

# First Aid Device for Emergency Entry: Low-temperature Plasma Jet Coagulation Equipment

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**Abstract:** Bleeding control in emergency is a pivotal issue. The value of rapid coagulation of trauma has been found through emergency cases. With the rapid development of coagulation and homeostasis technology, a variety of new homeostatic materials and methods have been developed and applied. This paper depicted the potential application of a portable low-temperature air plasma jet coagulation equipment, of which its medical characteristics such as coagulation, issue repair, disinfection and sterilization as well as its construction were presented.

**Keywords:** First aid device; Low-temperature air plasma jet; Coagulation technology; Portable equipment

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## Introduction

Uncontrollable bleeding is the main cause of death in emergency, and effective control of bleeding can reduce the number of preventable deaths<sup>[1]</sup>. It is recognized that controlling bleeding is a crucial step for the injured before being transferred for treatment, and fast and easy-to-use life intervention measures play an important role in emergency. Bellamy mentioned that 2500 American soldiers died in the Vietnam due to uncontrollable bleeding caused by limb injuries<sup>[2]</sup>. Even if soldiers who suffered excessive bleeding were transferred to the hospitals for treatment, there was still a considerable amount of casualties difficulty and risk<sup>[3,4]</sup>.

At present, the most effective coagulation and hemostasis methods used in emergency include hemostatic dressings, hemostatic agents, etc. With the exposure to the side effects of these efficient drugs or equipment, the scope of use and the necessity to use has become important issues. In this work, a portable low-temperature air plasma jet (LTAPJ) coagulation device is proposed to achieve rapid coagulation of wounds without side effects.

## 1. Emergency hemostasis methods and agents

Rapid hemostasis and coagulation methods can be divided into chemical drugs and physical methods. Chemical drugs generally activate endogenous coagulation and interfere with wound thrombin, fibrinogen, and fibrinogen. Physical methods include pressurization, packing, etc., which achieve hemostasis by blocking blood flow.

Hemostatic agents block wound blood flow by accelerating the formation of fibrin or inhibiting fibrin dissolution. Zeolite is the most representative due to its molecular sieves that can selectively absorb water at the wound site without absorbing other substances, making platelets, red blood cells, and coagulation factors concentrated, leading to the rapid production of hemostatic clot<sup>[5]</sup>. The use of local hemostatic dressings have been a hot topic in the field of hemostasis in recent years. The preferred hemostatic dressing of the US military is the Combat Gauze based on white clay, and other hemostatic dressings provided are the Cellox Gauze and Chito Gauze based on chitosan<sup>[6]</sup>.

## 2. Application of LTAPJ coagulation device

The hemostasis physical therapies mainly are hemostatic clamps and hemostatic forceps, but there is a lack of quick-acting hemostasis and coagulation instruments<sup>[7]</sup>. 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 with a temperature between 30-40 °C. Its low temperature and rapid effective coagulation properties make it highly valuable for hemostasis and coagulation. Meanwhile, LTAPJ coagulation can effectively reduce the harm caused by traditional coagulation and hemostasis processes, such as thermal damage and drug side effects. Meanwhile, LTAPJ contributes to wound disinfection, sterilization, and accelerated tissue healing.

## 2.1 Coagulation mechanism of LTAPJ

LTAPJ contains various active components, e.g., charged particles, electrons, ions, chemically active substances (ROS, RNS), etc. which play an important role in the interaction between plasma and living organisms. The participation of LTAPJ in the coagulation process is mainly manifested as: (1) LTAPJ stimulates wounds, induces accelerated aggregation of platelets and coagulation factors<sup>[8]</sup>. The charged particles 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 as shown in Fig 1. After plasma treatment, the blood appears as a glomerular structure, namely the blood protein. Plasma treatment-induced coagulation of blood protein is one of the reasons for accelerating natural coagulation which is confirmed by changing the color of the solution and dynamic light scattering<sup>[9]</sup>; (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 current is greater than 0.4mA, clots quickly form on the surface of the whole blood sample<sup>[10]</sup>. LTAPJ can ensure that the coagulation of the wound is completed at a speed 3-5 times faster than the natural coagulation process (shown in Fig 2), and the coagulation process will not cause additional irritation to the wound.

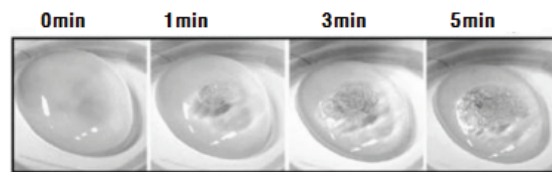


Fig 1. Changes in fibrinogen aggregation over time after plasma treatment

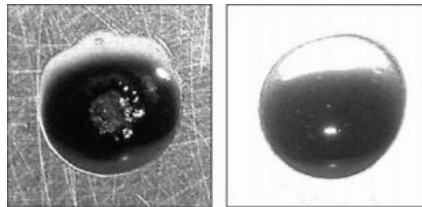


Fig 2. Coagulation effect of LTAPJ (Left: Plasma treatment for 15s; Right: Blood left for 1min)

## 2.2 The tissue healing, disinfection, and sterilization effects of LTAPJ

LTAPJ also has medical application value in tissue healing, disinfection and sterilization. It accelerates the coagulation of wounds, while its active substances can disinfect and sterilize the wound site and quickly promote wound tissue healing. Tissue repair owes to the reactive oxygen species (ROS), especially superoxide and hydrogen peroxide which promote the release of vascular endothelial growth factor and wound healing, improving the cell density of wound epithelial cells, the deposition of connective tissue and tissue structure. The disinfection and sterilization capability mainly rely on: 1. high-energy electron breakdown to destroy the membrane structure of bacterial cell walls; 2. strong oxidizing active substances to oxidize and inactivate bacterial cells; 3. trace amounts of ultraviolet radiation to destroy DNA genetic material.

## 2.3 Construction of portable LTAPJ coagulation equipment

The LTAPJ is easy to carry and simple to use, it 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, as shown in Fig 3. The device uses

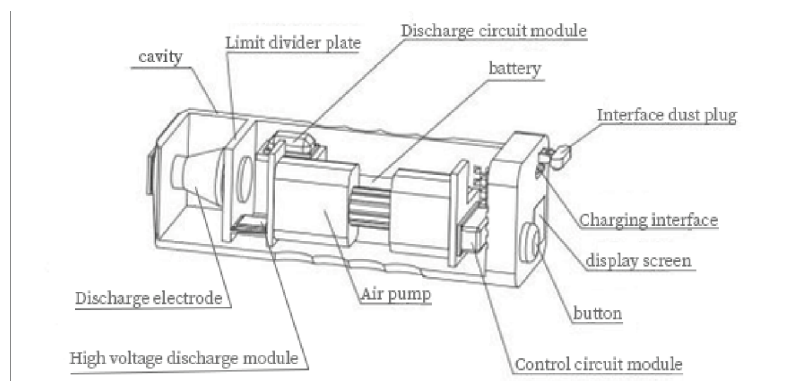


Fig 3. Schematic diagram of the structure of a portable LTAPJ coagulation device

an integrated control circuit to generate specific frequency PWM waves and achieve functional control of buttons, screens. The high-frequency high-voltage(HFHV) circuit module transmits the working gas to plasma jet through the plasma nozzle which is composed of discharge electrodes, nozzles, and ceramic cavities.

When applied to shallow epidermal wounds with a diameter of less than 3cm, it can quickly coagulate the wound, avoiding insufficient blood supply to the limbs due to prolonged compression time, and excessive irritation of chemical hemostatic agents to the wound. 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.

### 3. Summary

First aid work in emergency tends to be self-rescue and mutual aid under the complex environment, which requires portable and operable first aid devices. Based on the LTAPJ's rapid coagulation, wound healing, disinfection, and sterilization characteristics, the developed small and portable coagulation device can meet the requirements of convenient and rapid coagulation in complex emergency environments as a new type of coagulation device for trauma treatment.

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