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RETROSPECTIVES AND PROSPECTIVES OF THE IMPLEMENTATION OF ROBOTIC TECHNOLOGY IN THE FIELD OF MILITARY MEDICINE

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Abstract: *This scientific paper refers to robotic technology that can be implemented in the field of military medicine, with a focus on exploring the evolution and transformation of the first combat support hospitals into the latest and most modern field hospitals. Within the scientific dissemination, the authors analyze how the implementation of robots in various aspects of medical care in conflict zones, combined with aspects related to telemedicine, telepresence, and the master-slave architecture, can influence the human-artificial partnership in service of the military, aiming to reduce the mortality rate among soldiers operating in theaters of operations.*
Key words: *field hospital, mobile robots, implementation, telemedicine, human-artificial partnership*

1. INTRODUCTION

The term *military medicine* refers to a specialization within the medical field, focused on aspects related to the health of soldiers and military personnel. It constitutes a branch of occupational medicine that concentrates on the specific risks and needs encountered by military personnel, including both the prevention and treatment of medical conditions.

Military medicine focuses on providing medical assistance within military operations, carrying out its activities in various contexts, including the prevention and treatment of infections among soldiers, analyzing ergonomics and the health impact of military equipment and vehicles such as submarines, tanks, helicopters, and airplanes. Additionally, military medicine includes planning surgical management for soldiers injured during warfare and providing appropriate medical support to them. [1]

Military medicine is also a complex field that combines medical knowledge with organizational and logistical aspects, aiming to provide optimal medical assistance to military personnel, both during wartime and peacetime. This involves a variety of activities, from the prevention of illnesses and injuries to the evacuation and treatment of the wounded, as well as the rehabilitation and social reintegration of veterans. [2]

However, the healthcare system of an army is one of the most complex pillars, which is divided into several medical functions, thus combining branches of medicine and scientific research in the field. According to the organizational chart presented below (fig. 1), the three categories of armed forces can be identified: land, naval, and air forces, which, in the event of armed conflict, must cooperate with each other to ensure the successful completion of the mission under optimal conditions.

Fig. 1. Organizational Chart of the Health Medical System of an Army [3]

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An important role in conflict zones is played by the field hospital, an essential component aimed at reducing the number of casualties caused by various injuries, trauma, or diseases resulting from armed conflicts. [4]

2. FIELD HOSPITALS – PRESENTATION OF THE *ROLE* CONCEPT

2.1. Field Hospitals – Setup and Characteristics

The organization and optimal functioning of a field hospital, which is located on the battlefield (fig. 2), must be based on a series of performance progress parameters evaluated by military specialists, aiming to treat soldiers while adhering to sanitary standards, in conjunction with reducing the number of casualties affected by wars.

Fig 2. Military Field Hospital– Setup [5]

According to Figure 3, a field hospital consists of certain sections (emergency/ consultation/ treatment, administrative, logistics/ communications, pharmacy, sterilization, patient care), which, functioning as a unified whole, should lead to increased flexibility in medical practice and simultaneously ensure high-quality medical performance in order to achieve the army's objective – reducing the mortality rate among soldiers in conflict zones.

Furthermore, the modular organization of field hospitals provides easier triage operations for the wounded between the previously mentioned access areas, leading to the possibility of quick treatment and medical interventions for them.

According to a scientific article published by military researchers in the *Army Sustainment* Journal, the Military Medical Department initiated the transformation of combat support hospitals into field hospitals to provide support for expeditionary healthcare services and hospitalization.

Fig 3. Organization of a military field hospital [6]

The new hospital system addresses the critical shortcomings of combat support hospitals with updates at the organizational level, medical competencies, and the capacity to carry out divided operations.

Examples of best practices highlight the fact that during the Vietnam War, medical assistance remained unchanged since field hospitals replaced military mobile hospitals and evacuation hospitals. As the war escalated and enemies attempted to exploit perceived vulnerabilities, the army continuously adjusted to develop and design innovative solutions to improve the care of the wounded in conflict zones. [4]

2.2. Presentation of the *Role* Concept

The term "Role" or "Echelon" is used to describe the four-level structure of medical support, organized to provide treatments, resupply of medical equipment, evacuation of the wounded, and other key functions for the health stability of the forces participating in the armed conflict. The definition of the levels is made in accordance with the resources and capabilities available. Typically, the term "role" is used within air or ground forces, while "echelon" is a term often used in naval forces. These are of four types: Role 1, Role 2, Role 3, and Role 4, which the authors will present in more detail for a better understanding of this concept.

Role 1 is associated with small units, including capabilities that provide first aid, immediate lifesaving instructions, and triage of soldiers. Thus, it plays a decisive role in contributing to the health stability of the medical unit by providing recommendations for disease prevention and operational stress. Normally, managing daily medical cases and treating lightly wounded or ill soldiers falls under the responsibilities of this medical level.

In the case of Role 2, support is provided at the level of a larger unit, such as a brigade or a similar unit, although it can also be provided at other levels, in accordance with operational requirements. It is prepared for the evacuation of wounded soldiers from Role 1, triage, necessary treatments, resuscitation, and patient monitoring until they are able to return to activities or be evacuated. If there is also the possibility of dental treatment and certain emergency surgical interventions and post-operative management, it is referred to as Role 2 +.

Role 3 is, in most cases, provided at the level of a division or higher, consisting of additional resources such as specialized diagnostics, advanced surgical and medical capabilities, food inspection, and an operational stress management team, covering cases that cannot be handled by Role 2 or Role 2 +. Role 3 has the necessary capabilities to provide patient monitoring and comprehensive treatment, in accordance with the evacuation policy established by specialized personnel in operational theaters.

Medical support 4 or Role 4 can provide definitive care for the wounded that require treatment exceeding the duration specified by the evacuation policy in conflict zones or for taking over patients from Role 3. Typically, surgical procedures and specialized medical treatments, rehabilitation, and convalescence are included in this type of Role. This level is highly specialized, time-consuming, and provided in the home country. [7]

3. ROBOTIC TECHNOLOGY IN THE SERVICE OF MILITARY MEDICAL FIELD

3.1. Mobile Robots

Mobile robots are those mechatronic structures that have the ability to move from one location to another independently, meaning without external human support. In contrast to other robots known in the specialized literature, which can only move within a specific workspace, mobile robots have a major and more distinctive difference, namely the ability to move freely within a predefined workspace to carry out the assigned tasks. This mobility can make them useful for serving a wide range of applications in predictable environments and beyond.

Humanoid robots, robotic pets, and drones are just a few examples of mobile robots that can lend a *helping hand* to military medical personnel in conflict zones – a true *human/medical – artificial/robot* partnership.

In order to interact effectively with their surroundings, mobile robots use various sensors that collect data about the environment, information which they interpret to generate action commands. Their ability to perceive and understand a new environment is closely linked to the diversity of the information they hold. Advances in modern robotics have led to the development and implementation of mobile robots capable of a wide range of movements, from walking to running. The natural evolution of this field is remarkable, including both robots that mimic human walking and advanced drones, which are successfully used in the military medical environment. [8]

An example in this regard is the humanoid robot BEAR (Fig. 4), equipped with a rifle grip controller, which was tested in real conditions by American soldiers. This system, the result of collaboration between Vecna Technologies, ArthroTronix, and the Army's Telemedicine and Advanced Technology Research Center, provides an innovative approach for evacuating wounded soldiers from operational theaters.

Through the use of the two controllers, iGlove and M4, soldiers can operate the robot in an intuitive manner, significantly increasing the efficiency and safety of assigned rescue missions. [9]

In the context of modern wars and increasingly frequent natural disasters, frontline doctors face unprecedented challenges.

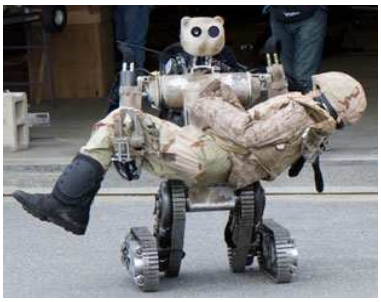

Fig 4. BEAR robot in a rescue exercise [9]

To address these complex situations, researchers at Johns Hopkins APL are exploring how technologies such as artificial intelligence, augmented reality, and robotics can be integrated to support medical teams and improve patient care in conflict zones.

Confronted with the prospect of future conflicts with a large number of casualties, APL is focusing its efforts on developing robotic solutions to assist doctors on the battlefield. The team, led by scientific researchers, created a realistic scenario to test the effectiveness of collaboration between doctors and dog-like robots under stressful conditions. The scenario involved a military doctor providing medical care to multiple wounded soldiers, utilizing two specialized robots. One robot handled the transportation of equipment, while the other assessed the patients' health status and transmitted real-time data to the doctor (Fig. 5).

The conclusion of the practical-applied scientific approach highlighted the collaboration/partnership between humans and robots as being essential in the combat environment. The researchers are constantly aiming to develop automated systems that allow doctors to provide general instructions to robots, and the robots then autonomously complete their tasks.

Fig 5. Rescue exercise with the help of dog-like robots [10]

This approach enables doctors to focus on strategic decisions, while robots handle repetitive and dangerous tasks. [10]

Another eloquent example of good practices was highlighted during the wars in Afghanistan and Iraq. Procuring the blood supplies necessary for treating injured combatants did not pose a significant challenge because the U.S. military controlled the airspace and had a well-organized and developed network of medical units. However, in future conflicts against a "near-peer" adversary, some specialists warn that this process could become much more complex. Wounded soldiers might need to remain on the front lines for several days while requiring blood transfusions or other urgent medical treatments.

Blood loss, also known as "bleeding out," is the leading preventable cause of death on the battlefield, according to military health specialists. Therefore, one of the most effective ways to save lives during military operations is to ensure rapid access to blood supplies for doctors and patients.

In this regard, advanced robotic technologies such as drones could revolutionize the way medical assistance is provided in emergency situations. By enabling the rapid delivery of blood and other medical supplies, the chances of survival for injured soldiers can be significantly improved. The use of drones for transporting medical materials on the battlefield (Fig. 6) is no longer just an idea but a rapidly emerging reality. Highly successful pilot projects, such as those in Rwanda and Uganda, have demonstrated the effectiveness of implementing these technologies in military airspace.

Fig 6. Drones transporting materials [11]

With the support of institutions like the Defense Health Agency, a swift implementation of drones in humanitarian military missions can be anticipated. [11]

3.2. Telemedicine, telepresence, and telerobotics

Telemedicine has been a widely discussed and debated topic recently, but with limited data regarding the specific clinical and economic benefits of its applications in the medical field. Telemedicine offers a variety of advantages, including the following: the development of medical services, the improvement and expansion of access to informational resources, support for the professional development of specialized military medical personnel, and the optimization of the health budget allocation.

Although telemedicine offers a wide range of advantages and contributes positively to the optimization of medical care, it also presents certain disadvantages, such as: a potential communication barrier between doctor and patient, the *misinterpretation* of some criteria for evaluating medical information, and organizational and bureaucratic difficulties. [12]

Contemporary technological advancements (Fig. 7) have significantly accelerated the implementation of telemedicine in both the civilian and military medical fields. A representative example is provided by prestigious medical institutions, such as the Mayo Clinic, which have invested heavily in the research, development, and implementation of these telemedicine platforms. [13]

Fig 7. Example of telemedicine use in the military environment [14]

Telepresence is the foundation upon which telerobotics is built. The main purpose of telepresence is to create the illusion that the operator is physically present at the intervention site, transmitting information about the environment in the most natural and intuitive way possible. The performance of telerobotic systems is closely linked to the quality of the communication network. Delays in data transmission, especially over long distances, can significantly affect the control of the robot, thereby compromising the accuracy and efficiency of medical interventions. By using a local network or dedicated fiber optics, the risk of interference and data packet loss is eliminated, which is essential to ensure the continuity and reliability of interventions in both civilian and military environments.

Short-distance telerobotic systems consist of a "local site," where the human operator interacts with a complex interface (monitors, joysticks, etc.), and a "remote site" that hosts the robotic manipulator. Although the two sites are located in the same place, they function as if they were separate. The second element of the system is the intervention site, which is remote. Here, the patient, medical assistants, and the robotic system (Fig. 8) perform the actions commanded by the operator. [15]

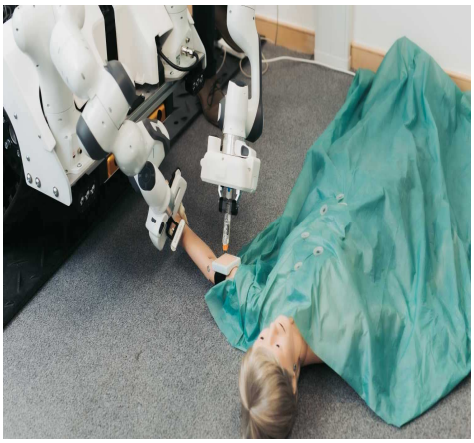

Fig 8. Example of telemedicine use in the military environment [16]

3.3. Master-slave

Many medical robotic systems offer the flexibility to be configured for both remote teleoperations and for use in a single room. [15]

In the “master-slave” architecture of telerobotic systems used in military medicine,

the operator console is considered the "master," while the robotic manipulator, located remotely, is the "slave". Bidirectional communication between the two systems is detailed in Figure 9 and allows the operator to control the manipulator and receive information about the work environment. Many medical robotic systems offer the flexibility to be configurated for both remote teleoperations and for use in a single room. [15]

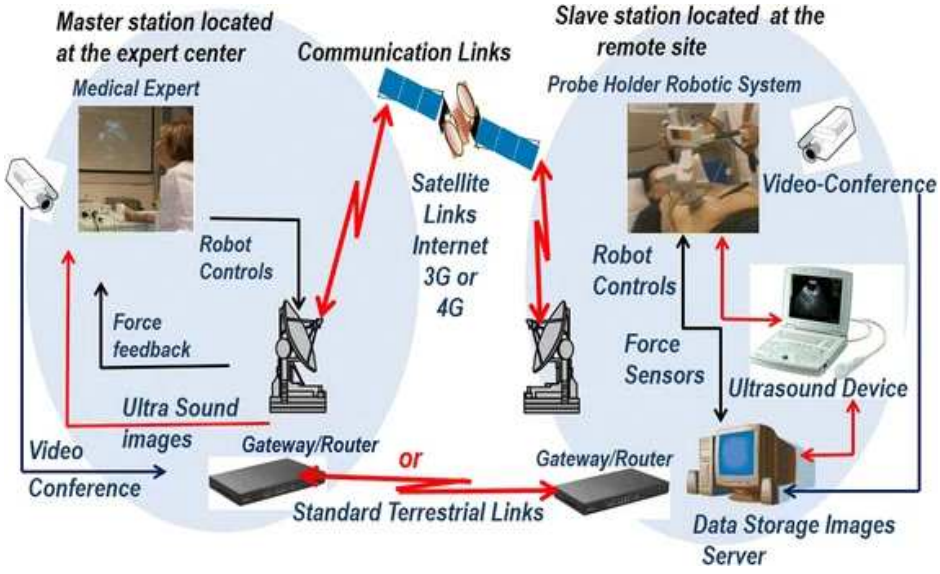

Fig. 9. Communication within the "master-slave" architecture [15]

4. CONCLUSION

Scientific researchers aim to develop capable robots that can learn from previous experiences and quickly adapt to new battlefield situations. By providing general instructions, military personnel can guide the robots in carrying out assigned tasks, and the robots can develop, while adhering to *ethical constraints*, their own strategies and tactical scenarios to achieve the objectives.

By sharing knowledge about tasks, humans and robots can *learn* from each other and continuously *improve* their performance in the tasks assigned.

This approach facilitates rapid adaptation to environmental changes and the management of unforeseen situations.

The integration of rob otic technology in military medicine is not merely a technological advancement trend but represents a natural and fundamental shift in providing high-performance medical services aligned with the contemporary demands of the ever-evolving military environment.

This research highlights the need for a comprehensive reassessment of medical practices, training protocols, and the role of human expertise in the era of advanced automation. By carefully and responsibly adopting these changes, we can ensure that military medicine remains at the forefront of innovation and continues to provide the highest quality care to service members.

The perspective of researching the current stage has provided a pertinent framework for analysis and, consequently, highlighted a diversity of possibilities for implementing robotic technology in military medicine. However, ongoing research and development are important and essential to address the remaining challenges and fully realize the potential of this field.

Scientific research areas should include advancements and innovations in teleoperation, telemedicine, and mobile medical or pharmaceutical robots, as well as the development of cybersecurity measures to protect critical systems.

The successful implementation of robotic technology in the field of military medicine requires a strongly interdisciplinary approach. Collaboration among engineers, doctors, decision-makers, and specialized military personnel is essential to overcome challenges and maximize the benefits of technology.

By promoting open communication and shared understanding, it can be ensured that the integration of robotics into military medicine serves the best causes and interests of military personnel and enhances the quality of medical care.

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Retrospective și prospective ale implementării tehnologiei robotizate în domeniul medicinei militare

Rezumat: *Această lucrare face referire la tehnologia robotizată ce poate fi implementată în domeniul medicinei militare, accentul fiind pus pe o incursiune referitoare la evoluția și transformarea primelor spitale de sprijin de luptă în cele mai recente și moderne spitale de campanie. În cadrul diseminării științifice, autorii analizează modul în care implementarea roboților în diverse aspecte ale îngrijirii medicale în zonele de conflict coroborate cu aspecte referitoare la telemedicină, teleprezență și arhitectura master-slave pot influența parteneriatul uman-artificial în slujba armatei având drept țintă micșorarea ratei de mortalitate în rândul militarilor care activează în cadrul teatrelor de operații.*

Cuvinte cheie: spital de campanie, roboți mobili, implementare, telemedicină, parteneriat om-artificial

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