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Analysis of the Automated Battle Injury Treatment Model Based on the Battle Injury Survival Chain

Fen Liu, Ziqiong Wang, Yuxia Yang, Weili Liu, Yan Qiao

Central Theater General Hospital of the Chinese People's Liberation Army Wuhan, Hubei 430035, China

Abstract. This paper explores an intelligent response framework for battle injury treatment by revealing the bottlenecks and efficiency barriers in battlefield rescue response. It aims to achieve seamless coordination and maximum effectiveness of the treatment process in real combat scenarios. The concept of an automated battle injury survival chain is analyzed, and its components are demonstrated. The integration of sensing devices, communication networks, and big data analysis is discussed to support an instant decision-making support system on the battlefield. An evaluation standard is established to assess the effectiveness of the automated survival chain model.

Keywords: Battle injury survival chain; intelligent automation; battle injury treatment.

1. Introduction

The field of battle injury treatment has always been a focus of military medical research, concerning the safety of soldiers and the combat effectiveness of the army. In recent years, with the development of technology and changes in warfare, the types of battle injuries and the difficulty of treatment have been increasing. Complex wounds and multiple injuries caused by explosions, gunshots, etc., have posed higher requirements for treatment techniques. Traditional battle injury treatment models often appear inadequate when faced with these complex injuries. Therefore, exploring a new, efficient battle injury treatment model is particularly important. According to relevant data, if battlefield casualties can receive effective treatment within the "golden hour," their survival rate will be greatly improved. However, due to the complexity of the battlefield environment and limited treatment resources, it is often difficult for casualties to receive effective treatment within the optimal treatment time. This necessitates finding a solution that can quickly and accurately treat casualties in a short time. By introducing automation technology, it is possible to achieve rapid classification, injury assessment, and quick treatment of casualties, thereby greatly improving treatment efficiency and success rates. The automation of the battle injury survival chain can significantly enhance treatment efficiency and reduce time delays in the treatment process. This not only reflects respect for soldiers' lives but also represents significant progress in the medical treatment system under modern warfare conditions.

2. Concept and Application of Automated Battle Injury Survival Chain

2.1. Overview of Battle Injury Survival Chain

"The battle injury survival chain, as an important concept in the field of military medicine, refers to a series of closely connected treatment stages implemented to ensure the survival of casualties from the moment of injury to final recovery on the battlefield" [1]. The completeness and efficiency of this chain are crucial for improving the success rate of battle injury treatment and reducing casualty mortality rates. The main elements that constitute the battle injury survival chain include rapid discovery of casualties, timely hemostasis and dressing, quick evacuation for treatment, comprehensive medical treatment, and subsequent rehabilitation training.

In the battlefield environment, rapidly discovering casualties requires medical personnel to have keen observation skills and quick reaction capabilities. Timely hemostasis and dressing effectively control the bleeding of casualties, preventing shock or even death due to excessive blood loss. Quick evacuation for treatment is an important stage to ensure that casualties receive further professional treatment. It requires not only efficient transportation tools but also the ability of medical personnel to provide continuous treatment during transportation. During the process of in-depth diagnosis and treatment of casualties, medical personnel need to utilize professional equipment and drugs to comprehensively assess the injuries and formulate targeted treatment plans to stabilize vital signs, alleviate pain, and restore physical functions as much as possible. "Rehabilitation training is the terminal stage of the battle injury survival chain. At this stage, medical personnel provide comprehensive rehabilitation services such as physical therapy and psychological counseling to help casualties recover their physical functions as soon as possible and return to combat positions" [2]. The battle injury survival chain is a complex and meticulous system engineering that requires close cooperation among battlefield medical personnel at each stage to ensure that casualties receive effective treatment in the shortest possible time.

2.2. Application of Automation Technology in Battle Injury Treatment

"Battle injury treatment, as an important component of military medicine, focuses on quickly and accurately assessing injuries and providing timely and effective treatment. The application of automation technology can significantly enhance the efficiency and quality of battle injury treatment, reduce errors caused by human factors, and improve the survival rate of casualties" [3]. In the battlefield environment, automation technology can assist medical personnel in rapidly assessing injuries. Medical robots equipped with advanced sensing devices can quickly collect physiological data from casualties, such as body temperature, blood pressure, and heart rate, and use big data analysis technology to make initial judgments and classifications of injuries. This automated injury assessment system can greatly reduce the workload of medical personnel and improve the accuracy and efficiency of diagnosis. Automation technology also plays an important role in surgical operations. With the advancement of medical robot technology, remote control or autonomous completion of some delicate surgeries has become possible. In battlefield treatment, this means that surgeries can be performed in complex environments without waiting for professional surgeons to operate in person. For example, surgical robots with stable mechanical arms and high-definition cameras can accurately perform suturing, hemostasis, and other operations, thereby saving more casualties' lives. In addition to directly participating in the treatment process, automation technology can also play a key role in material management and dispatch. Through an intelligent material management system, the inventory of drugs, medical instruments, and other materials can be monitored in real-time, and rapid deployment can be made according to actual needs. This ensures the continuity of the treatment work and effectively avoids resource waste. Accelerating the implementation of medical treatment through automation requires a paradigm shift in the military health system to address the challenges brought by large-scale operations. These challenges include a high number of casualties, high frequency of occurrences, the need for delayed battlefield treatment in resource-limited environments, insufficient numbers of trained medical personnel, increased risks of chemical, biological, radiological, and nuclear weapons and directed energy weapons, non-combat injuries, and almost continuous attack threats. These challenges require rethinking how to use artificial intelligence, machine systems, and human-machine collaboration to accelerate the realization of the "survival chain." This new paradigm is significantly different from the current expectation of multiple medical personnel treating individual casualties (currently, personnel involved in treatment need to leave the battlefield after casualties occur). A large amount of real-time casualty treatment data is needed, which needs to be reliably, accurately, and continuously obtained in the treatment environment. This is at the forefront of medicine—the interaction between casualties and rescuers. By integrating data, humans, and technology into solutions that optimize system performance, faster processes can be achieved. The survival chain model and the automation stack run in parallel. It is a framework for understanding how to create and accelerate human-machine collaboration in casualty treatment. Like the observe, orient, decide, act loop, the automation stack starts with passive data collection using sensors. We can use data from these sensors to understand the five W's of casualty care: Who: Who is present in the treatment environment (casualties and rescuers); What: What is wrong with the casualties (injury, physiological condition, etc.) and what did the rescuers do about it (treatment measures); When: When did the casualty's condition change and when did the rescuers take action; Where: Where did the treatment take place (location, temperature, altitude, and environment); Why: Why did the casualty's condition change and why did the rescuers take treatment measures (the casualty's condition and treatment measures are closely linked, and they are closely related to available resources and support environment). Clinicians combine perception and understanding data for evaluation to decide on clinical treatment measures. Intelligent (AI-enhanced) and non-intelligent (enhanced visualization, rule-based decision trees, etc.) decision support tools can improve clinical decision-making. Hardware (robotic equipment and medical devices) and AI-based software can assist rescuers by transferring human tasks to machines. Likewise, treatment can also be transferred to intelligent or non-intelligent machines, such as monitoring through intravenous pumps, intravenous infusion and drug administration, and using mechanical ventilators for breathing assistance. In the future, robots can assist medical personnel by identifying casualties, monitoring them using physiological sensors and imaging patterns, assisting medical personnel in surgery, helping them implement life-saving interventions, and intelligently performing supply and medical evacuation tasks. Providing accurate and reliable real-time passive data collection on casualties, medical personnel, and resources throughout the treatment process can iteratively develop the survival chain and automate each step of the survival chain's tasks. A digital twin of the casualty can bridge the gap between the physical and digital worlds, predicting the casualty's (future) condition and treatment needs by applying previous treatment experiences for system learning. This virtual representation, coupled with the resource capabilities of each treatment stage and the impact of evacuation time, can form personalized, data-based decisions, thereby optimizing battle injury treatment capabilities and mass casualty management capabilities.

3. Construction of Automated Battle Injury Treatment Model Based on Battle Injury Survival Chain

The core concept of automating the battle injury survival chain lies in improving the timeliness and accuracy of battle injury treatment through efficient data processing and intelligent decision support. This requires the close integration of modern information technology with battlefield medical care to achieve rapid transmission and sharing of information, ensuring that casualties receive the most effective treatment in the shortest possible time. Automation technology allows for the rapid collection of physiological data and wound conditions of casualties, and through intelligent algorithms, quick analysis is performed to provide decision support for rescuers, thus enabling the formulation of the correct treatment plan in the shortest time. On the battlefield, time is life, and every minute of delay may lead to irreparable consequences. Therefore, the combination of automation technology with emergency medical treatment processes in military medicine ensures that rescue operations can be quickly initiated even in complex battlefield environments. Centering on the casualty and aiming to improve treatment efficiency and quality means that in designing the automated battle injury treatment model, the needs and safety of the casualty are always prioritized, optimizing treatment processes through technological means to reduce human errors and delays. To achieve this goal, fully utilizing the internet, IoT, big data, and other modern information technologies is crucial. These technologies not only help us obtain and share information in real time but also predict the treatment needs of casualties through data analysis, providing strong support for frontline medical personnel.

3.1. Key Elements in Model Construction

In constructing an automated battle injury treatment model based on the battle injury survival chain, multiple key elements and influencing factors must be deeply considered. These elements not only concern technological implementation but also involve the coordination and efficiency of the entire treatment system. Technological maturity is the foundation for achieving automation. Currently, automation technologies such as artificial intelligence, IoT, and telemedicine have been applied in the medical field, but their practice in battle injury treatment is still in its early stages. Therefore, it is crucial to evaluate the stability, reliability, and adaptability of existing technologies. For example, the data transmission efficiency of remote monitoring devices, the accuracy of automated diagnostic systems, and the operability of robotic-assisted surgeries all need to undergo rigorous testing and validation. Personnel training and configuration cannot be overlooked. The introduction of automated systems will impact the roles and responsibilities of medical personnel. Hence, medical staff must be trained in relevant technologies to ensure they can proficiently operate new equipment, understand the working principles of automated systems, and effectively intervene manually when necessary. The composition of medical teams also needs to be adjusted to adapt to changes brought by new technologies. The special nature of the battlefield environment is another important consideration. The complex battlefield environment demands higher durability, portability, and rapid deployment capabilities for automated equipment. Equipment must be able to operate stably under harsh conditions, be easy to carry, and quickly set up to ensure timely treatment in emergencies. Introducing automation technology requires substantial funding, including the procurement, maintenance of equipment, and personnel training. Therefore, a comprehensive cost-benefit analysis is necessary to ensure the economic feasibility of the new model. Constructing an automated battle injury treatment model based on the battle injury survival chain is a complex and systematic project that requires a comprehensive consideration of technology, personnel, environment, and economic factors.

3.2. Implementation Pathway

The implementation pathway for the automated battle injury treatment model based on the battle injury survival chain mainly includes the following key steps:

(1) Establishing a Comprehensive Battlefield Perception System: This system needs to integrate various sensors, including vital signs monitoring, environmental monitoring, and enemy situation monitoring, to ensure real-time comprehensive understanding of the battlefield. Using network technology, perception data can be transmitted in real-time to the command center to provide information support for subsequent rapid responses.

(2) Constructing an Intelligent Decision Support System: This system will use big data analysis and artificial intelligence technology to deeply mine and process collected battlefield information. The system can quickly analyze battle injury situations, predict casualty survival probabilities, and provide optimal treatment plan suggestions for commanders based on the battlefield environment and resource conditions.

(3) Achieving Efficient Resource Allocation Mechanism: Under intelligent decision support, a system capable of rapid response resource allocation needs to be established. This system can automatically allocate medical resources and personnel according to treatment needs, ensuring that casualties receive necessary treatment in the shortest time.

(4) Improving Automated Casualty Transfer System: Utilizing advanced technologies such as drones and autonomous vehicles, a system capable of quickly and safely transferring casualties needs to be constructed. By linking with the perception system and decision support system, automated planning and optimization of casualty transfer routes can be realized.

(5) Establishing Detailed Casualty Treatment and Rehabilitation Processes: Upon the casualty's arrival at a medical facility, an automated casualty information identification system can quickly understand the basic information and injuries of the casualty. The treatment processes within medical institutions also need to achieve automated management to ensure timely and professional treatment for casualties. The rehabilitation phase also requires the use of intelligent devices to provide personalized rehabilitation plans for casualties.

4. Evaluation of the Effectiveness of the Automated Battle Injury Treatment Model Based on the Battle Injury Survival Chain

4.1. Construction of the Evaluation Index System

When constructing an evaluation index system for assessing the effectiveness of the automated battle injury treatment model based on the battle injury survival chain, multiple dimensions and indicators need to be comprehensively considered to ensure a thorough and accurate evaluation. This index system should encompass not only treatment outcomes but also the efficiency of the treatment process, resource utilization, and the operational compliance of medical personnel. Treatment outcomes is the core part of the evaluation index system and can be measured by specific indicators such as casualty survival rate, recovery rate, and incidence of complications. These indicators can directly reflect the practical effectiveness of the battle injury treatment model. Process efficiency is also an important aspect of the evaluation. This includes response time, casualty transfer time, and the smoothness of the treatment process. On the battlefield, the rational allocation and efficient utilization of medical resources are crucial. Operational compliance of medical personnel is another part of the evaluation. The automated battle injury treatment model should standardize the operational procedures of medical personnel, reduce human errors, and improve the quality of treatment. Establishing this evaluation index system will provide strong support for comprehensively and objectively assessing the effectiveness of the automated battle injury treatment model.

4.2. Evaluation Results and Analysis

In terms of effectiveness evaluation, the main focus is on the impact of the implementation of the battle injury treatment model on key indicators such as casualty survival rate, treatment time, and treatment quality. By comparing data before and after the implementation of the automated model, it is evident that the application of automation technology has significantly improved the survival rate of casualties. Specifically, in the automated model, the time from injury to receiving initial treatment has been significantly reduced. This is due to the rapid and accurate injury assessment and resource allocation capabilities of the automated system. By collecting and analyzing battlefield medical data in real time, the automated system can provide scientific decision support for medical personnel, ensuring the rational allocation and efficient utilization of treatment resources. With the help of the automated system, medical personnel from different professional fields can communicate and collaborate more smoothly, jointly providing comprehensive treatment services for casualties.

5. Conclusion

In the field of battle injury treatment, the automation of the battle injury survival chain enables medical personnel to more quickly and accurately assess injuries, take effective treatment measures, and save more lives. From a technological development perspective, continuous learning and optimization allow artificial intelligence systems to more accurately assess injuries, predict treatment outcomes, and provide personalized treatment plans for medical personnel. Big data technology can collect and analyze battlefield treatment data in real-time, providing scientific evidence for decision-makers, further improving treatment efficiency and success rates.

Regarding hardware equipment, future battle injury treatment devices will become more intelligent and portable. The application of smart wearable devices, drones, and other high-tech products will make battlefield treatment faster and more efficient. However, the application of automation technology is limited by the current level of technological development. Although artificial intelligence and automation technology have made significant progress in recent years, there are still many challenges in the complex and ever-changing battlefield environment. For example, the durability, stability, and adaptability of automated equipment need further improvement to meet the demands of treatment under extreme conditions. Therefore, only through continuous in-depth research and practical exploration can this model be further optimized and perfected, truly enhancing the level of battlefield medical treatment.

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