using the resources, and the adequacy of where and when they are used. It reinforces the health system's resilience to hybrid and military operations, providing key data on the current needs for its organization and operation in conjunction with tactical and operational plans and the national defense strategy. Concentration and coordination of medical resources, both native, assigned to a combat grouping, and those located in the operational space, i.e. available within the framework of military-civilian co-location, implemented by this system, creates an environment that ensures high efficiency and effectiveness of the assistance provided.

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