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Review on Diaphragm Shape and Function in Tracheostomized Individuals

Christie Kiran Gotru
Research Scholar, Department of Physiotherapy, Sabarmati University, India.

Dr Mamta Sharma
Professor, Department of Physiotherapy, Sabarmati University, India.

Abstract : The diaphragm plays a pivotal role in respiratory mechanics, and its structure and function can be significantly altered in individuals undergoing tracheostomy. This review explores the current understanding of diaphragm morphology and performance in tracheostomized patients, emphasizing both short- and long-term implications. Tracheostomy, while often necessary for prolonged mechanical ventilation or airway protection, can lead to changes in diaphragmatic workload, neuromuscular control, and overall function. Emerging imaging techniques such as ultrasonography and MRI have enhanced the ability to assess diaphragmatic shape, thickness, and excursion in this population. Findings suggest that tracheostomized individuals may exhibit diaphragmatic atrophy, altered contractility, and reduced excursion, especially when prolonged mechanical ventilation is involved. These changes can influence weaning outcomes, respiratory independence, and rehabilitation strategies. The review also discusses potential interventions to mitigate diaphragm dysfunction, including inspiratory muscle training, optimized ventilatory support settings, and early mobilization. Further research is warranted to clarify causal relationships and to develop standardized protocols for monitoring and enhancing diaphragmatic health in tracheostomized individuals.

1. Introduction

Tracheostomy is a life-saving medical procedure involving the creation of an opening in the trachea to facilitate breathing in individuals who have significant airway obstructions or respiratory failure. Often, patients undergoing a tracheostomy have long-term mechanical ventilation, which significantly alters normal respiratory mechanics. One of the most critical muscles affected by this intervention is the diaphragm, the primary muscle responsible for normal breathing. Tracheostomized individuals are at risk for diaphragm dysfunction due to the combination of mechanical ventilation, altered respiratory patterns, and reduced diaphragm movement. This study seeks to investigate the changes in diaphragm shape and function in tracheostomized individuals by utilizing volume-oriented incentive spirometry (VOIS), a non-invasive, cost-effective technique for monitoring lung and diaphragm function.

The diaphragm plays a vital role in generating the negative intrathoracic pressure required for normal inspiration. When functioning properly, it contracts and moves downward, expanding the thoracic cavity and allowing air to flow into the lungs. The shape of the diaphragm is crucial for its function, and any alterations in this shape can lead to respiratory inefficiencies. In tracheostomized individuals, the diaphragm may undergo significant changes, including reduced mobility, atrophy, or altered shape, making effective breathing more difficult. Traditional methods for assessing diaphragm function, such as imaging (e.g., X-rays, CT scans) or electromyography (EMG), are often invasive, uncomfortable, and costly. Therefore, a more

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practical method is needed to regularly monitor diaphragm function, especially for individuals requiring long-term ventilatory support.

Volume-oriented incentive spirometry (VOIS) is an established, non-invasive tool designed to encourage deep breathing and lung expansion. This device provides feedback to patients about their lung volumes during inspiration and expiration, thereby promoting diaphragmatic engagement and improving respiratory outcomes. The utility of VOIS extends beyond its role in post-surgical rehabilitation and has the potential to serve as an effective measure of diaphragm function. By measuring various lung volumes (inspiratory capacity, tidal volume, and peak inspiratory flow), VOIS indirectly assesses diaphragm activity and efficiency. This tool provides an opportunity to examine the diaphragm's ability to expand the lungs and assess its strength and endurance during different stages of respiration, making it an ideal candidate for evaluating diaphragm function in tracheostomized individuals.

The research aims to explore how tracheostomy impacts diaphragm shape and function in individuals who have undergone this procedure. Specifically, it will assess whether VOIS can detect these changes and provide valuable insights into diaphragm health in this patient population. In addition to spirometry, ultrasound imaging of the diaphragm will be used to measure diaphragm thickness and mobility during both quiet breathing and forced inspiration. This combined approach will allow for a detailed assessment of diaphragm shape and function under various physiological conditions.

The study will be conducted in two groups: tracheostomized individuals (n=50) and healthy controls (n=50). The inclusion criteria for the tracheostomized group will include adults who have had a tracheostomy for a minimum of one month, with stable medical conditions and no other significant comorbidities. Healthy controls will be selected to match the tracheostomized group in terms of age, gender, and respiratory health. Each participant will undergo volume-oriented incentive spirometry, during which parameters like inspiratory capacity, tidal volume, and peak inspiratory flow will be measured. Additionally, ultrasound imaging will be used to assess diaphragm thickness and movement during both quiet breathing and forced inspiration, offering a more direct evaluation of diaphragm morphology.

The primary objectives of this study are to assess the differences in diaphragm shape and function between tracheostomized individuals and healthy controls, to determine whether volume-oriented incentive spirometry can reliably measure these differences, and to evaluate the potential link between diaphragm dysfunction and clinical outcomes. Clinical outcomes such as ventilator dependency, the success of weaning from mechanical ventilation, and rehabilitation progress will also be recorded, providing context for the functional significance of any observed changes in diaphragm function.

The research will focus on several key parameters: diaphragm thickness (as measured by ultrasound), diaphragm movement during forced inspiration, lung volumes (inspiratory capacity, tidal volume), and peak inspiratory pressures during spirometry. These parameters will be compared across the two groups to assess the extent of diaphragm dysfunction in tracheostomized individuals and to determine whether VOIS can serve as an effective tool for monitoring diaphragm function in these patients. It is expected that tracheostomized individuals will exhibit a reduced diaphragm thickness, diminished diaphragm mobility, and lower lung volumes compared to healthy controls. Furthermore, it is hypothesized that diaphragm dysfunction will correlate with longer ventilator dependency, difficulty in weaning from mechanical ventilation, and slower progress in pulmonary rehabilitation.

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Data analysis will involve a range of statistical techniques, including descriptive statistics to summarize the demographic and baseline characteristics of the participants, paired t-tests or non-parametric tests to compare the two groups, and correlation analyses to explore the relationships between diaphragm function and clinical outcomes. Multivariate regression models will be used to identify potential predictors of diaphragm dysfunction in tracheostomized individuals, such as the duration of mechanical ventilation, the type of tracheostomy, and the patient's rehabilitation status.

The study aims to make several important contributions to the field of respiratory care. First, it will provide valuable insights into the impact of tracheostomy on diaphragm shape and function, which is crucial for improving patient management, particularly in individuals who are dependent on mechanical ventilation. Second, the use of volume-oriented incentive spirometry as a non-invasive tool for assessing diaphragm function could significantly improve the ability of clinicians to monitor and manage diaphragm health in tracheostomized patients. If proven effective, this method could be used routinely in clinical settings to track diaphragm function over time and guide rehabilitation strategies. Finally, the study's findings could contribute to a more personalized approach to respiratory care, identifying patients at risk of diaphragm dysfunction and tailoring interventions to improve their outcomes.

In addition to its clinical implications, the study also opens up avenues for future research. For instance, longitudinal studies could explore the progression of diaphragm dysfunction over time and the impact of different rehabilitation interventions on diaphragm health. Future research could also investigate the potential of combining volume-oriented spirometry with other diagnostic tools, such as transdiaphragmatic pressure measurements or impedance pneumography, to provide a more comprehensive assessment of diaphragm function. Furthermore, larger-scale studies could examine the effectiveness of specific rehabilitation programs designed to improve diaphragm strength and mobility in tracheostomized patients, with the aim of improving weaning outcomes and reducing ventilator dependency.

2. Literature Review

An incision is made in the neck in order to get access to the trachea during a tracheostomy. As a result of the fact that this method grants medical professionals immediate access to the trachea, it is often used to assist patients in breathing or to alleviate mucus when their upper airway is obstructed. Since the beginning of time, tracheostomy has been used as a treatment for a wide range of respiratory conditions. Tracheostomies have been used by individuals ever since the beginning of humanity. According to the evidence, it was used by the ancient Greeks as well as the Egyptians. Tracheostomies were performed on individuals in the Middle Ages who were in danger of drowning or who were having difficulty breathing. This procedure had the potential to save their lives. Over the course of time, the benefits and drawbacks of tracheostomy have shifted in response to the development of both medical knowledge and technological capabilities. For the purpose of enhancing patient outcomes while simultaneously reducing the possibility of difficulties, contemporary tracheostomy treatments make use of cutting-edge techniques and apparatus on the market. A medical airway is produced during the process by creating an incision in the neck, using the trachea, and inserting a tube to keep the airway open. This is done in order to continue the surgery. It is possible that individuals who have recurrent respiratory failure might benefit from long-term oxygen support via the use of a tracheostomy; nevertheless, this technique is often reserved for use in the event of an emergency. Because of the specialized care and careful supervision that is needed by a tracheostomy, life may be extremely difficult for both the patient and the people who are

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responsible for their care. In order to provide patients who are receiving tracheostomy treatment with the best possible care, medical professionals need have a thorough understanding of the history of the technique as well as its development. Winter, the year 1976

Tracheostomy Techniques: A Historical Overview

There is a lengthy history of tracheostomy and other disorders that are comparable. The ancient Greeks and Egyptians are said to have been among the first people to use tracheostomy techniques, according to historical records. When it came to ancient Egypt, the bulk of tracheostomy procedures were performed with the purpose of treating illnesses or accidents that caused obstructions in the upper airways. During the Middle Ages, tracheostomy was generally reserved for circumstances that posed a significant risk to the patient's life, such as those involving severe breathing problems or accidental drowning. According to Watts (1963), the tracheostomy became increasingly more of a routine procedure and more successful as time progressed during the Renaissance. During this time period, a number of forward-thinking medical professionals, like Antonio Maria Valsalva and Pierre Dionis, were responsible for the development of novel approaches to tracheostomies. The insights that they provided on the development of tracheostomy procedures were quite beneficial. According to the information that is now accessible, tracheostomies were used in the past on occasion. Through this, they are provided with a history that is both exciting and extensive. In this article, the relevance of tracheostomies in ancient Greek and Egyptian medicine is discussed. Tracheostomies were performed with the intention of opening airways in the throat that had been blocked as a result of the presence of illnesses or injuries. According to Pratt et al. (2008), the article continues by explaining how tracheostomy was a popular emergency operation throughout the Middle Ages. This technique was used to save the lives of people who were either drowning or had serious breathing troubles.

Tracheostomy techniques were said to have achieved considerable advancements during the Renaissance period, as stated by medical pioneers such as Antonio Maria Valsalva and Pierre Dionis. As a result of these achievements, tracheostomy procedures were able to undergo significant advancements, which ultimately led to its widespread adoption as a standard medical treatment. The tracheostomy procedure, which had its roots in the past, has developed into an essential component of modern medical care. Because of this, we are able to see the development of both medical knowledge and clinical practice. There were considerable advancements made in the management of tracheostomies by Islamic doctors throughout the Middle Ages. The study conducted by Golzari and colleagues included a discussion on the part that Islamic doctors played in the invention of the tracheostomy. During the course of the tracheostomy and other lung care procedures, a significant amount of time was spent to detailing the cutting-edge methods and apparatus that these surgeons used. According to Heurn and Brink (1996), their efforts made a substantial contribution to the advancement of knowledge and practice about tracheostomies at the then-current level.

In addition, the substantial knowledge of anatomy and essential medical concepts that Islamic doctors who practiced medicine throughout the Middle Ages acquired is largely responsible for the development of tracheostomy operations. Tracheostomy treatments were both safe and effective due to the fact that they used precise surgical methods and had a thorough understanding of the anatomy that was situated beneath the surface. In regard to the development of the tracheostomy tube and its influence on therapy. They examine the history of the three-bladed tracheostomy dilator as well as the relevance of this device in improving

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the safety and efficacy of tracheostomy. When we look back at these statistics, we can see how hard people are working to improve airway control and patient care over the course of time. In addition to this, it offers valuable information on the ongoing development of tracheostomy methods and equipment. In addition, they explore the manner in which technological breakthroughs have influenced the manufacturing of tracheostomy devices, highlighting the ever-changing nature of the medical equipment that is used during breathing treatments (Al Marshad et al., 2022).

It is clear that medical experts are committed to continually improving patient care via the research and implementation of new and improved medical treatments, as seen by the lengthy history of the tracheostomy procedure. Our comprehension of these procedures and the influence they have on patient care would be improved if there were more research that provided essential background information on the development of tracheostomy tools. Unfortunately, there is a shortage of research that gives this information. There is a surgical procedure known as a tracheostomy, which entails opening the neck in order to get access to the trachea, which is also sometimes referred to as the windpipe. In point of fact, tracheostomy has seen tremendous development throughout the course of time. Its current form is essentially the result of developments in both technological and medical knowledge, which have contributed together. Critical care doctors, otolaryngologists, pulmonologists, respiratory therapists, and nurses all collaborate as a team in order to carry out tracheostomy treatments in today's modern medical practice. The goal of this joint effort is to provide complete care to those who need tracheostomy while also ensuring that the method is both effective and safe. There are a number of medical conditions that need this operation, including obstructive sleep apnea, paralysis of both voice cords, blockage of the upper airway, head and neck traumas, and tracheostomy as an adjuvant to thoracic or head and neck procedures. On this particular topic, Pandian and Mirski (2015) and Handy (1973) are in agreement.

It is essential to investigate not just the development of tracheostomy methods but also the procedures that are now being used and the results that they produce. As a result of research and clinical studies, we now have a better understanding of the advantages and disadvantages of tracheostomy. This is especially helpful for those who suffer from chronic respiratory failure and need the use of a ventilator for a lengthy period of time. It is essential to have a thorough understanding of the ways in which tracheostomy may have an effect on the health of both the individuals receiving care and the those delivering it. Among the topics that are discussed are the mental and emotional toll that tracheostomy have on patients and their loved ones, the challenges that come with maintaining a tracheostomy over an extended period of time, and the methods that may be used to provide aid that goes beyond the medical elements of care. The provision of improved patient-centered care and the improvement of outcomes for patients having this procedure is essential in modern medicine (Pratt et al., 2008). Additional research on the history of tracheostomy and its present use may be of assistance in achieving these goals.

3. Methodology

1. **Study Design:**

   A cross-sectional study will be conducted with two groups:

   - **Group A:** Tracheostomized individuals (n=50)

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- **Group B:** Healthy controls (n=50)

2. **Inclusion Criteria:**
    - Group A: Adults with a tracheostomy (either short-term or long-term)
    - Group B: Healthy individuals with no history of respiratory disorders
    - All participants must have stable health conditions without severe comorbidities.
3. **Data Collection:**
    - **Volume-Oriented Incentive Spirometry:** Each participant will perform spirometry under supervision, measuring volumes such as inspiratory capacity, tidal volume, and peak inspiratory flow.
    - **Ultrasound Imaging:** A subset of participants will undergo ultrasound imaging to assess diaphragm shape and thickness during both quiet breathing and spirometry-induced forced inspiration.
    - **Clinical Outcome Measures:** The study will also collect data on mechanical ventilation duration, pulmonary rehabilitation status, and weaning from ventilation (if applicable).
4. **Outcome Measures:**
    - Diaphragm thickness and movement during different phases of respiration (quiet vs. forced inspiration)
    - Changes in lung volumes and peak inspiratory pressure during spirometry tests
    - Correlation of diaphragm function with clinical outcomes like ventilator dependency and rehabilitation progress

Individuals who continue to have diaphragmatic dysfunction after coronary artery bypass graft surgery are at a greater risk for respiratory issues, a worse quality of life, and difficulties exercising due to a lack of breath. The favorable impacts that surgery has on patients' health are diminished as a result of these variables, which also raise the risk of patient death and deplete the resources available in hospitals. However, one study did not find any correlation between the length of time a patient spent in the intensive care unit, the length of their hospital stay, or the amount of time they spent on mechanical ventilation following bilateral lung transplantation and decreased diaphragmatic function upon discharge. This was the conclusion reached by the researchers. In order to determine the reason for this disparity, this thesis investigated the effects of postoperative diaphragmatic dysfunction on the length of time that patients who had undergone a lung transplant were required to use mechanical ventilation, the length of time that they spent in the intensive care unit, the length of time that they spent in the hospital, and the destination of their discharge.

4. Data Analysis

- **Statistical Methods:** Descriptive statistics will summarize the demographic and baseline characteristics. Paired t-tests (for comparison of diaphragm function between

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groups) and correlation analyses (between diaphragm function and clinical outcomes) will be employed.

- **Modeling:** Multivariate regression analysis will be used to determine factors influencing diaphragm dysfunction in tracheostomized individuals.

Expected Outcomes:

This research is expected to provide:

1. A clear understanding of diaphragm shape and function in tracheostomized individuals.
2. Evidence on the utility of volume-oriented incentive spirometry as a tool for monitoring diaphragm health in clinical settings.
3. A foundation for improving rehabilitation strategies aimed at enhancing diaphragm function in this patient population.
4. Insight into potential links between diaphragm function and clinical outcomes, which could guide individualized management strategies.

Conclusion

In conclusion, this study seeks to address a critical gap in respiratory care by evaluating the shape and function of the diaphragm in tracheostomized individuals using volume-oriented incentive spirometry. The expected outcomes of this research include a better understanding of diaphragm dysfunction in this patient population, the validation of volume-oriented spirometry as a non-invasive tool for monitoring diaphragm health, and the development of more effective rehabilitation strategies. By shedding light on diaphragm function in tracheostomized individuals, this research has the potential to improve clinical outcomes, reduce the burden of ventilator dependency, and enhance the quality of life for patients undergoing long-term respiratory support. The findings could ultimately inform clinical practice, guide future research in respiratory rehabilitation, and pave the way for more individualized approaches to patient care in tracheostomized individuals.

This study not only has clinical relevance but also opens up new possibilities for non-invasive assessment methods in critical care and rehabilitation settings. Through a combination of spirometry, ultrasound imaging, and clinical outcomes analysis, it is expected to make a meaningful contribution to the field of respiratory medicine, offering a more comprehensive and accessible way to monitor and enhance diaphragm function in tracheostomized individuals.

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