PleuraPro: An Effective Pleural Effusion Drainage System

Adhora Madhuri[1], Nusaiba Sobir[1], Tasnia Binte Mamun[1], Dr. Kazi Saiful Islam[2], Mohammed Tarik Arafat[1], Taufiq Hasan Al Banna[1], Jahid Ferdous[1], Nusrat Binta Nizam[1], Shams Nafisa Ali[1]

[1]Bangladesh University of Engineering & Technology (BUET), Dhaka, Bangladesh.
[2]National Institute of Diseases of the Chest and Hospital

Problem description:

Fig 1: Existing Chest Drain Bag

One of the most frequent complications of coronary artery bypass grafting and thoracic surgery is **pleural effusion** i.e., buildup of fluid between the layers of tissue that line the lungs and chest cavity[1]. Pleural effusions may delay recovery, predispose to other post-operative complications such as **Thoracic empyema**, an infectious process defined by frank pus in the pleural space.[2] In resource-constrained regions like Bangladesh, hospitals struggle with the cost of advanced equipment like the Medela Thopaz[3] to address postoperative challenges of pleural effusions. Chest drain bag, that costs $2.20, is used as a cheaper alternative to drain fluid from patients. However, according to feedback from healthcare professionals, the bag has several issues: A tube that is connected with chest tube must be submerged under 2 cm of water to prevent pneumothorax; respiratory distress also occurs when more than 250 mL of lung fluid is drained at once after draining the initial 1L; continuous monitoring is necessary to avoid lung fluid overflow from tilting or when it's full; bag is made of soft plastic so need to be hung properly; besides the one-time usable plastic bag adds to pollution in Bangladesh.
To address these issues, we have designed a user-friendly, cost-effective solution named **PleuraPro** for ensuring better patient management.

Solution concept:

Our designed device has two parts- Drainage container and Alarm system part. The enhancements incorporated into our device are-

(1)A silicone rubber one-way valve, eliminating the need of water seal system like bag. This valve prevents backflow of air. **(2)** Alarm system to detect two water levels- 250 mL and 500 mL (notify when storage is full). Both water level detectors can be controlled independently with two different switches. The system also prevents leakage of water if the container tilts thus making it motion sensitive. Utilizing MOSFET technology which minimizes current passing through the fluid (4.5×10^{-7}A), ensures patient safety. **(3)** Our designed container can be reused after proper sanitization. Besides, we use a rechargeable 9V battery which can be used for more than a month without recharging. These result in less waste products. **(4)** Designed it as a hard plastic container to lessen the hassle of hanging and reduced its capacity to 500 mL to make it smaller in size and light weight.

Reduction to practice:

The parts of PleuraPro-

Fig 2: Drainage Container with circuit connections

Fig 3: One way Valve

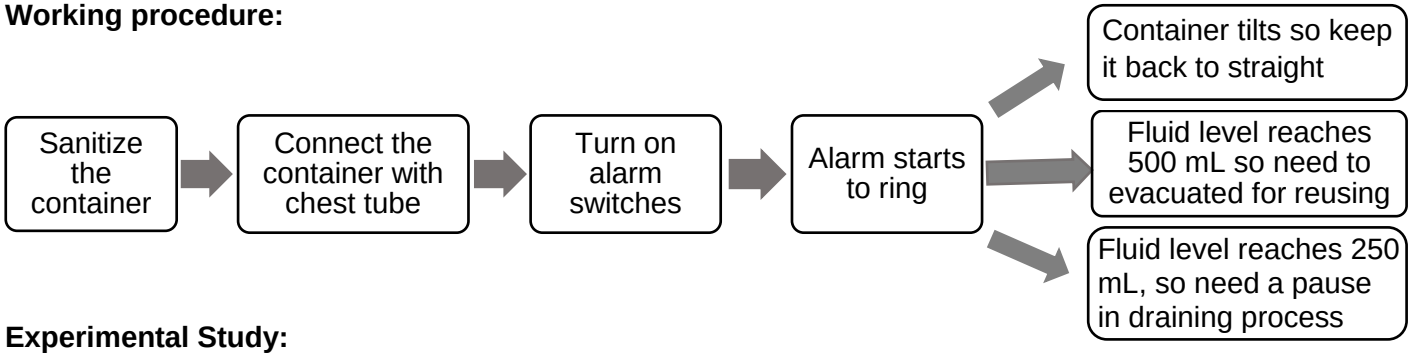
Fig 4: One way valve added to our designed 3D printed inlet of drainage container

Fig 5: Alarm System Part

Fig 6: Circuit and battery compartment for alarm system

Fig 7: Our full prototype

Working procedure:



Experimental Study:

We performed **sanitization test** to ensure that it is safe to reuse. Each container is first contaminated with lung fluid of pneumonia and TB patient collected from Dhaka Medical College. For drinking water, the upper limit of safety 100 CFU/100mL[4]. Tests showed that it passed the safety level for both boiling and cleaning with CIDEX.

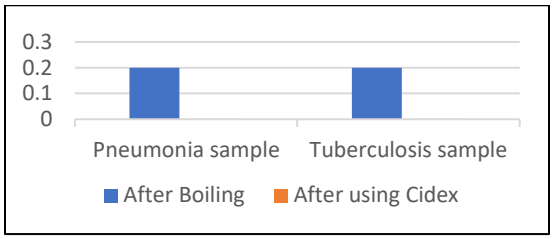


Fig 8: Counted CFU/mL

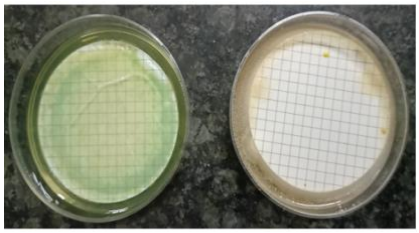


Fig 9: Micro-bacterial testing of pneumonia before and after boiling

Fig 10: Micro-bacterial testing after using *CIDEX*

Fig 11: Leak test set up

Leak test is done to check the valve's feasibility with 2.5 ,5, 7.5, 10, 15 cm H_2O pressure (Currently used chest drain bags have the tubes submerged in 2 cm of water, so the pressure produced here is 2 cm H_2O)
No leakages were observed.

Pathway to implementation:

Parts	Current Cost	Expected Cost
Drainage container	2.30$	2.30 $
Circuit compartment	15.00$	5.00 $

Cost will be reduced to less than half when goes in mass production as molding will be used instead of 3D printing. Our solution is cost-effective; as the reusable container incurs a one-time hospital cost, eliminating the need for patient purchases.

Currently we are working on getting permission for clinical trials. Our future plan is to modify device based on feedback from doctors, nurse and patients. We also have a plan to add a facility of suction pump to make a cheaper version of **Thopaz⁺ Digital Chest Drainage and Monitoring System**. We have a dream to convert it to a product that will be available in the global market. Our project can have a great impact in the medical sectors of developing and underdeveloped countries.
You can view the project in action by watching the accompanying video at the following link:
https://www.youtube.com/watch?v=oM64CXF8Nfk

Reference:

(1) Brookes JDL, Williams M, Mathew M, Yan T, Bannon P. Pleural effusion post coronary artery bypass surgery: associations and complications. J Thorac Dis. 2021 Feb;13(2):1083-1089. doi: 10.21037/jtd-20-2082. PMID: 33717581; PMCID: PMC7947477. **(2)** Iguina MM, Danckers M. Thoracic Empyema. [Updated 2023 Jul 4]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK544279/ **(3)** https://www.medelahealthcare.com/en/solutions/chest-drainage/thopaz **(4)** https://www.palintest.com/parameters/total-coliforms/