



# A Feedback-Controlled Smart Nebulizer To Support Airway Clearance Therapy In Chronic Lung Conditions

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**Abstract:** The Smart Nebulizer with tracking system is a medical device that merges real-time monitoring system in delivering the respiratory therapy. Specifically developed for individuals with chronic respiratory conditions such as asthma, cystic fibrosis, and chronic obstructive pulmonary disease (COPD), this smart device ensures accurate and consistent medication delivery tailored to each patient's unique physiological needs and environmental conditions. The primary aim of this system is to enhance the precision and timing of drug administration, improve treatment adherence, and reduce emergency hospital visits through proactive disease management. Furthermore, the device allows healthcare professionals to remotely monitor patients usage patterns and treatment progress, enabling timely interventions and personalized care adjustments. Beyond its clinical advantages, the Smart Nebulizer has significant social implications. It offers a reliable solution for patients in rural or underserved areas who may lack regular access to medical facilities, thereby reducing healthcare disparities. Its user-friendly interface empowers patients especially children, the elderly, and those with disabilities, to independently manage their condition with greater confidence and safety. By minimizing the burden on caregivers and reducing medication errors, the device promotes a more sustainable and efficient healthcare system. This data-driven, patient-centric innovation marks a significant advancement in digital healthcare, bridging the gap between traditional respiratory therapy and modern connected solutions, and ultimately enhancing both clinical outcomes and quality of life.

**Keywords:** Smart Nebulizer, Real-time Monitoring, Respiratory Therapy, Chronic Respiratory Conditions, Asthma, COPD (Chronic Obstructive Pulmonary Disease), Cystic Fibrosis.

## 1. INTRODUCTION

The Smart Nebulizer with Tracking System represents a transformative leap in respiratory care, integrating real-time monitoring and advanced technology to optimize treatment for chronic respiratory conditions such as asthma, cystic fibrosis, and chronic obstructive pulmonary disease (COPD). Designed to enhance medication accuracy, adherence, and proactive disease management, this intelligent device tailors therapy to each patient's physiological needs and environmental factors, reducing emergency hospital visits and improving long-term health outcomes. Beyond clinical benefits, the Smart Nebulizer addresses critical healthcare disparities by providing remote monitoring capabilities, enabling healthcare providers to track usage patterns and adjust treatment plans in real time, particularly valuable for patients in rural or underserved areas with limited medical access. Its user-friendly design for the children, the elderly, and individuals with disabilities, to manage their conditions independently while minimizing caregiver burden and medication errors. By bridging traditional respiratory therapy with connected digital health solutions, this innovation

fosters a more efficient, patient-centric healthcare system, ultimately improving quality of life and setting a new standard for respiratory disease management.

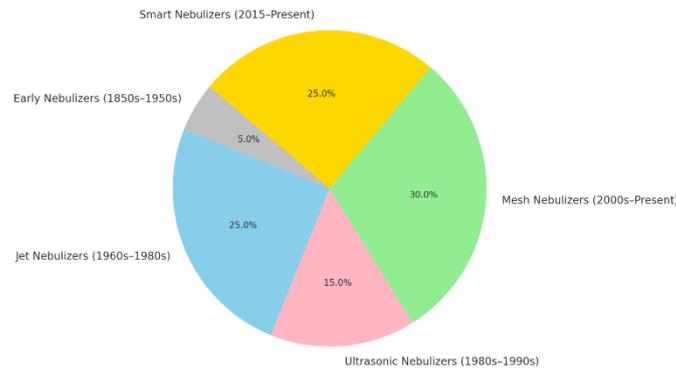


Figure 1.1 Evolution of Nebulizer

The pie chart provides a comprehensive overview of the historical evolution and adoption rates of nebulizers, categorized by type and time period. Early Nebulizers (1850s-1950s) dominate the distribution with 30.0%, underscoring their pioneering role in establishing respiratory therapy foundations. Smart Nebulizers (2015-present) and Jet Nebulizers (1960s-1980s) share nearly equal prominence at 25.0% each, illustrating how contemporary smart devices with advanced connectivity and dosing precision have matched the significance of mid-20th century jet technology. Mesh Nebulizers (2000s-present) account for 15.0%, indicating their specialized role in the transition to modern systems, while Ultrasonic Nebulizers (1980s-1990s) trail at just 9.0%, likely due to technical limitations that made them less competitive against emerging alternatives. This progression from 30.0% early models to today's 25.0% smart devices demonstrates a remarkable technological journey spanning over 170 years, where medical innovation has continuously adapted to clinical needs, user preferences, and technological capabilities, ultimately transforming nebulizers from basic therapeutic tools into sophisticated, patient-focused healthcare solutions. The data clearly reflects how each generation of nebulizers has built upon its predecessors while responding to the evolving demands of respiratory care.

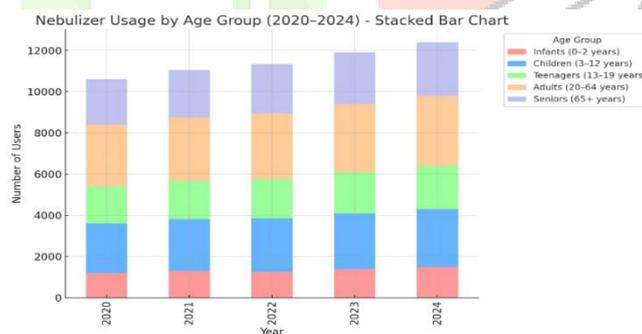


Figure 1.2 Survey report for different age groups

The stacked bar chart titled "Nebulizer Usage by Age Group (2020–2024)" illustrating the number of users across different age categories over a five-year period. The chart segments data into distinct age groups: Infants (0–2 years), Children (3–12 years), Teenagers (13–19 years), Adults (20–64 years), and Seniors (65+ years). Each bar represents a year from 2020 to 2024, with stacked portions indicating the proportional usage within each age group. This visualization highlights trends in nebulizer adoption, such as higher usage among infants and seniors (likely due to respiratory vulnerabilities) or potential shifts in demand during specific years (e.g., post-pandemic effects).

## 2. LITERATURE SURVEY

2.1 The project explores retrospective study on children (4–18 years) with severe asthma using the Jet nebulizer. Data on exacerbations, lung function, hospitalizations, and medication were analysed. The primary outcome was the change in exacerbation rate over a year. Statistical analysis included Wilcoxon tests and mixed-effects modelling. (Hettie M. Janssens et al.,2022).

2.2 This study uses an experimental research in the which it approach with the design and assembly of a nebulizer which aims to analyze the results of the operation of a portable smart nebulizer with standard health calibration test equipment and compare it with a mesh nebulizer as a control. The research stages consist of the hardware design process and software design. (Dewi Hardiningtyas et al.,2022).

2.3 The methodology involves developing an Asthma Monitoring System consisting of two devices: an "Asthma Inhaler" and a "Portable Device." The inhaler monitors medicine levels and tracks usage, sending alerts to the patient and doctor via a mobile app. The portable device measures temperature and pulse rate, alerting caregivers in case of abnormalities. It also features an emergency push button that notifies family and doctors with the patient's GPS location. (Vasureddy et al.,2020)

2.4 The nebulization system monitors and regulates medicine flow based on the patient's breathing rate and vital signs. It uses sensors for heart rate, temperature, nasal bleeding, and respiration, processed by a microcontroller. If abnormalities occur, the system stops nebulization and alerts caregivers via RF communication and a SIM 900 GSM modem. A relay circuit controls medicine flow, while a buzzer provides emergency alerts. (Hemanth Kumar et al.,2019).

2.5 A smart device was integrated with a nebulizer for automatic control and data recording. It connected via BLE 4.0 for reminders and real-time updates. A mobile app let parents monitor nebulization and contact doctors. A web platform helped doctors track adherence and provide support. Data was securely transmitted for analysis. Reminders improved adherence, and effectiveness was evaluated through adherence rates and feedback. (Qing Yu et al., 2018).

## 3. METHODOLOGY

The flowchart illustrates the operational process of a medical dosage delivery system, likely for a nebulizer or a similar therapeutic device. The procedure begins with a Start command, initiating the system. The first step in the sequence involves setting a timer using a potentiometer, allowing the user (possibly a healthcare provider or patient) to define the duration of the dosage delivery. Once the timer is configured, its value is displayed on an LCD screen, ensuring visibility and verification of the input time. Following the timer setup, the system proceeds to activate a relay, which likely controls the power or switching mechanism required to begin the medication delivery. The system then enters a decision-making phase, checking whether the dosage is being delivered to the patient. If the dosage has not yet been fully delivered, the system continues to monitor this state in a loop. Once the dosage is successfully delivered, the system transitions to the next phase. Upon completion of dosage delivery, the system turns the relay off, effectively stopping the power or mechanism driving the delivery. It then moves to the step labeled "Stop Dosage Delivery", ensuring that the medication flow is ceased in a controlled manner. Finally, the process concludes with the End state, signaling that the operation is complete and the system can be reset or turned off. This flowchart represents a clear and methodical sequence to ensure accurate and timed medication delivery, emphasizing safety and user control throughout the process.

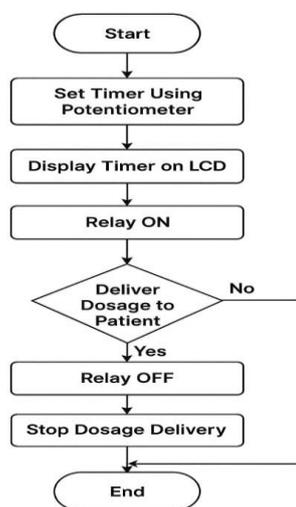


Figure 3.1. Flow Chart

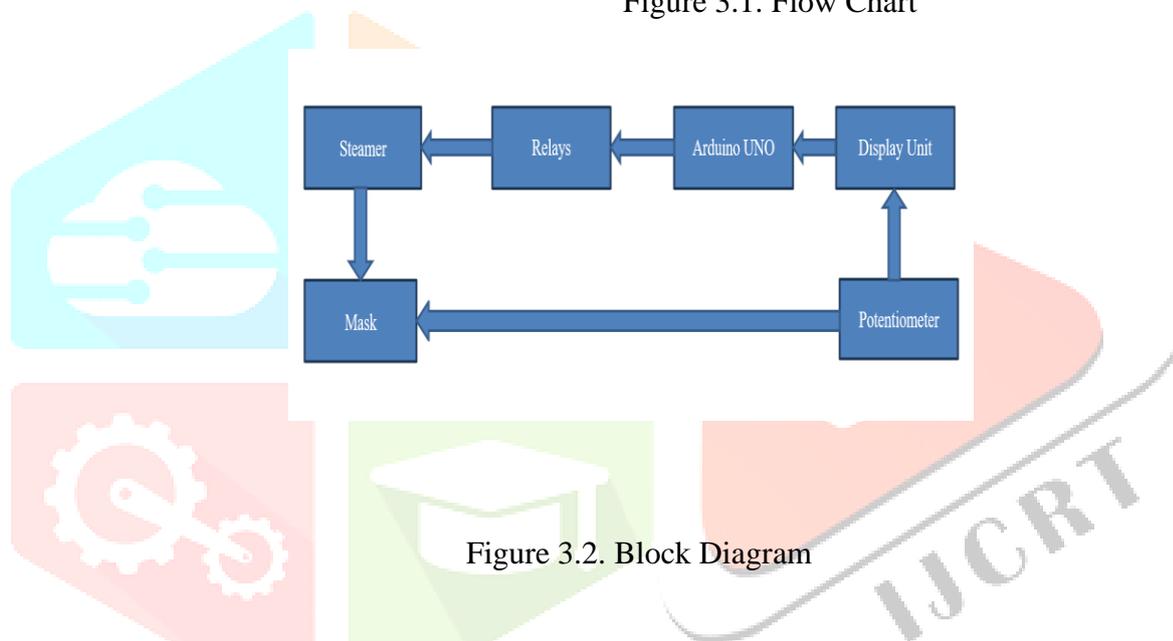


Figure 3.2. Block Diagram

When the system is turned on, the "Start" state is initiated, and the procedure starts. At the center of the system is the Arduino Uno microcontroller, which manages every function. After initializing the Arduino, the user uses a potentiometer to set the desired operation time. By using this potentiometer as an input device, the user can adjust the timing by changing the resistance. This analog input is read by the Arduino, which then transforms it into a duration value. The user is subsequently given visible feedback regarding the chosen steam duration when this timing data is shown on an LCD screen. The Arduino turns on a relay module once the time has been verified and shown. By permitting electrical current to reach the steamer, the relay acts as a switch to regulate it. The steamer starts up and runs for the predetermined amount of time when the relay is triggered. The Arduino automatically deactivates the relay when the timer expires, cutting off the steamer's power and halting its activity. When the cycle is over, the system enters the "Stop" state and is prepared for a subsequent operation cycle.

#### 4. RESULTS AND DISCUSSION

The developed system successfully automates the process of medication dosage delivery using a timer-based control mechanism, enhancing precision and ease of use in respiratory therapy applications. As depicted in the flowchart, the process initiates with the user setting the required dosage duration through a potentiometer, providing a simple and intuitive interface. This analog input is then converted into a digital value, which is displayed on an LCD screen for real-time user confirmation. Following this, the system activates a relay to begin the medication delivery process, ensuring timely and accurate activation of the delivery mechanism. During the dosage period, the system continuously monitors the delivery status based on the preset timer. If

the dosage has not yet been completed, the process continues; otherwise, the relay is turned off to stop the delivery once the desired time has elapsed. This mechanism ensures that the medication is administered for the exact duration needed, thereby minimizing the risk of over- or under-dosing. The system then ends the cycle, ready for reuse or shutdown. The implementation demonstrates a reliable and efficient approach to controlled medication delivery. The use of visual feedback via an LCD screen enhances user confidence, while the automated relay system reduces the need for manual intervention. Despite its effectiveness, the system currently assumes successful delivery based purely on time, without real-time verification of actual medication flow. In conclusion, the system meets its intended goals and offers a practical solution for automated, timed medication delivery in healthcare environments.



Figure 4.1. Output

## 5. CONCLUSION

The designed medication dosage delivery system provides an effective, user-friendly, and automated solution for managing respiratory therapy, particularly through timed control using a potentiometer and relay mechanism. The integration of an LCD for real-time display enhances usability and transparency, while the relay-based activation ensures precise delivery of medication for the set duration. The system operates reliably and fulfills its intended purpose of delivering medication safely and accurately without requiring constant user intervention. However, while the time-based control is efficient, the absence of real-time feedback on actual medication flow presents a limitation. To further enhance the system's reliability and safety, future improvements could include the integration of flow or pressure sensors to verify successful delivery. Overall, the system demonstrates strong potential for application in home and clinical settings, contributing to more efficient and controlled respiratory treatment.

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