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Research Article

First Aid Device for War Entry: Low-Temperature Plasma Jet Coagulation Equipment

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Abstract

Rapid coupling and hypothesis of trauma is the primary task of battlefield first aid At present, homeostatic agents and homeostatic accessories (belts) are the conventional equipment of battlefield first aid homeostasis Bleeding control on the battlefield is a pivotal issue The value of rapid life intervention and rapid Coagulation and hypothesis of trauma has been found through war cases With the rapid development of battlefield coalescence and homeostasis technology, a variety of new homeostatic materials and homeostatic methods have been developed and applied The medical characteristics of low performance plasma, such as coalescence, issue repair, discovery and sterilization, have attracted multiple attention in the medical field, and the R&D and application of related medical equipment have developed rapidly This paper analyzes the homeostatic methods, new homeostatic materials and related products of battlefield trauma first aid, puts forward the coupling and homeostatic mechanism of a portable low performance air plasma jet coupling equipment, of which its characteristics and structural parameters are also presented, and explores its application potential in emergency equipment

Keywords: First aid for war injury; Coagulation equipment; Low-temperate-recontact; Air plasma jet; Po1table equipment

Introduction

On the battlefield, severe trauma can occw· anywhere at any time, with the mam causes of death being bleeding (50%) and nerve trauma (36%), while the rest are devastating multiple injuries. Uncontrollable bleeding is the main cause of death on the battlefield, and effective control of bleeding can reduce the number of preventable deaths [1,2]. Excessive bleeding can reduce blood circulation in the human body, leading to hypoxia in the brain and other organs. Without effective intervention, uncontrollable hemorrhagic shock or other serious damage can occw·. It is recognized from the war that controlling bleeding is a crucial step for injured soldiers before being transfen-ed for treatment or sent to the hospital, and fast and easy-to-use life intervention measw-es play an impo1tant role on the battlefield Bellam [3] mentioned that 2500 American soldiers died in the Vietnam War due to uncontrollable bleeding caused by limb injuries. Even if soldiers who suffered excessive bleeding on the battlefield were transfe11'ed to hospitals for treatment, there was still a considerable amount of casualties' difficulty and risk, such as significant blood loss, increase the likelihood of multiple organ failw-e in the human body [4,5].

At present, the most effective coagulation and hemostasis methods used on the battlefield include hemostatic dressings, hemostatic agents, etc. With the exposure to the side effects of these efficient drugs or equipment, the scope of use and whether it is necessary to use them have become impo1tant issues. The configuration of modem battlefield emergency kits has added special hemostatic drugs and equipment, but conventional drugs are still equipped, Special materials are generally only used when conventional drugs are ineffective. Based on the configw-ation and existing problems of modem battlefield coagulation materials, a portable low temperature air plasma jet (LTAPJ) rapid coagulation device is proposed to achieve rapid coagulation of wounds without side effects and improve the survival ability of battlefield soldiers.

Battlefield Hemostasis Methods and Materials

The shrapnel from weapons and explosive devices on the battlefield causes a large amount of bleeding and trauma. 67% of bleeding injuries are uncontrolled, and 33% can be controlled using hemostatic agents or other hemostatic dressings. Emergency hemostasis and coagulation methods on the battlefield can be divided into chemical drugs, physical methods, and equipment hemostasis. Chemical drugs generally activate endogenous coagulation and interfere with wound thrombin, fibrinogen, and fibrinogen. The concentration of coagulation factors achieves the goal of rapid coagulation and hemostasis. Physical methods include pressurization, packing, etc., which achieve hemostasis by blocking blood flow.

Hemostatic agent

Hemostatic agents block wound blood flow by accelerating the fo1111ation of fibrin or inhibiting fibrin dissolution. War wound hemostatic agents require quick and convenient use. Mineral hemostatic agents mostly increase platelet and coagulation factor concentrations by absorbing water to stop bleeding. The most representative is zeolite. The porous structure of zeolite forms molecular sieves that can selectively absorb water at the wound site without absorbing other substances, making platelets, red blood cells, and coagulation factors these hemostatic factors concentrated, leading to the rapid production of hemostatic clots. Zeolite will generate water absorption and heat release reactions in the process of hemostasis, and the temperature of the wound will rise rapidly, leading to tissue bums and associated complications [6]. Therefore, zeolite is usually used for hemostasis of blood vessels, head and neck arteries, and soft tissue wounds of limbs. The hemostatic agent is in powder fo1111, and the use environment is relatively limited. Gel adhesive is mainly used to seal wounds through tissue adhesion to achieve hemostasis without intrinsic hemostatic activities. Representative hemostatic substances include chitosan and fibrin gel. Chitosan and cellular polysaccharide matrices have similar molecular structures, which can provide a favorable microenvironment for tissue regeneration, and have antibacterial and analgesic effects [7].

Local hemostatic excipients

The development and use of local hemostatic dressings have been a hot topic in the field of hemostasis in recent years. Due to their small size, good portability, and ease of use, they are very suitable for battlefield environments. Cun-ently, there are many hemostatic materials for local bleeding during wartime. The PLA's series of hemostatic products include emergency chitosan hemostatic sponges, polyacrylic acid resm hemostatic dressings, zeolite hemostatic dressings, etc., all of which have significant hemostatic effects. Wound hemostatic dressings are wound dressings that, combined with rapid hemostatic drugs, which can create a hemostatic and wound-healing environment. The prefen-ed hemostatic dressing in the latest TCCC guidelines of the US military in 2016 is the Combat Gauze based on white clay, and other hemostatic dressings provided are the Cellox Gauze and Chito Gauze based on chitosan [8]. In addition to relying on hemostatic materials, there are also some special clotting substances, such as poly (acetamide glucose) and dry fibrin, which belong to natural and human-like tissue clotting materials, and their hemostatic mechanisms are different from the physical methods of general hemostatic agents.

Poly (N-acetylglucosamine) (P-NAG) is a natural and biodegradable polysaccharide that exists m various marine organisms. It can be obtained through fe1111entation or broken down from microalgae. Its coagulation mechanism includes adhesion of tissue, attraction of circulating blood cells, clearance of vascular spasms, etc. This preparation is used to control various minor bleeding injuries, such as peritoneal abrasions [9] intestinal wall incision [10] capillary rupture [11] However, However, all forms of chitin or chitosan are not equally effective, and it is found that they are either very effective [12], either completely ineffective [13] when testing in animal injury models. Thus, it is difficult to use this hemostatic method on nal1'ow, deep, and il1'egularly shaped wounds when working on pads with a flat distribution of hemostatic agents. The active ingredients of dry fibrin dressings are fibrin powder, thrombin, factor XIII, and calcium. Cun-ent research results have shown that in controlling bleeding from various sources, such as liver injury [14] limb ballistic injury [15] aortic puncture [16] the therapeutic effects in various aspects are good. Artificial fibrin and fibrin have the same expensive characteristics, but regrettably it has had not yet been approved for clinical use by the FDA. There is no record or report of their use on the battlefield.

Application of Low-Temperature Air Plasma Jet Oagulation Device

The domestic coagulation and hemostasis methods mainly use zeolite materials, which are improved or combined with other materials such as nanofibers to form quick-acting hemostasis products. The hemostasis equipment is mostly physical therapies such as hemostatic clamps and hemostatic forceps, but there is a lack of quick-acting hemostasis and coagulation instruments on the battlefield. Blood coagulation refers to the use of physiological reactions of blood coagulation to achieve hemostasis, which has the advantages of wide applicability and less susceptibility to environmental impact on hemostasis effects [17]. Coagulation is the final stage of wound hemostasis and healing. Effective coagulation medical equipment can quickly allow bleeding wounds to enter and end the coagulation stage, achieving the goal of wound blood coagulation and wound healing. LTAPJ is an ionizing substance produced by ionizing air at a temperature between 30-40 °C. Its low temperature and rapid and effective coagulation properties make it highly valuable for hemostasis and coagulation in combat injuries. At the same time, LTAPJ coagulation can effectively reduce the harm caused by traditional coagulation and hemostasis processes, such as thermal damage and dmg side effects. In addition, LTAPJ also has medical effects such as wound disinfection, sterilization, and accelerated tissue healing, it has great potential for application in the tiletamine of war injuries.

Coagulation mechanism of low-temperature air plasma jet

The essence of human blood coagulation is the process of converting soluble fibrinogen into insoluble fibrinogen. Wounds in the human body stimulate the aggregation of platelets and coagulation factors, and platelets undergo complex changes to produce thrombin, which converts fibrinogen in plasma into fibrin. The interwoven fibrin causes platelet clots to entangle with blood cells and form blood clots. The application of thermal equilibrium plasma in blood coagulation has been applied in clinical practice for a long time, this plasma coagulation mechanism achieves coagulation by drying the blood and denaturing tissue proteins at high temperatures. LTAPJ contains venous active components, such as charged particles, electi·ons, ions, chemically active substances (ROS, RNS), etc. These components play an important role in the interaction between plasma and living organisms The participation of LTAPJ in the coagulation process is mainly manifested in the following three aspects: (1) LTAPJ stimulates wounds, induces accelerated aggregation of platelets and coagulation factors [18].

The charged particles generated by LTAPJ can activate endogenous coagulation in the human body, promote rapid aggregation of platelets and coagulation factors in the wound, and accelerate the coagulation process; (2) The final step in the coagulation process is the production of thrombin, which converts fibrinogen into fibrin monomers and aggregates to form fibrin microfilaments. After plasma treatment, the blood appears as a glomerular structure, which is analyzed as blood protein. Plasma treatment-induced coagulation of blood protein is one of the reasons for accelerating natural coagulation. LTAPJ can ti·eat fibrinogen solution in physiological media and coagulate it, which is confirmed by changing the color of the solution (from ti·ansparent to milky white) and dynamic light scattering (DLS) [19] LTTPJ polymerized fibrin is shown in (Figure 1) (3) LTAPJ micro-current can dissolve red blood cells and release hemoglobin, which helps to stop the formation of blood clots. Coagulation tests show that when the measured cmTent is greater than 0.4mA, clots quickly form on the surface of the whole blood sample [20]. LTAPJ can ensure that the coagulation of the wound is completed at a speed 3-5 times faster than the natural coagulation process, and the coagulation process will not cause additional in-itation to the wound. The coagulation effect ofLTAPJ is shown in (Figure 2)

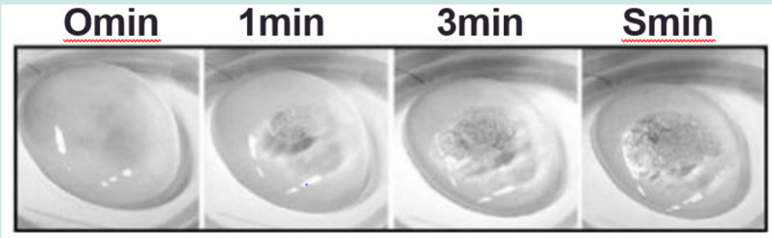

Figure 1: Changes in fibrinogen aggregation over time after plasma treatment

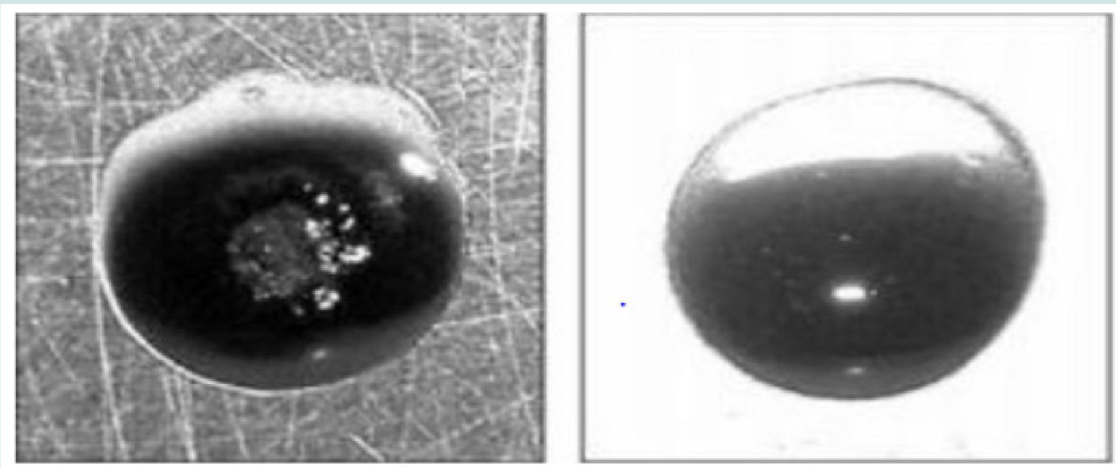

Figure 2: Coagulation effect of low-temperature air plasma jet Left: Plasma treatment for 15 seconds; Right: Blood left for 1 minute

The tissue healing, disinfection, and steri I ization effects of low-temperature air plasma jet

LTAPJ also has medical application value in tissue healing disinfection and sterilization. LTAPJ accelerates the coagulation of war wounds, while its active substances can disinfect and sterilize the wound site and quickly promote wound tissue healing. The portable LTAPJ coagulation device prepared by utilizing the excellent medical characteristics of LTAPJ has high application potential in battlefield emergency treatment. Tissue repair is based on the generation of reactive oxygen species (ROS), especially superoxide and hydrogen peroxide promote the release of vascular endothelial growth factor and wound healing, improving the cell density of the super value-added area of wound epithelial cells, deposition of connective tissue, and tissue structure. LTAPJ's disinfection and sterilization capability mainly rely on high-energy electron breakdown to destroy the membrane structure of bacterial cell walls, strong oxidizing active substances to oxidize and inactivate bacterial cells, and trace amounts of ultraviolet radiation to destroy DNA genetic material.

Construction of portable low-temperature air plasma jet coagulation equipment

LTAPJ is an ideal clotting substance that has no toxic side effects on wounds. It can compensate for the shortcomings of drug clotting to a certain extent, providing a new hemostatic method for battlefield wounded. The product is easy to cany and simple to use. The plasma clotting device consists of the shell, jet nozzle, vent-plug, button, display screen, charging port, rubber plug, discharge electrode, high-voltage circuit module, micro air pump, control circuit module, and battery. The discharge circuit module is composed of a portable LTAPJ coagulation device, as shown in (Figure 3). The device uses an integrated control circuit to generate specific frequency PWM waves and achieve functional control of buttons, screens, etc. The high-voltage circuit module drives the MOS transistor power amplification, and then the high-frequency high-voltage electricity is generated by the high-voltage package and transmitted to the plasma nozzle. The plasma nozzle is composed of discharge electrodes, nozzles, and ceramic cavities, A high-frequency and high-voltage electric field is fonned between the discharge electrode and the nozzle to ionize the air in the space, forming a plasma jet. Under the action ofa strong gas source, the LTAPJ jet is formed outward through the nozzle. Based on the portable working mode on the battlefield, it has a built-in lithium battery power supply, and the shell and internal components are configured according to military three defense standards to ensure normal use in the ever-changing environment of the battlefield (Figure 3).

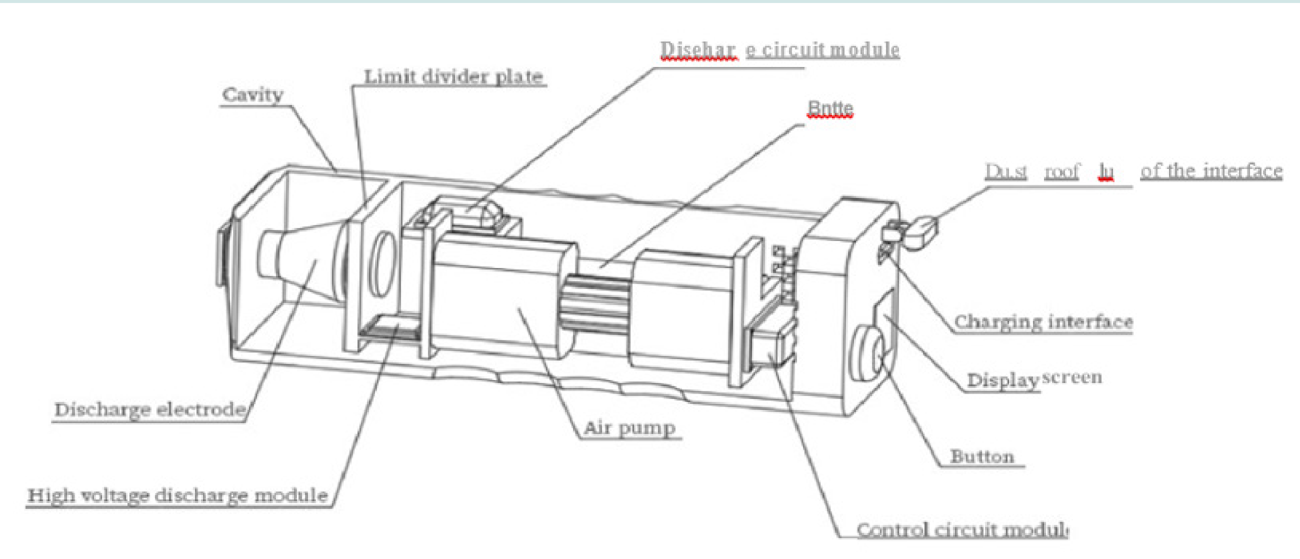

Figure 3: Schematic diagram of the structure of a portable low temperature air plasma jet coagulation device

This special LTAPJ coagulation device can be applied to the rapid hemostasis and disinfection of individual combat injuries in complex emergency environments. When applied to shallow epidermal wounds with a diameter of less than 3cm, it can quickly coagulate the wound, avoiding the traditional hemostatic techniques such as physical compression tourniquets and chemical hemostatic agents, i.e. insufficient blood supply to the limbs due to prolonged compression time, and excessive iITitation of chemical hemostatic agents to the wound. In general, wound hemostasis and disinfection cannot be caITied out simultaneously by the device. The multiple active ingredients contained in the plasma jet can be used to sterilize and disinfect the wound while undergoing hemostasis treatment, avoiding problems such as bacteremia caused by untimely disinfection of the wound and effectively improving the sw-vival rate of injured personnel.

Summary

On modern battlefields, wars tend to be fragmented, and individual combat is being caITied out. First aid work on the battlefield tends to be self-rescue and mutual aid under the complex environment, which requires portable and operable first aid equipments. Portable LTAPJ coagulation device can be used as a good first aid configuration for individual combat due to its fast coagulation effect and easy portability. Based on the characteristics of LTAPJ's rapid coagulation, wound healing, disinfection, and sterilization, the developed small and portable coagulation device can meet the requirements of convenient and rapid coagulation in complex battlefield environments. The application of a portable LTAPJ coagulation device in battlefield wound coagulation can provide a new type of coagulation method for trauma emergency treatments, improve the prevention and control ability and emergency level of battlefield wound bleeding.

Acknowledgment

None.

Conflict of Interest

None.

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