Research and Development of Intelligent Clothing for Subaxillary lymphedema Protection

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Abstract. In view of the problem that patients with subaxillary lymphedema are prone to recurring edema after treatment, a wearable edema monitoring and alarm system is designed to enable the wearer to effectively monitor the edema state, to avoid the pain caused by arm edema. The system uses FSR resistive ribbon film pressure sensor, voltage conversion module, and arduino control board FLORA as the control core. The electronic components are combined with the clothing. The sensor converts the pressure signal to the voltage conversion module. When the pressure value of the wearer's arm edema exceeds the voltage conversion module threshold, the buzzer and threshold value LED light will send out an alarm signal. FLORA is connected with the voltage conversion module to detect real-time edema pressure data. Considering the wearability of the electronic module and the washability of the long-sleeved shirt, the FSR resistive ribbon film pressure sensor is designed around the upper arm of the long-sleeved shirt, the voltage conversion module and the arduino control board FLORA are placed in pocket of the long-sleeved shirt to realize the research and development of subaxillary lymphedema protective intelligent clothing.

1. Introduction
Subaxillary lymphedema is one of the common complications after surgery, which seriously affects the physical and mental health of patients, causes dysfunction of the affected limbs, and aggravates the occurrence of negative emotions such as postoperative anxiety and depression [1]. How to effectively prevent and care for lymphedema of the affected limb is the key to the treatment of postoperative patients [2]. This article’s subject is subaxillary lymphedema, develops wearable intelligent clothing, which is detects the wearer's edema state, and reminds the wearer to stop working then take a proper rest to avoid the pain caused by arm edema with overwork.

2. Subaxillary lymphedema

2.1 Symptoms of subaxillary lymphedema
Swelling and pain are common symptoms of patients after surgery. 72 hours after surgery is the peak period of edema. The patient manifests as heaviness of limbs, numbness, discomfort, elevated skin temperature, and restricted mobility. Inflammation after trauma will aggravate the swelling of the limbs. If the swelling cannot be relieved in time, it will cause limb pain and decreased joint mobility.
Swelling can also aggravate the patient's pain, especially during physical activities or walking, and affect the patient's recovery [3].

2.2 Treatment methods
Traditional swelling treatment methods include ice compress, elevating the affected limb, functional exercises, air pressure therapy, drug therapy, Chinese acupuncture, etc. These methods are effective, but it takes a long time to reduce swelling [4]. At present, the most commonly used is the comprehensive decongestion therapy (Complete Decongestion Therapy, CDT). Which is an improved method to reduce swelling on the basis of manual lymphatic drainage (manual lymphatic drainage, MLD) proposed by German doctor Foeldi in the 1980s. CDT adding personalized Skin care, elastic bandage dressing and functional exercise [5].

2.3 Patients with subaxillary lymphedema's demand to intelligent clothing
Subaxillary lymphedema leads to axillary lymph swelling and the arm swelling. Patients need to strengthen proper care after the operation to prevent the arm from swelling due to prolonged work or natural sagging. On the one hand, clothing fabrics require high elasticity, softness and comfort; on the other hand, intelligent clothing with a wearable detection and alarm system is required to enable the wearer to detect edema in real time and avoid severe edema in the arm causing pain.

3. Intelligent clothing

3.1 Definition of intelligent clothing
Intelligent clothing is also called functional clothing, which refers to clothing that contains special functions and is combined with technology to meet the needs of special groups. It has the characteristics of multi-discipline and intersecting integration. It combines artificial intelligence electronic components with clothing styles, fabrics, colors, etc., to achieve functions such as big data, information perception, and alarm prompts to provide intelligent services for special groups of people.

3.2 Application paths of intelligent clothing

3.2.1 Fitness and entertainment. Fitness and entertainment intelligent clothing is mainly for the convenience of fitness people, through special fabrics, let clothing achieve a certain fitness function, and accelerates the human experience of intelligent clothing. For example, the Athos intelligent fitness clothing developed by Canadian scientific research institutions, if you look at this clothing only from the appearance, it is not much different from ordinary clothing worn by fitness enthusiasts or professional athletes, but the designer uses information interactive technology such as Bluetooth and software APP. Bringing a humanized and technological fitness experience to consumers should be one of the most humanized and fully functional clothing in the field of intelligent clothing development at this stage [6].

3.2.2 Healthcare Currently. At present, the market for medical and healthcare intelligent clothing is the broadest. With the intensification of population aging, the incidence of various diseases has increased, and consumers' awareness of health care has continued to increase. For example, Singapore developed a "memory shirt" in 2004, which senses whether the user falls down through an internal silicon sensor device and sends a warning to the custodian [7].

3.2.3 Military equipment. The development of material technology has brought new vitality to intelligent clothing. For example, the military port fabric developed by the team led by Chinese academician Yao Mu is made of multiple multi-different composite chemical fiber filament fabrics. It has the advantages of antistatic, anti-wrinkle, easy to clean and dry, and has become a new generation of military uniform fabrics in China [8].
4. Research and development plan for electronic module of intelligent clothing for subaxillary lymphedema protection

Subaxillary lymphedema intelligent clothing monitoring and alarm system is composed of FSR resistive ribbon film pressure sensor, voltage conversion module, threshold LED indicator, arduino control board FLORA, buzzer, optocoupler, etc. The system has the functions of collecting and processing the value of the wearer's arm edema pressure change. The FSR resistive ribbon film pressure sensor converts the pressure change of the subaxillary lymphedema into resistance change, and outputs it to the pressure conversion module. The potentiometer on the pressure conversion module can adjust the threshold value and set the alarm threshold, and divides the corresponding value of subaxillary lymphedema into two grades: mild and severe. When the pressure of the wearer's arm swelling on the sensor exceeds the set threshold, the threshold switch indicator of the voltage conversion module will light up, and the optocoupler will trigger the buzzer to sound after sensing the brightness of the indicator, then the alarm system will start. The subaxillary lymphedema intelligent clothing monitoring and alarm system uses the arduino control board FLORA as an independent unit. When the wearer's edema frequently occurs, it is connected to other modules to obtain real-time edema pressure data and provide the data to the doctor for assistance in treatment. It can be taken out when the edema is stable. The structure diagram of the electronic alarm system is shown in Figure 1.

![Figure 1. Structure diagram of electronic alarm system](image1)

4.1 Arduino platform introduction

Arduino is an open source electronic prototype platform, including hardware (Ardui-no control board) and development software (Arduino IDE). The arduino system is established on the basis of the Java language, and there are also abundant open source codes on the Internet for reference [9].

4.2 Design of monitoring and alarm system for subaxillary lymphedema

4.2.1 Signal acquisition. FSR Resistive ribbon film Pressure Sensor Figure 2 is used as the basis of the subaxillary lymphedema signal acquisition module, put the sensor surround the outer side of the upper arm of the long-sleeved shirt. When the wearer's arm becomes thicker because of edema, the sensor senses pressure changes and collects pressure data.

![Figure 2. FSR Resistive ribbon film Pressure Sensor](image2)
4.2.2 Signal Processing. The pressure sensor converts the pressure change of subaxillary lymphedema into a resistance change, and the pressure curve is shown in Figure 3. The original pressure resistance signal of subaxillary lymphedema collected by the sensor, the voltage conversion module converts the resistance signal change into a voltage change 0-3V range and switch signal, the voltage signal can be more easily read by the arduino control board FLORA.

![Pressure Curve](image.png)

**Figure 3.** Pressure curve change diagram

4.2.3 Signal monitoring. The signal monitoring consists of the arduino control board FLORA, the adjustable threshold potentiometer in the voltage conversion module, and the buzzer. The potentiometer judges determines the threshold of the wearer's pressure data. When the pressure exceeds the threshold adjusted by the potentiometer, the threshold switch indicator LED will light up, and the photocoupler will drive the buzzer to alarm. It is reminded that patients should rest immediately to avoid discomfort caused by edema. When the pressure is lower than the threshold, the threshold switch indicator LED goes out. Arduino control board FLORA outputs the voltage signal as digital, which is used for arduino programming and real-time status recording of edema.

5. Research and development plan for wearable design of intelligent clothing for subaxillary lymphedema protection

5.1 Arduino control board FLORA, FSR resistive ribbon film pressure sensor, voltage conversion module and long-sleeved shirt

FLORA is a miniature wearable and washable control board, which can be programmed with arduinoIDE development software. FLORA can be stitched on common fabrics, connected by conductive sewing thread, and control the input module and output module. In the future intelligent clothing design, it will be widely used [10]. By combining the arduino control board FLORA, the voltage conversion module with the pocket of the long-sleeved shirt, and the FSR resistive ribbon film pressure sensor is placed in the upper arm of the long-sleeved shirt with a ribbon-like structure. The long-sleeved shirt is made of high-stretch fabrics. The flap pockets are designed on the sides of the two sleeves, using for the built-in voltage conversion module; the patch pockets are designed on the chest of the body for putting the FLORA control board inside. When not wearing, the control board and voltage conversion module can be taken out of the pocket to clean the long-sleeved shirt. The wearable design is shown in Figure 4.

![Wearable Design](image.png)

**Figure 4.** Wearable design of FSR resistive ribbon film pressure sensor

5.2 Wearable design of FSR resistive ribbon film pressure sensor

A strip of 6cm wide and 35cm long is sewn on the upper arms of the two sleeves to place the FSR resistive ribbon film pressure sensor. The end of the sensor is connected to voltage conversion module, and the pressure changes by sensing the thickening of the arm to collect Pressure data.
5.3 Wearable design of voltage conversion module
For the long-sleeved shirt, the flap pocket is designed on the upper arm of the left and right sleeves, and the voltage conversion module is attached inside bag. The bottom of the pocket has a hole for connecting the FSR resistive ribbon film pressure sensor.

5.4 Wearable design of FLORA
The long-sleeved shirt is designed with a patch pocket on the left and right chests of the body, and the FLORA board of the arduino control board is attached to the pocket to facilitate the needs of patients with different limbs. Through the above data collection and monitoring, the effect of preventing edema is achieved.

5.5 Long-sleeved shirt and pocket design

5.5.1 Style design. On the one hand, considering the ease of putting on and taking off the patient's armpits and arms, the style adopts raglan sleeves with high range of motion; on the other hand, to avoid swelling of the affected limb by mosquito bites, long sleeves are used. Both sleeves of the long-sleeved shirt are equipped with flap pockets. According to the patient's lymphedema, the voltage conversion module is placed in the bag to avoid falling off; ribbons are sewn on the left and right upper arms for FSR resistive ribbon Placement of the membrane pressure sensor; patch pockets are sewn on the left and right chests to place the FLORA control board, monitor the circumference of the arm, and take out the control board and voltage conversion module when washing. The size of the long-sleeved shirt is 165/84A, the length is 61cm, the bust is 104cm, the sleeve length is 67cm, and the cuffs are 21cm.

5.5.2 Color design. In terms of color selection, use pure or light colors with less dyeing process. Consider that the patient's limb skin is too transparent and sensitive when edema. It is not suitable to wear clothing with more complicated dyeing steps to prevent skin allergies. Therefore, it is mainly white, light blue and light pink.

5.5.3 Fabric design. The discomfort caused by subaxillary lymphedema of patients has become more urgent for clothing fabrics. The elasticity requirements for the fabric texture are high, ordinary clothing fabrics are generally elastic, and the comfort is low when the patient wears, especially when the arm edema level is high, resulting in restraint or even inability to wear, so the long-sleeved shirt uses elastic fabrics, its composition is 90% polyester fiber and 10% spandex to ensure that the resistance is reduced during the putting on and taking off.

6. Conclusion
This article has carried out the research and development of protective intelligent clothing for patients with subaxillary lymphedema, comprehensively using the arduino control board FLORA, FSR resistive ribbon film pressure sensor, voltage conversion module, long-sleeved shirt design (the flap
pocket, the patch pocket). Design and other technologies, design and develop wearable long-sleeved shirts and intelligent clothing with arduino as the control core, buzzing alarms for the severity of arm edema, reminding patients to rest. The intelligent clothing initially realizes the function of preventing postoperative edema and pain of the subaxillary lymphedema due to long working time. In the future, it can be optimized from the perspective of zero-touch fabrics and textile flexible sensors to improve the comfort and sustainability of patients’ wearing.

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