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INFORMATION TECHNOLOGY IN TRACHEOSTOMY

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Abstract
This paper examines on tracheostomy along with its physical considerations.

Keywords: Tracheostomy, airflow and pressure dynamics, humidification, acoustics.

Introduction

In the recent years, a number of tracheostomies was done due to obstruction of the upper airway, chronic respiratory failure, and inability to clear secretions. More than 100,000 adults receive a tracheostomy in the United States each year, and more than half are performed to facilitate prolonged mechanical ventilation (MV) for acute respiratory failure.

Definition: A tracheostomy (also called a tracheotomy) is an opening surgically created through the neck into the trachea (windpipe) to allow air to fill the lungs.

Main reasons to do tracheostomy:

- Prolonged dependence on a ventilator for breathing
- To bypass an obstructed upper airway
- To clean and remove secretions from the airway
- To deliver oxygen to the lungs more easily or safely

Types of tracheostomies:

- **Cuffed Tracheostomy Tubes:** These tubes have an inflatable cuff that seals the airway, ensuring that all air passes through the tube. This type is often used for patients on mechanical ventilation.

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- **Uncuffed Tracheostomy Tubes:** These tubes lack an inflatable cuff and are typically used for paediatric patients or adults who do not require a sealed airway.
- **Fenestrated Tracheostomy Tubes:** These have small holes or fenestrations on the outer cannula. When the inner cannula is removed, the patient can breathe through both the tube and fenestrations, allowing them to speak and participate in weaning trials.
- **Metal (Silver) Tracheostomy Tubes:** These are rigid tubes made of metal, often used for patients who have had a tracheostomy for a long time.
- **Double Cannula Tracheostomy Tubes:** These tubes have an outer cannula that stays in place and an inner cannula that can be removed and cleaned.
- **Adjustable Flange Tracheostomy Tubes:** The flanges on these tubes can be adjusted to alter the tube's length inside the trachea, accommodating patients with unusual neck anatomy or tracheal depth.
- **Paediatric and Neonatal Tracheostomy Tubes:** Specifically designed for children and newborns, these tubes are smaller and more flexible.
- **Tracheostomy Tubes with Speaking Valves:** These are designed to allow patients to speak by directing airflow through the vocal cords.

Complications:

- Bleeding
- Air trapped around the lungs (pneumothorax)
- Air trapped in the deeper layers of the chest (pneumomediastinum)
- Air trapped underneath the skin around the tracheostomy (subcutaneous emphysema)
- Damage to the swallowing tube (oesophagus)
- Injury to the nerve that moves the vocal cords (recurrent laryngeal nerve)
- Tracheostomy tube can be blocked by blood clots, mucus or pressure of the airway walls. Blockages can be prevented by suctioning, humidifying the air, and selecting the appropriate tracheostomy tube.

Tracheostomy and physics:

A **tracheostomy** is primarily a medical procedure related to airway management, but there are several **physical principles** involved in its function, particularly around **respiratory physiology** and the **use of devices** like the **tracheostomy tube**, **ventilators**, and **humidifiers**. These principles include aspects of **fluid dynamics**, **pressure mechanics**, and **aerosol physics** that govern airflow and airway management.

1. **Airflow and Pressure Dynamics**: It is the management of airflow through the newly created stoma in the trachea and the pressure gradients that allow air to move effectively in and out of the lungs.

Airflow resistance: The tracheostomy tube introduces a potential resistance to airflow, which could make breathing more difficult. The resistance is influenced by the **diameter** of the tube, the **length** of the tube, and the **viscosity** of the air (which can change if the air is dry or if secretions accumulate).

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Pressure gradient: A **pressure difference** between the inside of the lungs and the outside environment is necessary for air to flow.

2. **Ventilation mechanics:** It depends on the principle of positive or negative pressure ventilation to move air into the lungs.

3. Airway humidification

Humidifiers: These devices operate on the principle of **phase transition**—converting water from liquid to vapor using heat (as in **heated humidifiers**) or ultrasonic vibrations (as in **nebulizers**) to make the inhaled air more comfortable and prevent dryness.

4. Acoustic Considerations (Speech): For patients with a tracheostomy, particularly those with a **fenestrated tracheostomy tube**, there may be a desire to speak. The physics of **acoustic resonance** is altered because the air bypasses the **larynx**. **Speech valves** (e.g., **Passy-Muir Valve**) can be used to redirect exhaled air through the vocal cords, enabling the patient to speak. The principles of **airflow** and **resonance** play a role in how well these devices restore speech.

Artificial intelligence in tracheostomy

Artificial Intelligence (AI) is transforming healthcare by providing innovative solutions that enhance patient outcomes, optimize clinical workflows, and reduce medical errors. In tracheostomy care, AI has emerged as a critical tool for improving decision-making, predicting complications, and personalizing patient management. This thesis explores the integration of AI in tracheostomy, focusing on its applications in preoperative planning, postoperative monitoring, complication detection, speech rehabilitation, and home-based care. The fusion of AI with robotics, wearable sensors, and predictive analytics has the potential to revolutionize tracheostomy procedures, ensuring safer and more efficient patient care.

Information technology in tracheostomy

Information Technology (IT) is revolutionizing tracheostomy care by providing digital tools and solutions that improve patient outcomes, streamline clinical workflows, and enhance remote monitoring capabilities. IT applications such as electronic health records (EHRs), telemedicine platforms, wearable devices, and mobile applications are transforming how tracheostomy patients are managed both in hospitals and at home. This thesis explores the role of IT in tracheostomy care, focusing on its applications in data management, remote monitoring, communication between healthcare providers and patients, and enhancing overall patient safety.

Material of the tube: The most commonly used tracheostomy tubes are made from **polyvinyl chloride (PVC), silicone, or polyurethane**.

Conclusion:

A tracheostomy modifies the dynamics of breathing, affecting airflow resistance, pressure regulation, and the need for additional support like humidification. The physics of **fluid dynamics**, **pressure**, **airflow resistance**, **ventilation mechanics**, and **aerosol physics** are all involved in the effective use and management of a tracheostomy tube.

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