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Development and application of triage and evacuation equipment for casualties at sea

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Abstract

Traditional triage cannot meet the needs of modern warfare. This paper describes the design of triage and evacuation equipment for casualties at sea that can quickly address mass-casualty triage and store and transmit information during battlefield treatment and medical evacuation. This equipment consists of a high-capacity medical information card, a simulated patient generator, a triage classifier and a multifunctional airbag triage vest.

Key words triage, evacuation, equipment, mass casualties, naval

Introduction

The 21st century has seen a tendency for human to move towards the ocean. Rights to and interests in the ocean are deeply related to the survival of nations and development of countries. It is the mission and duty of a country's navy to protect the country's maritime rights and interests. In recent years, as the fights for the ocean have become much more fierce and complicated, China has strengthened efforts in protecting maritime interests. Enhancing the overall effectiveness of naval battles and safeguarding maritime rights and interests by continuously improving the navy's health service support capability have become a significant focus. Because the naval battlefield is spacious and unsheltered and the shipboard is space-constrained with concentrated action stations and vulnerable sailors, various types of wounded troops and different conditions will be generated in a short time once a naval battle occurs. Because of limitations in rescue time and capabilities, conflicts between immediate and potential rescues emerge, the number of injuries requiring care can exceed the resources available. To improve the situation, the sick and wounded must be rapidly and accurately triaged into one of the following categories: priority treatment, emergency treatment, suspended treatment and expected treatment. This triage method allows medical personnel to ration limited medical resources to perform care in a way that treats as greatest number of patients as possible. Traditionally, triage is performed by the triage surgeon by checking triage tags, inquiring about the injury, observing a patient's physiological status and writing triage tags. The efficacy of this classification system relies on the surgeon's personal medical ability and experience, which may not always be accurate [1]. In addition, the paper triage tags are hard to fill out during battle. Traditional paper-based triage tags and instruments cannot meet the needs of battle medical rescue and evacuation in a timely manner in the information age.

Based on actual battlefield needs, we developed triage and evacuation equipment for casualties at sea that successfully achieved the quick triage of mass casualties and the storage and transmission of information during emergency treatment and medical evacuation, which can significantly improve the efficiency and capability of medical rescue on the battlefield.

Design and methods

The triage and evacuation equipment of casualties at sea consists of a high-capacity medical information card, a simulated patient generator, a triage classifier and a multifunctional airbag triage vest. The high-capacity medical information card acts as a carrier to record and transmit information about mass casualties; the classifying surgeon reads the information card with the classifier to describe the integrated casualty information. In training, the simulated patient generator can be used to generate simulated mass casualties from the database; the system can generate a large number of wounded with different kinds of trauma for simulated training, which improves the care providers' treatment capacity. Once the simulated information is received, the triage service module will generate a trauma score, perform triage and transmit the data to the database. Comprehensive

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information about the casualties in the database can be read using the doctor workstation and the nurse workstation and then medical manipulations, such as performing surgery, issuing medical orders, writing triage tags and conducting examinations, can be conducted. The resulting data will then be recorded and analyzed. The system can be used to automate and standardize data and processes, enable faster and more accurate information flow and improve the surgeons' performance. The airbag multifunctional triage vest can effectively protect the safety of the surgeons, who can use the medical equipment to perform the primary treatment. It is very important to have time for effective treatment during the "platinum 10 minutes" and the "golden time" emergency period.

Modules and implementation

High-capacity medical information card

The development of the medical information card has inverted the traditional battlefield paper medical document, which is used to identify wounds and track the casualties' progress through the triage. Since World War, many countries have attached great importance to medical evacuation files and provided their own triage tags and battlefield record formats [2,3]. Some countries use a nationally standardized triage tag, while other countries use commercially available triage tags. However, paper-made records can be easily damaged, which is not conducive to transmitting information to institutions at all levels [4,5]. The medical information card utilizes radio frequency identification technology; a Radio Frequency IDentification (RFID) chip that follows ISO14443 standards is inside and it is protected by a PVC plastic shell that is high- and low-temperature resistant, waterproof and corrosion-proof(Figure 1A).

Using modern information technology, the high-capacity medical information card combines RFID technology with mobile storage technology. The card not only features RFID technology's advantages of low cost, contactless reading and good performance, but it also has the removable storage device characteristics of large storage capacity and high read/write speed. With integrated circuit technology, the card has been extremely compressed to be just smaller than an ordinary ID card and it can be worn around the neck. With chip technology, the card has a high maximum storage capacity of up to 6 GB. A certain amount of information can be stored and the storage space is sufficient to ensure the adequate integrity and consistency of the information store based on actual needs and financial support. In addition, the medical information card requires the use of special tools, including a supporting handheld classifier, a PC add-in card reader (with USB interface) to read and write the information on the card. The card also requires dedicated software to retrieve the information and ensure the information's security, even if the card is lost. With all this technology, the high-capacity medical information card is easy to carry and provide good storage ability, confidentiality and other characteristics.

Simulated patient generator

The simulated patient generator developed by our team can prerecord the wounded models and cases by the simulating a wounded management station before the training and compiling a casualty information database [6]. The simulated patient generator features a master control CPU module, a Wi-Fi wireless transmission module and an RFID reading and writing module. The RFID reading and writing device is compatible with 3 types of standards [7]: ISO14443A/B and IS015693 with a 5-cm reading distance and an RF field work frequency (Fc) of 13.56 MHz. The master control CPU has an ARM processor architecture with such features as small volume, low power consumption, low cost and high performance and the ARM processor has a 32-bit reduced instruction set processor architecture, which has been widely used in many embedded system designs (Figure 1B).

The casualty information database records the basic information of the wounded. During the simulation training process, the casualties' information can be sent from the database to the triage groups according to specified methods. The system can provide specific types of casualties for the medical personnel's simulation training and it can show a variety of trauma types to medical personnel at the same time, which increases the intensity of training and improves the medical personnel's ability to rescue and treat the patients. According to feedback from previous maneuvers, when medical personnel encounter critical patients, they often cannot accurately judge or treat the traumatic condition. Based on traditional traumatic and disease conditions, the patient generator uses a database that contains a variety of traumatic and disease conditions, which has improved medical personnel's mastery of rescuing and treating casualties. After the casualties are classified by the medical personnel who are responsible for the triage work, their information is sent to the group workstation automatically. The doctor workstation and the nurse workstation for every rescuing department is compatible with the Military Health No. 1 System.

Triage classifier

The triage classifier can easily and quickly capture the casualties' information, provide the trauma index and conduct the casualty triage, which can guide the military medical in providing first aid to the wounded and performing medical

evacuations. The classifier transmits real-time casualty information to treatment institutions' servers through wireless LAN and can automatically analyze the information. These data are then transmitted to the base hospital that will receive the patients via telemedicine, which can achieve timely communication with the higher-level hospital. The system is compatible with the COMPASS Navigation Satellite System for real-time communications and is integrated with the Military Health No. 1 System [8]; it supports information reading, storing and sharing and offers information query functions(Figure 1C).

The triage classifier can help the military triage surgeon easily and quickly read the high-capacity medical information card, get complete injury information and fill in the triage tags via a touch screen. The intelligent triage software installed in the classifier can generate a trauma index and provide scientific references for triage judgment. Six types of current international trauma score methods have been integrated into the intelligent triage software, including the Simplified Trauma Score (STS), the Trauma Index (TI), the Pre-Hospital Index (PHI), CRAMS, the Trauma Score (TS) and the Revised Trauma Score (RTS) [9,10]. The Simplified Trauma Score is mainly used in the battlefield trauma assessment and scoring and the other methods are mainly used in non-war military operations, such as military medical support during disaster relief [11]. Introducing trauma scoring methods into mass causalities triage, can increase the accuracy of and scientific support for trauma assessment and can promote the application of information technology to treatment on the battlefield, thus improving its efficiency. Teaching applications of the triage classifier could improve medical personnel's awareness and understanding of information technology equipment development, which is of great importance to battlefield medical treatment.

Multifunctional airbag triage vest

In light of the particularity and complexity of the marine environment and the characteristics of naval medical support, we have designed and developed a multifunctional airbag triage vest dedicated to marine casualty triage. The multifunctional airbag triage vest is wholly composed of an airbag device, a multi-pocket design and fluorescent strips. The airbag device of the multifunctional airbag triage vest is made up of mutually independent airbags, which are up-down extended long strips arranged from left to right [12]. The airbag is connected to a check valve via a pipe. Other components include a safety valve, an automatic valve, a leash, an inflatable nozzle, a buckle, rings and a carbon dioxide cylinder. The airbag device is closely joined with the overall structure of the triage vest in an appropriate manner (Figure 1D).

Longitudinally oriented strip pockets are located outside the front of multifunctional airbag triage vest on the right front of the chest. The square paste area is on top of the pockets. All five of the strip pockets, which are used to place wound markers, correspond to different colors. The paste areas outside of the pockets can be pasted with different colored markers according to the patient's situation. The wound markers are

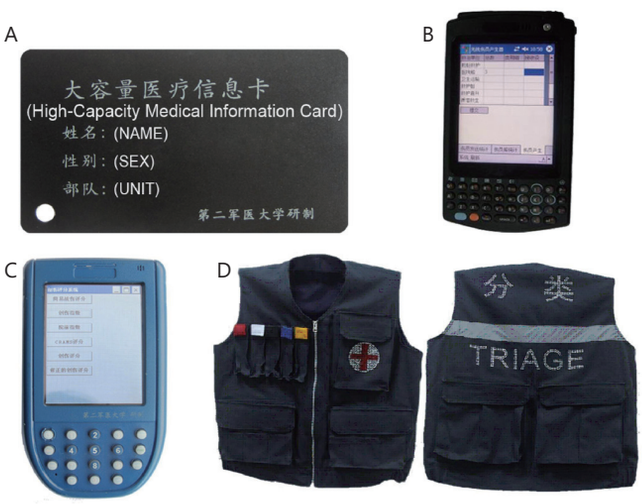

Figure 1 Four modules of triage and evacuation equipment for casualties at sea. (A) The high-capacity medical information card, which has an RFID chip inside and a PVC plastic shell outside, can identify wounds, track the progress of casualties through triage and transmit information to institutions at all levels. **(B)** The simulated patient generator can provide specific types of casualties for the simulation training of medical personnel, which increases the training intensity and improves the rescue abilities of medical personnel. **(C)** The Triage classifier can capture the casualties' information, provide the trauma index and conduct the casualty triage, which can guide military medical personnel in providing first aid to the wounded and performing medical evacuations. **(D)** The multifunctional airbag triage vest is composed of an airbag device, a multi-pocket design and fluorescent strips, and it is capable of carrying wound markers and other medical instruments. Red tags indicate hemorrhage, White tags indicate fracture, Black tags indicate infectious disease, Blue tags indicate radiation disease and Yellow tags indicate biological agents.

15x3.5-cm cloth or plastic strips of a specific color. Wound markers representing different special kinds of injuries can attract the attention of treatment agencies and evacuation staff at different levels to signal a need for prioritized treatment, evacuation or other protective measures for the wounded.

The surgeons who wear the multifunctional airbag triage vest could use personal digital assistant to quickly assess injuries and provide effective and reasonable triage. Furthermore, medical treatment and evacuation can be prioritized according to the injury severity. The multi-pocket layout design of the multifunctional airbag triage vest is capable of carrying wound markers, sorting markers, a sphygmomanometer, a stethoscope, a one-handed tourniquet, hemostatic bandages, roll splints, mouth gags, tongue forceps, dental pads, triangle bandages, gauze and other medical instruments. This design allows care providers to do primary treatment to casualties with specific injuries, which could save time for medical evacuation and further treatment. At the same time, we have specially designed the water-saving device to include mutually independent airbags, which could protect the medical staff's safety by effectively lowering the drowning hazard for marine medical rescue staff in cases of accidental falls into water.

Application and discussion

The triage and evacuation equipment for casualties at sea has played a significant role in guiding the troops' military maneuvers and the hospital maneuvers. In the support maneuvers of non-war military operations organized by the PLA No.411 Hospital and No.413 Hospital and the "Harmonious Mission 2010"and the "Harmonious Mission 2011" held on the No.866 hospital ship, the application of the triage and evacuation equipment improved the overall treatment efficiency and promoted the progress of the security information technology reform, which has been reported by the CCTV. In 2009, the equipment was proven effective and practical by the "2009 Marine Health Service Maneuvers" organized by the Second Military Medical University and the East Sea navy fleet of PLA. In that maneuver, more than 300 casualties were rescued and treated successfully using the equipment, proving that the equipment and the associated information system achieve their general goal and tactical index and were of great help in advancing the modernization and scientific progress of army health service training. The triage and evacuation equipment for casualties at sea takes full advantage of modern information technology to create a convenient classified service operation mode for information about the wounded. It also addresses the traditional triage methods' accuracy deficits, improving the accuracy of and scientific support for injury evaluation and promoting the application of information technology to battle casualty assessment and treatment. The efficiency of naval battlefield treatment has improved as a result.

Abbreviations

PHI: pre-hospital index; RTS: revised trauma score; STS: simplified trauma score; TI: trauma index; TS: trauma score.

Competing interests

XL and GC, inventors of this manuscript, led the study and should be considered as co-corresponding authors. XL and GC are professors and TX, LQ, ZX and XuL are postgraduates of Department of Health Service, The Second Military Medical University, which might have an interest in the submitted work. All other authors (TX, XL, GC, LQ, ZX and XuL) have no financial interests that may be relevant to the submitted work.

Authors' contributions

XL and GC conceived and designed the study. TX wrote the paper. LQ, ZX and XuL contributed to technical or material support. All authors read and approved the final manuscript.

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