

Design and Experimentation of a Low-cost Exertion Gauntlet for Lymphedema

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Introduction:

With 250 million patients worldwide, chronic lymphedema patients have to regularly massage to mediate the discomfort of the swelling for daily life activities. Lymphedema is a non-curative swelling of different body parts due to the damaged lymphatic system. If left untreated, severe lymphedema can lead to serious complications such as permanent skin damage, infections, and even skin cancer. Lymphedema is most commonly caused by lymph node removal or damage due to cancer treatment. A specialized method of gentle massage known as Manual Lymphatic Drainage (MLD) is effective, but treatments are hampered by distance, high cost and accessibility of specialists. Complex decongestive therapy (CDT) is the gold standard in the therapy of lymphedema. Compression bandaging is a vital component of CDT. Another treatment, a lymphedema compression pump includes a complex and bulky system. Therefore, an exertion gauntlet consisting of various massage patterns can safely and gently interact with humans proving more efficient than the existing methods.

In this proposed methodology, an exertion gauntlet is designed. The device has 3 stages for each staging level of lymphedema namely, Static vibration apparatus, Vertical massage apparatus and Circular massage apparatus. The experimentation of applied pressure over the arm muscles is initiated by this apparatus around various pressure points and the results are analyzed for lymphedema. Various features of this device like cost-effectiveness, portable device and non-reliability on massage therapists make the device novel, affordable and easy to handle.

Objectives:

Problem Statement

“Given a patient with lymphedema, the problem addressed is to build non-invasive electro mechanical exertion devices for drainage of excess lymph fluid from the affected areas through various automated exertion activities.”

The objective of the proposed work is to:

- Study relevant lymphatic fluid drainage systems.
- Study the relevant method for the classification of severity scale of lymphedema.
- Model the testing prototypes to satisfy various severity levels of lymphedema.

- Build an extensible exertion gauntlet to perform a set of lymphatic exercises.
- Monitor and assess the results through a pilot study.
- Convert the design into a product-based edifice.

Methodology:

In this proposed methodology, a massager is designed which is user-friendly and does not require additional manual support. This massager is self-operated and according to the requirement, various lymphedema exercise patterns can be set to help the flow of lymphatic fluid.

Note: Stage in Fig.1. is based on graded scales.

The initial workflow of the proposed methodology is:

- Generate air pressure to tighten the sleeve.
- Select the severity level of lymphedema prescribed by a physician.
- Based on the severity level of lymphedema, a particular massage pattern/ therapy is set.
- When a user selects a particular therapy, the microprocessor sends commands to the various massage apparatus.
- If the user selects level 1: Low Vibration Pattern apparatus is set on. Users can adjust the intensity of the massage using the I/O device.
- If the user selects level 2: First Low vibration pattern is on, then Medium Vibration Pattern apparatus is set on. Users can adjust the intensity of the massage using the I/O device.
- If the user selects level 3: First Low vibration pattern apparatus is on, then the Medium Vibration Pattern apparatus is set on and finally High-Pressure Pattern apparatus is set on. Users can adjust the intensity of the massage using the I/O device.
- All the apparatus will be run repeatedly until the swelling reduces to an extent.

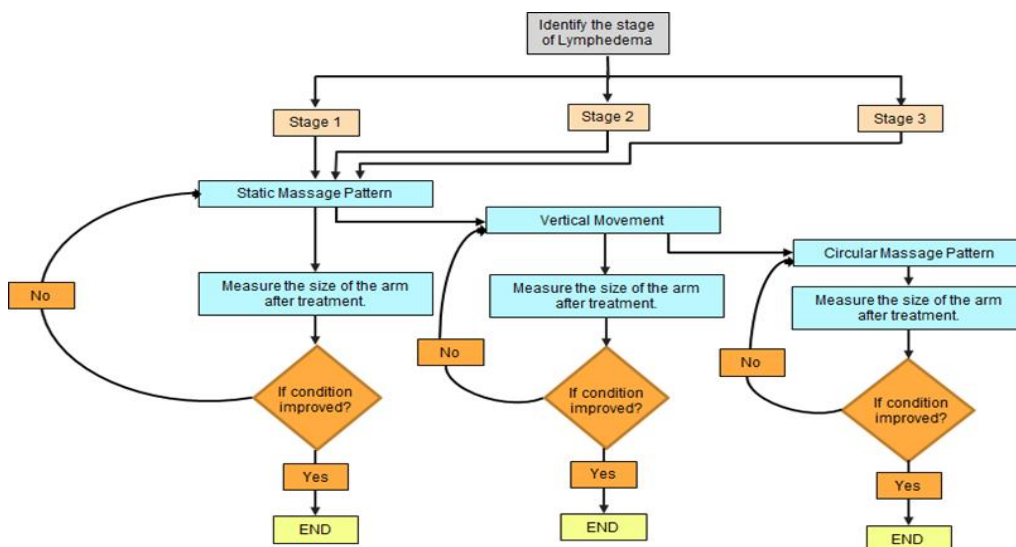


Figure 1: Work Flow

Hardware Implementation:

In this proposed methodology, a massager is designed which is user-friendly and does not require additional manual support. This massager is self-operated and according to the requirement, various lymphedema exercise patterns can be set to help the flow of lymphatic fluid.

Components used:

Coin Vibration Motors, Arduino Uno's, IRF520 Power MOSFETs, 1N4007 Diodes, Castor Wheels, Servo Motors, Gear Motors, Rack and Pinion setup, Air Compression Pump.



Figure 2: Stage 1 Setup

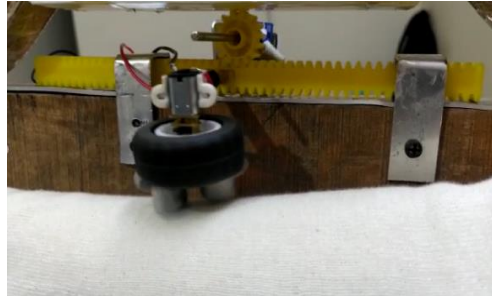


Figure 3: Stage 2 Setup

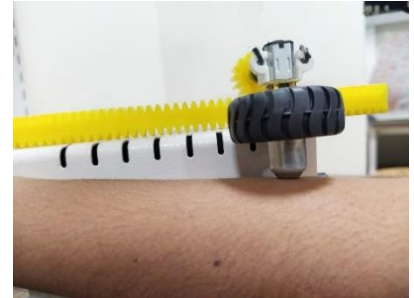


Figure 4: Stage 2 Setup

PCB Design:

The PCB design and fabrication for the proposed circuit has been carried out and design snippet is attached below:

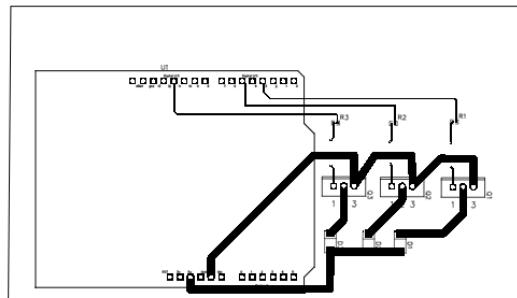


Figure 5: PCB Design

Software Implementation:

Simscale software is used to validate the proposed methodology and helps to validate the results. In accordance with the mapping of the affected region, the vibrator having the frequency of 16k pa are been considered and placed on the nodes, the pressure acting inwards the walls of the blood and the frequency produced by the vibrators are been balanced and hence make the blood to flow in the normal flow rate that the velocity ranging from 0.1 to 0.6 m/s , thus the below fig 7, depicts the similar mechanism after the effect of vibrator coins or motors once they are placed in proper condition as a result the in reference with velocity magnitude scale the blue region is the most acceptable region for the normal flow of blood.

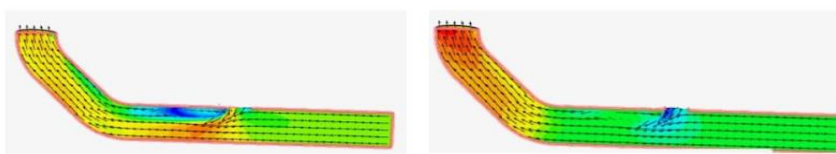


Figure 6: Patient hand before the pressure is applied

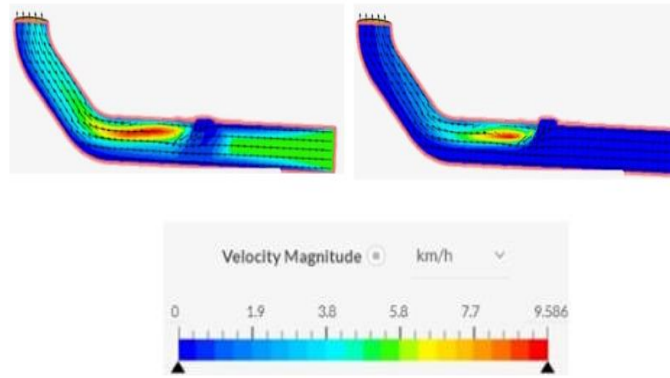


Figure 7: Patient hand after applying the pressure

Results:

This massager is expected to be self-operated. As followed by the various manual massaging techniques, both the absorption and clearance steps can be achieved by glove’s massaging apparatus which consists of massaging balls with vibration mechanism. According to the requirement, pressure can be varied by using various lymphedema exercise patterns to help the flow of lymphatic fluid.

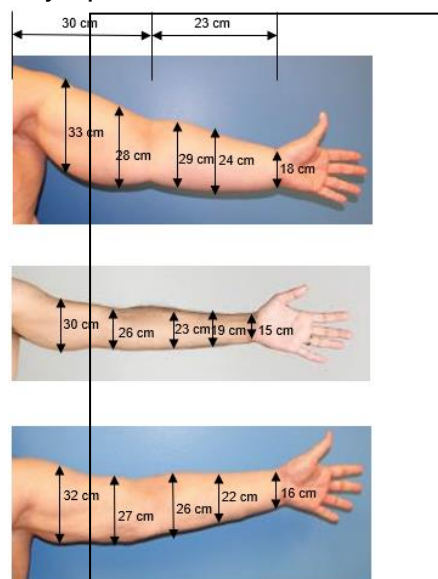


Figure 8: Experimental Results

The proposed work serves as preliminary research in the development of lymphedema massaging modules that can be integrated into an aesthetically pleasing wearable device for more efficient treatment. Many female mastectomy survivors suffer from truncal and upper body lymphedema, therefore a self-operated hand massager with various lymphedema exercise patterns helps the flow of lymphatic fluid.

Scope for future work:

The device is expected to overcome the limitations and difficulties faced by the lymphedema patients using existing methods. Various features of this device like cost effectiveness, portable device and non-reliance on massage therapists makes the device novel, affordable and easy to handle.

Comparison of existing methods in term of cost:

Table No. 1

Sl. No.	Existing Methods	Features and limitation	Cost
1	Pneumatic Compression Devices	Provides an enhancement of the therapeutic response. Complex and Bulky System.	21,000 to 48,699 INR
2	Manual lymphatic drainage	MLD helps to speed up lymph fluid flow through the lymphatics. Reliance on a provider for treatment.	8,824.50 INR to 17,650.92 INR
3	Complex Decongestive Therapy and Physiologic Surgical Procedures	Shows promising results in early stages of the disease. If the patient presence in later stages of the disease, Complex surgeries may be involved.	Upto 58,832.64 INR per year.
4.	Low-Cost Full Arm Exertion Gauntlet for Lymphedema	Various automatic massage patterns inspired by traditional massage therapy/manual lymphatic drainage. Cost effective and portable device. Non reliability on massage therapists.	5000 to 6000 INR

Application of the project:

1. Lymphedema Patients (outcome of lymph node removal due to malignant tumors).
2. Elephantiasis (Lymphatic Filariasis).
3. In the initial stages of Cognitive Decongestive Therapy.
4. Pain and Palliative Care.