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COMPLICATIONS AFTER TRACHEOSTOMY: LITERATURE REVIEW

Ayodeji Ojo, 6th Year, Group 7

Department/Clinic: Institute of Clinical Medicine, Clinic of Chest Diseases Immunology and Allergology.

Supervisor: Prof. Dr. Ričardas Janilionis

The Head of the Department/Clinic: Prof. Edvardas Danila, Phd

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ayodeji.ojo@mf.stud.vu.lt

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1. SUMMARY

Tracheostomy is a medical procedure that involves opening of the trachea and keeping the trachea open with a tube temporarily or permanently to divert airflow from the larynx. Although this procedure was initially used to secure airways in patients with upper airway obstruction when the usual route for breathing is somehow blocked or reduced. Its use has shifted towards elective or planned procedures rather than emergency interventions. Tracheostomy has also expanded to meet other medical conditions like vocal cord paralysis, throat cancer, paralysis, severe head/neck trauma and neurological conditions that block or narrow the airways. Among contemporary surgical procedures, tracheostomy has an unexpectedly extensive history dating as far back as 3600 BC. Classical authors like Frederick Griffith Pearson and Hermes Conrad Grillo [3],[7] have written extensively on the relevance of tracheostomy and how to mitigate the complications that arise from this procedure. Most contemporary researchers have also published finding from their research to corroborate the works of Grillo and Pearson. This underscores the relevance of tracheostomy and the need for healthcare providers to be acquainted with the complications associated with tracheostomy and the strategies for their prevention and management.

This review used literature resources (classical and modern), books, and online databases like PubMed, Academic search Ultimate, Google Scholar and Tripdate to collect scholarly findings on tracheostomy with focus on the pre-surgical, surgical, and post-surgical complications of the procedure; the risk factors that contributes to these complications; preventive measures and interventions that can mitigate the risks of complications; and review the methods for monitoring and assessing the outcomes of tracheostomy care. This review also looked at surgical tracheostomy and the percutaneous dilatational tracheostomy, the two techniques employed to create the opening for tracheostomy. Although, these techniques differ in methodology and complications, this review focused on the complications that arise from the surgical tracheostomy technique. These complications range from immediate, early, or late depending on when they are observed after the procedure. The review also highlighted some preventive steps and treatment options to combat the complications that arise from tracheostomy.

While tracheostomy is considered a common medical intervention procedure, and erroneously reputed as an easy routine procedure, some of the complications from it can be life threatening and can reduce the patient's quality of life. It is therefore essential for surgeons and healthcare providers to

understand the pathophysiology of injuries caused by tracheostomy to effectively apply surgical techniques to manage and mitigate these complications.

2. KEYWORDS

Tracheostomy, surgical method, immediate complication, early complications, late complications

3. INTRODUCTION

3.1 Definition and Description

The term "tracheostomy" is derived from two Greek words meaning, "to cut the trachea," which refers to a medical procedure in which an artificial opening is created in the trachea at the cervical level to the external environment bypassing the larynx and upper respiratory and digestive systems. [1]. Tracheostomy encompasses the procedure and the resulting tract between the trachea and the skin [1]. Although historically, tracheostomy served as the primary method for securing an airway in patients with upper airway obstruction. However, due to the ease and speed with which a tracheostomy can establish a stable airway compared to endotracheal tubes its application has broadened in recent times, and it is now a valuable tool for managing patients with prolonged mechanical respiratory insufficiency and ventilatory insufficiency caused by secretion retention. [2]. Pearson described the procedure as an opening in the trachea, which can either be permanent, as seen in an end-tracheostomy, or temporary, where the opening is maintained by a tube, with the aim of redirecting airflow from the larynx [3].

Over the past few decades, the use of percutaneous dilatation tracheotomy performed by anesthetists has significantly increased, reflecting its growing acceptance in clinical settings. This surge, evidenced by the tripling of this procedure, underscores the necessity for healthcare providers to have a thorough understanding of the complications associated with tracheostomy and the strategies for their prevention and management [3]. The trend in performing tracheostomy has shifted towards elective or planned procedures rather than emergency interventions over the past few years, as the practice of percutaneous dilatation tracheotomy by anesthetists has significantly increased [2].

This shift towards delayed tracheostomy is motivated by the significantly higher complication rates associated with emergency tracheostomies, which can be 3 to 5 times greater than those performed electively. Furthermore, complications resulting from endotracheal intubation are less severe and more manageable for patients compared to those that arise from tracheostomy procedures. Despite these

considerations, the medical community continues to debate the ideal timing for transitioning from endotracheal intubation to tracheostomy to minimize risks and optimize patient outcomes [3].

3.2 Aim and Objectives

This literature review aims to provide a comprehensive examination of the complications associated with tracheostomy by different authors in various literatures. By synthesizing insights from various authors, the objective of this review is enumerated as follows.

1. Evaluate the spectrum of the complications of tracheostomy from the pre-surgical, surgical, and post-surgical complications.
2. Explore the risk factors that contribute to the development of tracheostomy complications, considering patient specific and procedural specific variables.
3. Explore various preventive measures and interventions enumerated in the literature that can mitigate the risks of complications.

4. METHODOLOGY

To identify the most recent and relevant research for this literature review, extensive research was conducted using online databases like PubMed, Academic search Ultimate, Google Scholar and Tripdate as search tools. The search spanned from these databases inception to April 2024. The structure of the search started from systematic review following with cohort studies and prevalence studies. The search process yielded no published systematic but one ongoing systematic study and eight ongoing clinical trials. The search yielded 10 review articles, 5 research articles, 7 case reports and 5 books from the university library. Furthermore, the narrative literature view was excluded, but their reference lists were perused, to pick the references that were overlooked by searching the reference databases. To ensure a comprehensive exploration, multiple keywords were used in different search iterations covering both recent and historical perspectives. The search was restricted to studies written in English. To identify additional relevant sources, the reference lists of the retrieved articles were reviewed using the "snowball method," as described by Nikolopoulou [4].

Additional resources used for this review were taken from the books “surgery of the trachea and bronchi by Professor Hermes Conrad Grillo, and Patterson’s book on Pearson’s thoracic and abdominal surgery.” These books were mainstay throughout the narrative review writing process, as they provided

classical definitions on procedures and complications. Corroborative materials, supplementary articles, and books were obtained from the university library database to gain a more comprehensive and balanced perspective of the topics explored from different authors from both the classical and contemporary point of view. A two-step screening method was used to ensure that only truly relevant articles were selected. This method involved initially scanning the titles of all the articles obtained to identify those potentially relevant to the research theme, after which, the abstracts of the selected articles were reviewed to gain a clearer understanding of their content, followed by a thorough examination of the full texts to assess their relevance to the subject under review.

Furthermore, all relevant information was catalogued with Microsoft excel to keep track of the framework of various authors on specific aspects of the review. This process provided a complete overview of all aspects of the review, ensured a thorough analysis of each literature work, recognized the contributions of each author, and enabled the creation of a comprehensive catalog of both similar and opposing ideas discussed by the authors. Throughout this research process, Zotero Reference Manager was used to manage and organize the references and bibliography. The software played a crucial role in simplifying the citation management process, enhancing the efficiency and accuracy of the materials utilized in the literature review. The search terms used in the search include, tracheotomy, tracheostomy from an historical point of view, Lithuania history of tracheostomy, complications of tracheostomy. procedure or intraoperative complications of tracheostomy, post operative complications of tracheostomy.

5. THEORETICAL FRAMEWORK

5.1 Anatomy of the Trachea

The upper airway consists of several key structures, including the hyoid bone, larynx, cricoid cartilage, and trachea [Fig. 2]. Within the larynx are the true vocal cords, the region above the true vocal cord known as the supraglottic airway, and the region below the vocal cord is known as the subglottic airway. Situated between the larynx and the trachea is the cricoid cartilage. The cricoid cartilage is incredibly significant because its posterior position is the entry site of the laryngeal nerves. As a result of this complex anatomy, complete resection of the cricoid cartilage is not feasible without risking damage to both recurrent laryngeal nerves, which would compromise the protective functions of the laryngeal mechanism [5].

The trachea is approximately 10–12 cm in length, begins just below the cricoid cartilage and extends to the main carina [5]. Typically, the trachea's shape resembles an elongated half-circle, with the posterior part almost flat and composed of soft tissue, known as the membranous portion. The anterior part consists of a series of cartilaginous rings, connected by membranes between each ring. The trachea's location is partly within the thoracic cavity and partly outside it, and its position in the chest changes with neck movement—moving upwards when the neck extends and downwards when it flexes. This mobility decreases with age, which is a crucial factor to consider in tracheal resection and reconstruction, as it helps minimize tension on tracheal anastomoses following resection [5].

Fig 1: Anatomy of the trachea and larynx [5].

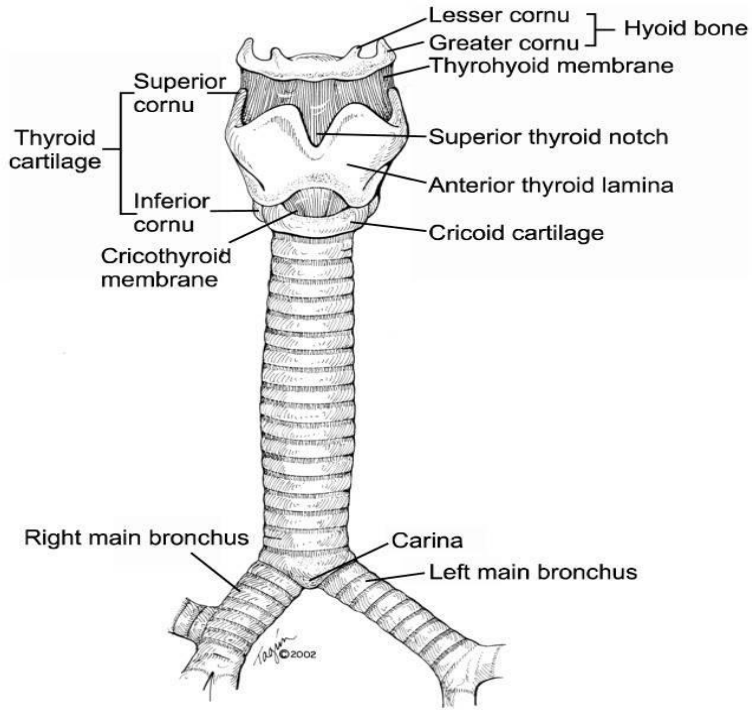
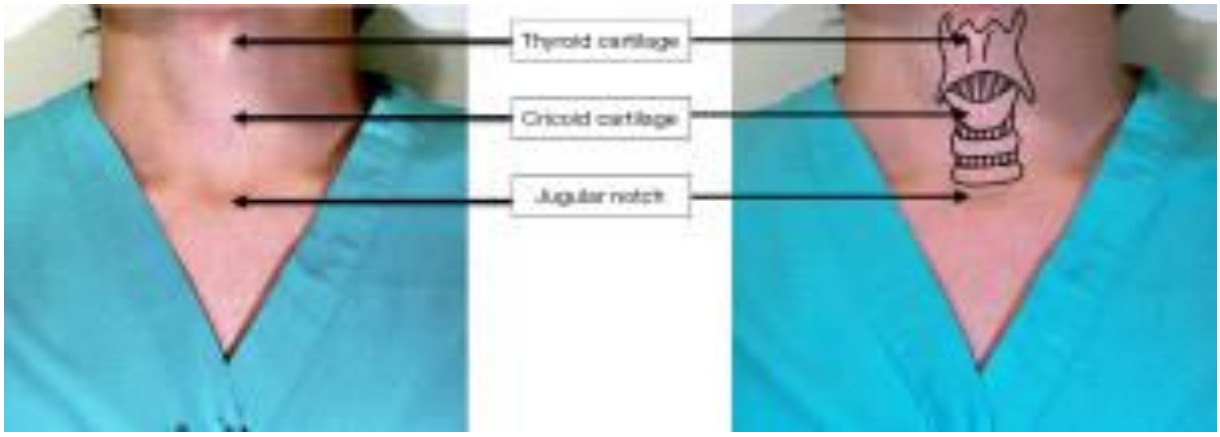


Fig 2: Surface anatomy of the anterior neck [6].



5.2 The Trachea's Blood Supply

The comprehensive blood supply of the trachea is essential knowledge before any tracheal surgery can be conducted. Hermes C. Grillo highlighted the importance of small segmental arteries that enter the trachea through lateral tissue pedicles on each side. Additionally, Grillo and Miura provided a detailed description of the blood supply to the upper trachea, highlighting that blood supply is derived from three main branches of the inferior thyroid artery, with the lowest branch being the most significant. [7]. In 1977, Salassa and his team expanded on this by confirming Grillo and Miura's findings regarding the cervical trachea's blood supply and charting the arterial supply of the thoracic trachea. They found that the thoracic trachea receives blood from the bronchial, supreme intercostal, subclavian, right internal thoracic, and innominate arteries. Their research showed that segmental tracheoesophageal arteries frequently connect to lateral longitudinal arteries, which in turn connect to transverse inter-cartilaginous arteries. They identified three to seven tracheal arteries within the lateral pedicles. They also noticed that in contrast to dogs, which have intramural collateral tracheal blood supply that ensures tracheal viability even after completing circumferential dissection and anastomosis, humans experience tracheal necrosis following such procedures [8].

5.3 Brief History of Tracheostomy.

The word tracheostomy was first used by Heister in1739 [9]. Among contemporary surgical procedures, tracheostomy has an unexpectedly extensive history. Frost [10] outlined five distinct phases the evolution of tracheostomy's historical understanding. The first phase is known as the phase of allusions, this period spans from 3600 BC to AD 1500 and includes references to tracheostomy in Egyptian tablets, the Papyrus Ebers (1500 BC), the Rig Veda (100-1500 BC), and occasional mentions in Islamic and European medieval literature [9].

Although other accounts did not stratify tracheostomy as Frost, there is a consensus amongst most authors that the earliest known depiction of tracheostomy dates to historical accounts found on the Egyptian tablets [11]. There were also various accounts from the historical perspective stating that Alexander the Great performed a makeshift tracheostomy using his sword to save a soldier from choking on a bone. However, this historical phase of tracheostomy according to Frost did not describe actual cases of tracheostomy [10]. Frost continued that the second phase, in the history of tracheostomy started from 1500 to the early 19th century, and this phase is synonymous with isolated reports of successful cases of the procedure, although the procedure was often viewed negatively due to its high failure rate [10]. The first

scientifically documented successful tracheostomy in this era was performed by Antonio Musa Brasavola in 1546 to relieve airway obstruction caused by enlarged tonsils [10].

Frost described the third phase in the historical relevance of tracheostomy as the phase of systematic investigation. Due to the limited acceptance of tracheostomy, there was growing interest in understanding the procedure, which culminated in Trousseau's 1833 report on 200 tracheostomy surgeries performed on children with advanced diphtheria, with one-quarter surviving. [10]. This phase in the history of tracheostomy concluded with Jackson's comprehensive analysis of the tracheostomy techniques and complications in 1909. This resulted in the first breakthrough in the understanding of the procedure, and also the reduction in the amount of mortality associated with tracheostomy, and influenced a new generation of surgeons in the field of tracheostomy [3] [10]. Chevalier Jackson's technique laid the foundation for the modern tracheostomy procedure. Later, in 1943, Dr. Duncan Galloway broadened the applications of tracheostomy to include accessing the lower airways for clearing secretions and treating respiratory failure [12].

The fourth phase in the historical significance of tracheostomy according to Frost was driven by the poliomyelitis epidemics of the mid-20th century, leading to the consideration of mechanical ventilation and various intubation methods, to alleviate the suffering of individuals suffering from this condition. In 1932, Wilson proposed the prophylactic use of tracheostomy [3]. Although this phase initiated the popularity of tracheostomy as a procedure in patients in need of medical ventilation, the foundations of the complications of tracheostomy also started during this period. There was a gradual shift in focus from the relevance of the procedure to the various complications associated with the procedure [7].

According to Frost, the fifth phase of tracheostomy, also known as the modern phase, is more marked by a thorough integration of mechanical ventilation and endotracheal intubation. This phase has experienced significant advancement in trachea surgery due to the work of prominent surgeons like Hermes C. Grillo, Joel D. Cooper and Frederick G. Pearson among others. As the poliomyelitis pandemic continued in the 1950's, the establishment of respiratory intensive care units served as an important bed rock in the understanding of the complications of tracheostomy. It also served as a platform for understanding the management of these complications.

Historically, it was believed that tracheal cartilage could not heal effectively, deeming tracheal resection and reconstruction as unfeasible [5]. Grillo emphasized that the prolonged and widespread usage of tracheostomy following the outbreak of poliomyelitis 1950 increased the incidence of further complications that were not previously known. During the epidemic, the use of tracheostomy significantly

increased, particularly to support ventilation in individuals with respiratory insufficiency and failure. Additionally, this period saw a rise in the occurrence of new complications, including post-intubation lesions, tracheal stenosis, acquired tracheoesophageal fistulas, and broncho-esophageal fistulas. [7].

Some of the complications observed arose from the widespread use of mechanical ventilators with endotracheal tubes. Because these tubes had low-volume-high pressure cuffs, they caused pressure-induced ischemic injuries to the tracheal wall. As these ischemic related injuries healed, it was noticed that the patients had circumferential scarring and narrowing of their affected tracheal, resulting in tracheal stenosis. Simple dilation techniques were insufficient as the injury compromised the entire tracheal wall thickness, necessitating the removal of the damaged segment for effective treatment [5].

Grillo initiated a series of experimental procedures with canines to develop surgical treatments for tracheal stenosis. His research demonstrated the possibility of resecting a portion of the trachea and performing a primary re-anastomosis. Following successful results, Dr. Grillo applied his techniques to human patients with tracheal stenosis. Over time, these methods were refined and extended to treat various tracheal diseases requiring resection, including tumors [5], [13].

5.4 Technical Approaches to Conducting Tracheostomy

A tracheostomy is a surgical procedure that involves making an incision in the front wall of the trachea to create an opening. Two primary techniques are utilized to create this opening, the surgical tracheostomy and the percutaneous dilatational tracheostomy. The percutaneous technique typically involves inserting a tube between the first and second or the second and third tracheal cartilage rings. Conversely, surgical tracheostomy tubes are usually inserted between the second and fourth tracheal rings.

In many medical centers, standard tracheostomy is increasingly being replaced by percutaneous dilatational tracheostomy, a trend driven by its minimally invasive nature. This shift is expected to persist, and it is influenced by two factors, one of which is the eagerness of non-surgeon physicians to perform the procedure in the intensive care unit due to its perceived simplicity and cost. Compared to the traditional surgical tracheostomies which are usually done in operating rooms and are more expensive. Pearson acknowledged that both procedures can be in some instance safely carried out at bedside as well. Additionally various randomized small clinical trials carried out favored the percutaneous approach due to cost reduction and the possibility of having a more secured airway in the percutaneous tracheostomy

method. See table 1 below [3]. Although this review will briefly explain the methodology of both procedures, more focus will be given to the complications of the traditional surgical procedure.

Table 1: Randomized trials comparing open to percutaneous tracheostomy[3]

Author (Year)	No. Patients	Population	PDT Type	PDT Site	ST Site	Conversion PDT? ST?	Complications		Procedural Death
							PDT	*ST*	
Crofts et al[21] (1995)	53	Mixed adult	Ciaglia-Cook	Bed	OR	0	5 events	10 events	0
Friedman et al[22] (1996)	53	Mixed adult	Not stated	Bed	OR	0	12%	41%	0
Heikkinen et al[23] (2000)	56	Mixed adult	Portex	Bed	Bed	1	0	3.8%	0
Freeman et al[24] (2001)	100	Mixed adult	Portex Per-Fit	Bed	OR	4	Not stated	Not stated	1
Massick et al[25] (2001)	100	Mixed adult	Ciaglia-Cook		Bed	2	16%	21%	0
Sustic et al[26] (2002)	16	Spinal cord injury	Portex UK*	Bed	OR	0	12.5%	37.5%	0
Melloni et al[27] (2002)	50	Mixed adult	Ciaglia-Cook	Bed	OR/Bed	0	4%	36%	0
Kaylie et al[28†] (2003)	24	Mixed adult	Ciaglia-Cook	Bed	Bed				0
Wu et al[29] (2003)	83	Mixed adult	Ciaglia				Same	Same	0
Antonelli et al[30] (2005)	139	Mixed adult	Fantoni	Bed	OR	0	19%	37%	0

Selection criteria for study entry may have excluded severely ill patients in most trials.
**Ultrasound-guided guidewire dilating forceps.*
†Procedure utilization study.
OR, operating room; PDT, percutaneous dilational tracheostomy; ST, standard tracheostomy.

5.4 Brief Description of Percutaneous Dilatational Tracheostomy

Percutaneous dilatational tracheostomy is typically done in the intensive care unit on patients already intubated and sedated. However, more complex cases may be handled in an operating room. The procedure uses the Seldinger technique, which involves accessing the trachea with a needle, inserting a guidewire, and then dilating the trachea before introducing the tracheostomy tube over the guidewire. Patient selection is crucial when deciding which tracheostomy technique to employ. Absolute contraindications for tracheostomy include unstable patients or those with anterior neck infections. Some patients may necessitate an open approach due to anatomical or other specific concerns. Table 2 below outline essential pre-operative criteria that should be evaluated before performing a percutaneous dilatational tracheostomy.

Table 2: Key preoperative considerations for percutaneous dilatational tracheostomy [6].

The ability to hyperextend the neck
A minimum of 1 cm gap between the inferior cricoid cartilage and the suprasternal notch.
The patient's ability to tolerate temporary hypercarbia and hypoxemia.

5.5 Brief Description of Surgical Tracheostomy

Surgical tracheostomy is considered for patients who have contraindications to percutaneous dilatational tracheostomy. The procedure requires dissecting the tissues in front of the trachea and making an incision in the anterior tracheal wall, enabling the placement of a tracheostomy tube under direct visualization. Various incision techniques are commonly employed for surgical approaches. The horizontal technique is considered the least traumatic approach to the cartilage, although it may present challenges when inserting the tracheostomy tube. The technique involves making a horizontal cut at the midpoint between the cricoid cartilage and the sternal notch [6].

Another commonly used technique is the tracheal window approach, which involves making an incision in the midsection of the third or fourth tracheal ring to form a window. The underlying rationale for this method is to reduce damage to the surrounding cartilage when inserting the tracheostomy tube. However, this approach may elevate the risk of developing tracheal stenosis [6]. The A Bjork flap, in contrast, is a U-shaped flap with its base located inferiorly. It is formed in the anterior trachea through two vertical incisions extending from the lateral edges of the tracheotomy site. The rationale behind this technique is to keep the tracheal incision close to the skin edge and facilitate tube replacement prior to the maturation of the tracheostomy site. Complications associated with tracheostomy can be classified into three categories: immediate, early (within 0–7 days post-procedure), and late (beyond day 7) (see Table 6 below).

6. INDICATIONS FOR TRACHEOSTOMY

From an historical perspective according to Grillo, the primary indications for tracheostomy are in the provision of relief in situations relating to emergency airway obstruction, the management of secretions after central nervous system related injuries and in the reduction of dead space to enhance ventilation [7]. However, from a contemporary point of view, the indications for tracheostomy vary depending on practice setting, patient age and geographic location. Myriad studies from the Americas and Europe have associated acute renal failure as a leading cause for mechanical ventilation in adults. [3], [15], which inadvertently is associated with the usage of tracheostomy. Tracheostomy was used to provide the airway in 24% of these patients, with minor differences between countries [3]. In the adult population, the incidence of prolonged mechanical ventilation often occurs after acute trauma, major surgery, and chronic neuromuscular disorders. In contrast, tracheostomy in infants and children is associated with conditions such as tracheal

stenosis, acquired subglottic stenosis, vocal cord paralysis, tracheomalacia, and central nervous system disorders.

While non-invasive ventilation methods can sometimes eliminate the need for tracheostomy, they currently have a limited impact on long-term mechanical ventilation. Although tracheostomy is no longer indicated as a first-line intervention in emergency situations requiring airway stabilization, as the airway is typically quickly reestablished by inserting an endotracheal tube orally. However, its application is still incredibly significant in cases like acute facial or cervical trauma. Furthermore, it is mainstay amongst other options in airway management during elective surgeries, like those associated with extended mechanical ventilation support. For example, in patients requiring long-term usage of trans laryngeal endotracheal tube [7].

Approximately 5–10% of patients in intensive care units need prolonged mechanical ventilation, in which tracheostomy might be seen as a better alternative to prevent post-recovery complications [6]. During the COVID 19 pandemic for example, tracheostomy became more prevalent in different ICUs as more people required extended mechanical ventilation. The need for tracheostomy increased to about 33% in some ICU's. This buttresses the relevance of this old surgical technique even in a contemporary period [16]. Table 3 below is a list of the important indications for tracheostomy from both the classical and contemporary points of view.

Table 3: Indications for Tracheostomy

Prolonged mechanical ventilation
More effective pulmonary hygiene to manage airway secretion.
Chronic aspiration
Upper airway obstruction: Bilateral vocal cord paralysis Obstructive sleep apnea accompanied by arterial desaturation Retractions, Stridor
Neuromuscular disorders
Trauma
Assisting with ventilation support and weaning

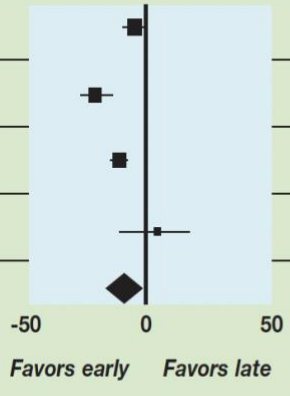
6.1 Prolonged Mechanical Ventilation

The primary reason for considering a tracheostomy in ventilated patients is to avoid harm caused by prolonged use of trans-laryngeal tubes. Prolonged trans-laryngeal intubation is known to cause scarring of the glottic commissures and subglottic space. The initial injury usually occurs at the posterior glottic commissure within five days of intubation and tends to worsen over time. This can be prevented by removing the endotracheal tube from the larynx. Other key considerations for opting for a tracheostomy include increased patient comfort. Tracheostomy also provides a more secure airway, reduces airway resistance, and lowers the threshold for weaning the patient off the ventilator. Early tracheostomy not only limits laryngeal injury but also appears to offer additional benefits [3]. While there is no agreement on the exact timing for initiating a tracheostomy, a meta-analysis of five randomized controlled trials revealed that performing a tracheostomy within seven days of intubation shortened both the duration of mechanical ventilation and the length of intensive care unit stay [3]. Tables 4 and 5 illustrate the impact of early versus late tracheostomy on these variables.

These benefits are most relevant for patients expected to recover from respiratory failure with a brief period of mechanical ventilation. A prospective multi-institutional study conducted across 12 countries and over 300 ICUs found that only 50% of patients received a tracheostomy between three and four weeks after starting mechanical ventilation. While these results underscore the importance of careful patient selection, the risk of laryngeal stricture from prolonged endotracheal intubation reinforces the preference for an early tracheostomy [3].

Table 4: The impact of early versus late tracheostomy on the length of ventilation in days. [3].

Author (Year)	Early Tracheostomy No.	Early Tracheostomy Mean (SD)	Late Tracheostomy No.	Late Tracheostomy Mean (SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Bouderka et al (2004)	31	14.50 (7.30)	31	17.50 (10.60)		28.34	–3.00 (–7.53 to –1.53)
Rodriguez et al (1990)	51	12.00 (7.14)	55	32.00 (22.25)		25.57	–20.00 (–26.20 to –13.80)
Rumbak et al (2004)	60	7.60 (4.00)	60	17.40 (5.30)		31.76	–9.80 (–11.48 to –8.12)
Saffle et al (2002)	21	35.00 (20.62)	23	31.40 (24.94)		14.32	4.10 (–9.38 to 17.58)
Total (95% CI) χ^2=22.96, df=3	**163**		**169**			**100.00**	**–8.49 (–15.32 to –1.66)**



Random effects meta-analysis of weighted mean difference suggests a shorter duration after early tracheostomy.
Reprinted with permission Griffiths J, Barber VS, Morgan L, Young JD: Systematic review and meta-analysis of studies of the timing of tracheostomy in adult patients undergoing artificial ventilation. BMJ 330:1243, 2005.

Table 5: The impact of early versus late tracheostomy on the length of stay in the critical care unit in days [3].

Author (Year)	Early Tracheostomy No.	Early Tracheostomy Mean (SD)	Late Tracheostomy No.	Late Tracheostomy Mean (SD)	Weighted Mean Difference (Random) 95% CI	Weight (%)	Weighted Mean Difference (Random) 95% CI
Rodriguez et al (1990)	51	16.00 (7.14)	55	37.00 (29.66)		40.93	–21.00 (–29.08 to –12.92)
Rumbak et al (2004)	60	4.80 (1.40)	60	16.20 (3.80)		59.07	–11.40 (–12.42 to –10.38)
Total (95% CI)	**111**		**115**			**100.00**	**–15.33 (–24.58 to –6.08)**
χ^2=5.34, df=1					-50 0 50		
					Favors early *Favors late*		

Random effects meta-analysis of weighted mean difference suggests a reduced length of stay after early tracheostomy.
Reprinted with permission Griffiths J, Barber VS, Morgan L, Young JD: Systematic review and meta-analysis of studies of the timing of tracheostomy in adult patients undergoing artificial ventilation. BMJ 330:1243, 2005.

6.2 Mechanical Obstruction of the Airway

In situations leading to mechanical obstructions, there are many contemporary methods that are used before the consideration of tracheostomy. For instance, benign stenosis resulting from emergency situations is treated nowadays with systematic dilations. Classically, tracheostomy might have been considered as a form of intervention, but it is no longer applicable in this type of complication. Organic upper airway obstruction due to a tumor, is usually resolved these days with an endotracheal tube, which can usually be maneuvered past the blockage to ensure emergency ventilation until the initial pathology can be resolved [7]. For difficult intubations in cases of organic upper airway obstruction as those just mentioned, a flexible bronchoscope can also be used to help guide the endotracheal tube past the obstruction. This method is also effective for patients with anatomically challenging airways, while a rigid bronchoscope is used as a last resort.

Occasionally, an endotracheal tube can be guided over a rigid pediatric bronchoscope into the trachea with the help of a “pusher” tube and a straight-bladed laryngoscope if other methods fail. Cases involving high obstructions typically necessitate the insertion of a large-bore needle or small-bore catheter through the cricothyroid membrane to facilitate emergency oxygenation prior to intubation or tracheostomy, depending on which intervention is considered most appropriate. [7]. Although emergency tracheostomy is considered as a quite easy procedure due to it perceived simplicity of tracheal access, it is associated with

many complications, and now mostly considered as an elective procedure, significantly reducing early complications like carotid injury or pneumothorax.

6.3 Management of Secretions

During recovery from surgery or illness, abundant respiratory secretions, a weak cough, or both, may necessitate tracheal access even if mechanical ventilation is not required. If mechanical ventilation is anticipated, a regular tracheostomy is typically indicated. Although, Grillo suggested that the use of mini-tracheostomy is more effective as it reduces the disruption of the natural airflow pattern in the respiratory system and has less impact on speech and swallowing [7]. A prospective trial demonstrated a significantly lower rate of sputum retention in high risk patients who underwent prophylactic mini tracheostomy compared to those receiving standard respiratory care emphasizing Grillo's findings [3].

However other researchers advocate against the usage of tracheostomy in patients with prolonged mechanical ventilation needs. They argued that the advancements in airway humidification, endotracheal catheter suctioning, pulmonary physiotherapy, and frequent flexible bronchoscopy aspiration have reduced the necessity of tracheostomy for secretion management [17]. Lewith *et al.*, on the other hand argued that the use of tracheotomy for pulmonary management is still relevant in today's medicine as different facilities have different guidelines depending on the severity of the patients' need [18].

6.4 Mechanical Ventilation Support

Currently, the most prevalent use of tracheostomy is in the management of mechanical ventilatory support [7,16,18]. Although primarily, endotracheal tubes are often used for extended periods, their prolonged use is associated with some serious injuries like injury to the glottis and subglottis. For this reason, the use of tracheostomy is preferred in situations where mechanical ventilations are required for more than 48 hours. Additionally, the use of tracheostomy is more comfortable for the patients [7], [18]. Another important consideration in managing secretions during prolong airway management is the ease of suctioning when tracheostomy is involved compared to when endotracheal tube is used. Grillo suggested that the replacement of endotracheal tube with tracheostomy should be carried out not more than within 5 to 7 days in adults requiring prolonged mechanical ventilation except in situations where it is planned that the patient can be weaned off shortly [7].

Tracheostomy remains an important option for providing a temporary or permanent airway in cases of chronic obstruction when definitive correction is either postponed or not feasible. In such cases, a

Tracheal T-tube is preferable. A Tracheal T-tube is a silicone-made airway stent shaped like the letter T, designed to support the trachea [19]. The tube helps preserve an adequate tracheal airway while providing support to a stenotic trachea that has been reconstructed or repaired. However, in cases of obstructive benign stenosis accessible in the neck, the tracheostomy or T tube stoma should be placed within the stenotic segment to prevent further tracheal damage and facilitate future resection [7].

6.5 Neuromuscular Disorders

Ventilator dependence in these conditions arises from severe respiratory muscle weakness. Tracheostomy is considered for various situations. For instance, during acute episodes in conditions like the Guillain-Barré syndrome, Duchenne muscular dystrophy, and for comfort in palliative cases (like amyotrophic lateral sclerosis). Contrary to the common belief that being on a ventilator significantly diminishes quality of life, studies have shown that most patients report satisfaction with their lives. However, the poor prognosis associated with amyotrophic lateral sclerosis tends to lead to a more mixed view on mechanical ventilation [19],[20].

6.6 Trauma

Immediate tracheostomy plays a crucial role in managing acute airway obstruction caused by cervicofacial trauma, including complex midface fractures, mandibular fractures, laryngeal trauma, and high-velocity gunshot wounds. While the need for tracheostomy is often clear during initial assessment, impending airway obstruction might only become evident after sedation or general anesthesia, especially if rapid muscle relaxation is induced. This risk can be mitigated by slowly inducing anesthesia with inhalational agents [21]. However, burn patients are an exception to the recommendation of early tracheostomy. If the burn affects the neck's skin, placing the tracheal stoma within eschar or adjacent to burn wounds increases the risk of bacterial infection and pulmonary sepsis. Inhalation injuries from fire by-products can also cause severe mucosal inflammation and an exaggerated scarring response to any additional injury [22].

6.7 Preexisting Tracheal Disease

Although airway obstruction due to tracheal stricture is uncommon, a tracheostomy could be indicated for patients with this condition. As such, the careful selection for the location of tracheostomy stoma is important to retain as much normal tracheal tissue as possible and to avoid worsening the existing

injury. In emergencies requiring an airway, a safe approach includes performing a rigid bronchoscopy to widen the stricture before positioning the stoma at the site of the stricture [3].

7. EFFECT OF TRACHEOSTOMY

7.1 Increased Breathing Effort

According to Pearson, the upper respiratory tract presents a significant barrier to airflow, accounting for 80% of the total resistance during nasal breathing and 50% during oral breathing. It is deduced that tracheostomy increases overall airflow resistance due to the small diameter of the tracheostomy tube. The degree of this effect is influenced by factors such as minute ventilation and the characteristics of the ventilator in use [3]. Hence, patients placed on tracheostomies usually experience an increase in breathing work, and this becomes more significant when patients are weaned off from the ventilator.

Although Sani and Wani argue that the work of breathing is reduced after tracheostomy, compared with breathing through an endotracheal tube, stating that their experiment revealed that tracheostomy offers less resistance as compared to the thermal liable endotracheal tube [23]. This finding is also synonymous with Pearson who reported that in patients with repeated failed extubation, tracheostomy reduces the work of breathing more effectively than endotracheal tube and natural way. Therefore, advocating for faster transition to the tracheostomy from endotracheal tube for patients suspected to need long term mechanical ventilation, as reduced work of breathing in tracheostomy result in lower intrinsic positive end expiratory pressure.

7.2 Swallowing

Typically, patients with a tracheostomy face an increased risk of aspiration and swallowing difficulties because of the tracheal tube. It is a common misconception that inflating the tracheal cuff prevents aspiration. In fact, inflating the cuff raises the esophageal pressure above it. Both the cuff inflation and the stabilization of the trachea to the skin by the tube can restrict laryngeal elevation, preventing the epiglottis fold from properly covering the supraglottic larynx. Additionally, the open lumen of the tube can facilitate silent aspiration. Positive tracheal pressure can prevent liquids from entering the glottis and help in coughing out secretions [3].

According to Pearson, using the one-way Passy-Muir speaking valve closes the tracheal tube to reduce the aspiration of thin liquids in patients who are under tracheostomy. Despite this, closing the

tracheal tube does not affect the pressure in the upper esophageal sphincter or pharynx. Factors influencing the recovery of swallowing function of the patient post tracheostomy include the patient's overall health, nutritional status, strength, age, and other comorbidities [3].

7.3 Decannulation

According to Pearson, after the full recovery of a patient from respiratory failure, there is a gradual weaning off the patient from the ventilatory support. The process of removing the tracheal tube begins with downsizing which involves replacing the current tracheal tube with a smaller one (usually reducing to a size 4, which has an inner diameter of 5 mm) [3]. Downsizing, along with closing the tube opening while keeping the cuff deflated, helps reduce tube-related resistance, decreases the risk of tracheal injury, and minimizes aspiration. This step also allows the patient to demonstrate their ability to breathe independently without mechanical assistance. Once the patient comfortably tolerates the smaller tube size, the tracheal tube is removed. The risk of postintubation tracheal stenosis is minimal, so routine bronchoscopy is generally not required unless there are indications of airway obstruction. Patients are advised to promptly report any symptoms such as persistent cough, stridor, or worsening difficulty in breathing, which would necessitate an immediate bronchoscopy examination.

8. RESULTS OF LITERATURE SEARCH.

Tracheostomy complications are classified into three timeframes: immediate, early (0–7 days post-procedure), and late (beyond day 7).

Table 6: Complications of tracheostomy [6].

Immediate	*Early*	*Late*
Hemorrhage	Hemorrhage	Tracheal stenosis
Air embolism	Pneumothorax	Tracheomalacia
Aspiration	Subcutaneous emphysema	Aspiration
Damage to nearby structure	Stomal infection	Tracheo vascular fistula
Hypoxemia, hypercarbia	Pneumomediastinum	Granulation tissue
Loss of airway	Stomal infection	Accidental decannulation
Death	Tube displacement	Tracheoesophageal fistula
	Dysphagia	Pneumonia
	Accidental decannulation	Dysphagia

9. IMMEDIATE COMPLICATIONS OF TRACHEOSTOMY

9.1 Hypoxia

According to Grillo, most immediate complications associated with tracheostomy are due to the rushed performance of the procedure under emergency conditions, often resulting in poorly defined anatomical landmarks. Hypoxia and cardiac arrest during an urgent tracheostomy are critical concerns associated with immediate complication of the procedure. Hypoxia occurs when there is an insufficient oxygen supply to the body, and it can rapidly lead to cardiac arrest, especially in emergency settings where the patient's airway is compromised. The urgency of the situation often necessitates rapid intervention, which can sometimes result in suboptimal oxygenation. This immediate complication can be significantly mitigated when the tracheostomy is performed under controlled, elective conditions where an adequate airway is first established, allowing for proper oxygenation throughout the procedure. Ensuring adequate preoperative preparation, which includes the stabilization of the patient's airway, can prevent these severe outcomes [7].

Pearson also concurred with Grillo that Hypoxia is an operative or immediate complication during tracheostomy, however he attributes hypoxia to trachea secretions and reported that hypoxia is usually reduced after suctioning. However, in instances when respiratory failure is pronounced resulting in hypoxia, elective tracheostomy may have to be postponed [3].

9.2 Laceration of Nearby Structures and Blood Vessels

From a classical perspective as researched by Grillo and Mathisen, tracheostomy when performed in emergency situations sometimes has resulted into the forceful insertion of an unsuitable tube which usually results in the laceration of the membranous tracheal wall [7]. Currently, tracheostomies are mostly performed after an airway has been established. A rare exception might occur in cases of cervical trachea separation caused by blunt trauma, where emergency bronchoscopy fails to reveal a passage to the distal trachea. Careful selection of the appropriate tube size and gentle insertion technique are essential to avoid this complication.

Other authors like Mehta and Mehta as well as Lee *et al*., in their separate findings related to lacerations, explained that accidental laceration of innominate artery, recurrent laryngeal nerves, greater vessels of the neck and esophagus has been implicated as immediate or early complication. These are mostly attributed to poor visualization and hasty surgical techniques that can damage critical structures [6], [24]. Careful evaluation of the neck vasculature, good lighting and precise surgical technique are necessary to

mitigate this and minimize the risk. Most of these complications have been significantly reduced because of improvement in surgical techniques and adequate anesthesia.

9.3 Hemorrhage

According to Pearson, bleeding or hemorrhage as an immediate complication is usually minor with the pathogenesis resulting from injury to the anterior jugular veins, the divided thyroid isthmus, and small tracheal arteries. However, substantial bleeding may be seen in patients with either superior vena cava syndrome or with engorged neck veins [3]. Jonas *et al*., also acknowledged that small amount of self-limiting bleeding is expected after the initial procedure of the tracheostomy procedure [25], [26]. This bleeding is usually self-limiting and minimal and in instances where the bleeding has been significant, evaluation is usually made by the team that placed the tracheostomy tube. This might require surgical exploration or vessel ligation which is seen in about 5 % of cases [25]. Alsuniad *et al.,* and other authors like Morris *et al.,* stated that while major bleeding is uncommon during a tracheostomy procedure, even minor bleeding can become serious if it blocks the airway [25], [27].

Bleeding as an immediate complication is mostly associated with errors in surgical technique. Common sites of bleeding include the anterior jugular veins, the thyroid isthmus, and vascular variations such as the thyroid artery [28]. These observations attest to Pearson's hypothesis of bleeding as an immediate complication. Walvekar *et al.*, on the other hand categorized bleeding during tracheostomy procedures into different strata based on bleeding severity. According to these authors, the several types of bleeding can be divided based on unusual bleeding, excessive, major, and massive bleeding. Unusual bleeding refers to any amount deemed "abnormal" by the individual performing the procedure. This subjective assessment relies on the surgeon's experience and judgment in determining what constitutes unexpected or excessive bleeding during each specific case [26]. Excessive bleeding, on the other hand, is defined objectively as any amount exceeding 20ml, which surpasses the estimated blood loss anticipated during the procedure [26].

Major bleeding is characterized by a more significant decrease in hematocrit, the percentage of red blood cells in whole blood. This category encompasses situations where the hematocrit level drops by 3 points or more, or when the patient requires transfusion of two or more units of packed red blood cells. The last categorization depicted as massive bleeding represents the most severe form occurring when the hematocrit level plummets by 6 points or more, or when transfusion of four or more units of packed red blood cells becomes necessary. It is important to note that the frequency of these bleeding events varies across studies. Major bleeding has been reported to occur in 0 to 7% of cases, while minor bleeding (not exceeding 20 ml) can occur in a wider range of 0 to 80% [26].

In line with Morris *et al.,* observation, massive bleeding can occur due to pressure necrosis from cuffs with high pressures. Other factors that increase risks of massive hemorrhage are improper positioning of the cannula tip due to direct pressure or twisting from the ventilator circuit, improper tube placement at a lower position, overextension of the head, exposure to radiation therapy, and the use of steroids [27]. To mitigate the risk of bleeding complications in tracheostomy, it is essential to perform a comprehensive preoperative evaluation of the patient's medical history, including any coagulation disorders, coagulopathies, or hematological issues. The administration of anticoagulants, aspirin, and anti-inflammatory drugs can also contribute to increased bleeding during the procedure, and these must be appropriately evaluated before the procedure.

Superficial bleeding is usually managed with local pressure, light dressing, or packings with adrenaline, however, if there is continuous nonstop bleeding after tracheostomy tube placement, surgical exploration should be considered. Mehta *et al.,* highlighted that preventive measures, such as performing the tracheostomy at or above the third tracheal ring, using a tube of appropriate length, and utilizing guided ultrasound to identify vessels, could help avoid this complication [24]. Pearson concluded that to prevent postoperative hemorrhage, each bleeding vessel should be individually ligated. Additionally, the use of electrocautery or other thermal coagulation tools should be discontinued once the tracheotomy is performed to minimize the risk of airway fire [3].

9.4 Loss of airway

The occurrence of airway blockage leading to hypoxia is a critical complication associated with tracheostomy, necessitating immediate intervention [26], [29]. According to Trottier *et al.,* the blockage of the tracheostomy tube after percutaneous dilatational tracheostomy (PDT) happens in 0–3.5% of cases, posing a significant risk of sudden respiratory decline and potential fatality [29]. Causes of obstruction include mucus accumulation, clot formation within the airway, or misplacement of the tube. Mucus plugs, if aspirated, can lead to further complications such as atelectasis or lung abscess.

To promptly address blockages caused by mucus or clot formation, suctioning of the tracheostomy tube, or replacing the inner tube is recommended. Issues related to loss of airways are predicated on other complications such as tube displacement which could also result in obstruction of airway, emboli related loss of air way complications and other phenomena. To reduce the risk of this complication, choosing the correct tube size and length based on the patient's anatomy can help prevent posterior tracheal obstruction, which could lead to airway loss. As observed by various reviews, guidewire usage during tube placement

or exchange can reduce the risk of airway loss during the procedure. Furthermore, choosing the correct tube size and length based on the patient's anatomy can help prevent posterior tracheal wall obstruction [12], [27], [29].

10. EARLY COMPLICATIONS OF TRACHEOSTOMY

10.1 Pneumothorax

Pneumothorax is a rare but serious early complication of tracheostomy. It occurs when air escapes into the pleural space, causing the lung to collapse. This complication is most associated with procedures in small children or in patients with difficult anatomical structures, such as short necks, obesity or in kyphotic individuals [7]. While Pearson agreed with Grillo that the incidence of pneumothorax during tracheostomy is a rare complication, he added that the etiology of the complication is unclear in adults except in situations where extensive dissection is performed in the mediastinum. However, he recommended that once pneumothorax is identified, a chest tube is placed to re-expand the lung [3].

According to Panajoroen *et al.,* the occurrence of this complication can be as high as 17% but it is mostly prevalent in the pediatric population and attributed to the relative elevation of pleural domes [30]. Walvekar *et al.,* also acknowledged this complication agreeing with the previous authors about the rarity of this complication in the adult population [26]. Furthermore, Walvekar *et al.,* added that direct pleural injury by the surgeon during the procedure might increase the prevalence of pneumothorax in the adult population [26]. They also noted that one consequential effect of pneumothorax is the potential damage to the posterior tracheal wall and esophagus, resulting from knife contact or excessive force during tracheostomy insertion. Pneumothorax may also occur if the tracheostomy tube is mistakenly introduced between the anterior wall of the trachea and the anterior mediastinum, creating a false passage. This can be promptly identified when the patient lacks an adequate airway after intubation [30]. Although it is quite a rare complication, Treatment involves the insertion of a chest tube to remove the air from the pleural space and allow the lung to re-expand.

10.2 Procedure Related Hemorrhage

According to Pearson, minor bleeding shortly after surgery is relatively common in patients who are taking antiplatelet or anticoagulant medications. When the source of bleeding is from the tracheal cut edge, it typically responds well to wound packing. However, if the bleeding is substantial, the patient will need to be taken back to the operating room to address and control the bleeding vessel directly [3]. However, Grillo expanded on procedural related hemorrhage by stating that although infrequent, it remains a

significant concern. The potential for bleeding that arises from injury to blood vessels during the tracheostomy procedure are from the erosion of the innominate artery. This complication requires immediate attention and intervention to prevent catastrophic outcomes. Furthermore, the innominate artery is particularly at risk when the tracheostomy tube is improperly positioned. Prolonged pressure from the tube can lead to erosion and subsequent massive hemorrhage. Emergency measures include applying finger pressure and overinflating the tracheostomy tube cuff to temporarily control bleeding [7].

Walvekar *et al.,* continued by explaining that procedural related bleeding can be avoided by paying meticulous attention to details of the procedure. Properly securing the airway during the procedure reduces the patients' movement and minimizes the potential for procedural errors caused by spontaneous movement by the patient [26]. Also, local anesthetic is encouraged prior to tracheostomy to induce vasoconstriction and reduce the risk of intra and post-operative hemorrhage. Furthermore, they advocate for careful identification of structures, such as the anterior jugular vein and thyroid isthmus, as crucial to avoiding intraoperative dissection [26].

Walverkar *et al.,* suggested that dissection should be confined to the midline, and recognition of surgical landmarks is essential to prevent lacerations [26]. Furthermore, they emphasized the need to investigate any bleeding around the stoma, especially within the first 48 hours as early bleeding often stems from local factors like injury to the anterior jugular veins, inferior thyroid veins, or tracheal erosions caused by excessive suctioning. Systemic coagulation issues can contribute as well to bleeding, which all buttresses the previous findings by Pearson.

According to Pearson, significant bleeding from the tracheal lumen necessitates a bronchoscopy to identify the source. In most instances, the etiology of the bleeding is due to suction-related trauma [3]. Also, accidental decannulation within the first week after placement of tracheostomy requires urgent intervention as immediate control of the airway should be achieved through oral intubation, and re-insertion through the fresh stoma should be avoided to prevent complications. If such an episode occurs without an unusual trigger, it may suggest that the initial tracheal tube is inadequate and may need to be replaced with one that fits better.

10.3 Cannula Obstruction.

According to Grillo, obstruction as a complication is mostly caused by hemorrhage, damage to major neck blood vessels, and improper intubation into the mediastinum instead of the airway. This complication is more prevalent in percutaneous tracheostomy [7]. Pearson noted that excessive secretions, insufficient

suctioning, improper tube cleaning, or infrequent inner cannula changes can lead to either gradual or sudden airway obstruction [3].

Walvekar *et al.,* on the other hand, attributed obstruction mostly to chronic settings, where tracheostomy can disturb the natural balance and physiological homeostasis of mucus clearance within the respiratory system. This disruption occurs primarily through direct interference with two key airway defense mechanisms: the mucociliary function and the cough reflex. Tracheostomy impedes the effective functioning of these mechanisms, compromising the body's ability to clear mucus efficiently. When secretions cannot be cleared, mucus accumulates and sticks to the airways, eventually blocking the lumen of the trachea [26]. Although coughing and blind suctioning helps in clearing mucus, a residual amount of this glycoprotein-rich liquid invariably leaves a coating on the tube's internal luminal surfaces. Over time, they gradually lose their water component becoming drier, thick, and more viscous increasing the risk of obstruction and reducing airway flow [31].

Additionally, this mucus accumulation might serve as a nutritional base for microorganism proliferation, also predisposing people to ventilator associated pneumonia [31]. As the glycoprotein-rich liquid accumulates, it creates an environment that is ideal for bacterial growth, sheltered from both the immune system and systemic antimicrobials. The development of ventilator-associated pneumonia has been strongly linked to tracheal tube obstruction. Instances have been recorded in various literature where near total obstruction has led to emergency interventions [31].

Another complication implicated in tracheal tube obstruction is occlusion due to blood clot. The pathogenesis of this complication is related to minor airway bleeding due to tracheal erosion and irrigation resulting in clot formation. The prevalence of this complication is not recorded in many literatures. Post operative reasons like tube dislodgment, poor tube sizing, and anatomic malposition of tube causing the tip of the tube lying against the posterior tracheal wall and causing a "ball-valve" effect have all also been implicated in this complication [31]. Fortunately, most of these complications can be prevented via attentive hygiene and nursing. Using tracheal tubes with an inner cannula which can frequently be removed and cleaned can also prevent bleeding and stop clot accumulation in the airway or in the tube.

There are no standard interventions when treating this condition, as it varies depending on the severity. In mild cases, it is important to identify the problem and prevent total obstruction. Steven L Orebaugh advocates for irrigation with normal saline, and suctioning using a catheter to reduce buildup and maintain airway. Removing the inner catheter is advocated for cleaning and maintaining ventilation [31]. While in more acute situations where the obstruction process is well advanced, the patient may suffer from

severe hypoxic or hyper carbic situations before seeking medical help or situation is noticed. In situations like these, attempts to ventilate the patient with bag apparatus usually results in extremely high pressure and resistance, and as such, the removal of inner canular in instance where it is present may help to reestablish ventilation.

A definite solution in this instance involves rapid removal and replacement of the tracheal tube in case there is a maturation of the tracheostomy, otherwise or in cases of complication, intubation might be carried out to ensure continuous and adequate ventilation [26]. In these situations, the tracheal tube should be promptly removed and replaced with a clean one if the tracheotomy has fully matured. If not, the patient may be quickly ventilated or intubated from above, as described by Epstein, to ensure proper oxygenation and ventilation, thus alleviating the obstruction caused by tracheal stenosis [38].

10.4 Sepsis and Stomal Infection

According to Grillo, sepsis, particularly of the invasive or necrotizing type, is surprisingly rare despite the potential for tracheostomies to become contaminated. This contamination typically involves resistant strains of *Staphylococcus aureus* with *Pseudomonas aeruginosa*, and *Streptococcus* and *Escherichia coli* also frequently present. This occurs even when sterile surgical techniques are used and meticulous care is taken with the stoma, tubes, and suctioning. Antibiotics are generally avoided unless there is clear evidence of local infection or pulmonary involvement, to prevent the overgrowth of other microorganisms. The contamination typically resolves once the device is removed and the stoma is allowed to heal. [7].

Pearson stated that wound infection is uncommon if the skin closure around the tube is not too tight; however, a sealed closure can lead to infection in the enclosed contaminated space. The subcutaneous tract typically closes and contracts on its own within a week [3]. In relations to other literatures, there were not so many instances of sepsis as a major complication, as other authors like Metha *et al.*, discussed sepsis after trauma as one of the major indications of quick transition from endotracheal tube to tracheostomy. In their study, quick transitioning from endotracheal tube to tracheostomy following traumatic events reduces the prevalence of sepsis in patients due to pneumonia infection [32].

Local infections are seen in about 5% of tracheostomy procedures, typically affecting the stoma site, the tip of the tube, and the area around the cuff. These infections are more frequently observed when the procedure is performed surgically [24]. The predisposing factors include large stoma and antiseptic agents used for cleaning or ischemia secondary to cuff pressure. The risk of infection can be reduced by limiting extensive neck incisions, performing routine dressing changes, and conducting thorough assessments

during dedicated tracheostomy rounds. Prophylactic antibiotics are not usually advised before the procedure. For minor infections at the stoma site, proper wound care is typically adequate. However, in rare and severe cases like necrotizing tracheal infection, treatment may involve oral intubation and debridement of the affected tissue [33].

10.5 Subcutaneous Emphysema

Subcutaneous and mediastinal emphysema are early complications resulting from air leaks into the surrounding tissues [34]. These are usually identified by palpable crepitus around the tracheostomy site and require close monitoring. It is considered as an unusual complication of tracheostomy and usually attributed to excessive coughing or the usage of uncuffed tracheal tube or when the tube used is not properly fitted and inadvertently causes result in air leakage. Other factors complicated in this process include tight closure of the wound with sutures that blocks the escape or release of air that comes around the tube. [31]. The prevalence of this phenomenon is mostly associated with patients who have underlying airway obstructions which prevents free air movement from the larynx into the oral cavity and the result of this is the substantial leakage of air into the surrounding tissues associated with the process called subcutaneous emphysema.

In situations where this is quickly noticed and the etiology of the problem is promptly identified and corrected, the correction of subcutaneous emphysema can occur with air is slowly reabsorbed without any direct interventions. Factors corrected in these instances include replacing uncuffed tube or the replacement of tight sutures. Additionally, patients with persistent cough can be treated with antitussive to prevent the exacerbation of the issue [35]. However, in severe subcutaneous emphysema, placement of drains or small incisions beneath the skin to allow air escape from large subcutaneous air collection can also be a form of intervention but this does not exclude proper examination and identification of the primary underlying factor causing the air leakage [31].

According to Lee *et al.,* the Incidence of subcutaneous emphysema ranges from 0–5%. They also concur with the previously established cause of subcutaneous emphysema, which involves the accumulation of air in the tissue anterior to the trachea. This occurs as a result of positive pressure ventilation or forced coughing against a tightly packed or obstructed neck dressing. Air exhaled from the trachea can then move through the subcutaneous tissue into the neck or spread through the pre-tracheal fascia into the mediastinum. [6]. On the contrary, Durbin, in his research on the early complication of tracheostomy argued that the rate of subcutaneous emphysema varies from 0% - 4% among those who underwent tracheostomy [20].

Lazzarotto *et al.* asserted that the air may be introduced into the subcutaneous tissues during tracheostomy via patients' excessive cough when the trachea is open during or immediately after the procedure. General risk factors for subcutaneous emphysema include extensive tissue dissection, tracheostomy tube obstruction, and high-pressure mechanical ventilation. Furthermore, the use of a fenestrated tracheostomy tube is also associated with an increased risk. [36]. Although subcutaneous emphysema is an uncommon complication, it can be serious, particularly when accompanied by pneumothorax and/or pneumomediastinum. Preventive measures, such as avoiding a tight tracheostomy tube strap and the use of a fenestrated tracheostomy tube, are essential to reduce the risk of this complication [35].

Other researchers like Alshoubi and colleagues agree with Orebaugh's assessment of promptly identifying and addressing the underlying cause, leading to a gradual improvement in the condition [35]. Walvekar *et al*., highlighted the paradoxical recommendation of emergency tracheostomy in managing subcutaneous emphysema resulting from other causes. Recently, the placement of subcutaneous drains has proven to be an effective and safe method for providing decompression and resolving subcutaneous emphysema. Less effective techniques include inserting medium or large-bore intravenous catheters into the plane or employing multiple incisions or blow holes to aid in decompressing the accumulated air [26].

10.6 Tube Dislodgement

Mispositioning of the tracheostomy tube is a significant concern during the insertion process, posing the risk of airway obstruction, the formation of a false passage, and possibility of potential damage to adjacent structures, including the esophagus. In challenging tracheostomy cases, there may be a need for multiple attempts to ensure proper tube placement, potentially leading to extended periods of oxygen deprivation. Morbidly obese individuals face an elevated risk of this complication, primarily due to the increased distance between the skin and trachea. This increased distance hampers visualization and causes more subcutaneous tissue, increasing the likelihood of creating a false passage [37].

Morris and colleagues reported that tube dislodgment often occurs before the stoma is fully healed, rendering it susceptible to movement or complete displacement. Displacement can manifest as either complete, also known as decannulation, or partial dislodgment, wherein the tube's tip may shift into a false passage anterior to the trachea. Factors contributing to this problem include loosely tied restraints, excessive neck and airway edema, coughing, agitation, inadequate sedation, morbid obesity, mismatched tracheostomy tube being too short for the tract, and downward traction from the ventilator circuit

[27]. Typically, complete healing of the stoma requires about a week, and premature dislodgment before this period can result in stoma collapse, significantly jeopardizing the airway.

The dislodgment of the tracheostomy tube within the first postoperative week is regarded as a medical emergency, underscoring the critical importance of securely fixing the tube in place. Accidental dislodgment shortly after surgery can disrupt tissue planes, complicating the process of simple tube replacement [27]. Effectively managing tube dislodgment involves ensuring essential supplies, such as suctioning equipment, a new tracheostomy tube equipped with an obturator, oxygen, and emergency endotracheal intubation equipment, to be readily accessible at the bedside. Taking prompt action is imperative to prevent airway compromise and uphold the patient's safety. Timely identification and swift intervention are essential in the management of displaced endotracheal tubes. In instances where a suction catheter cannot be introduced, potential risks include tube migration into a false passage or obstruction due to mucus. Dislodgment can occur in both mechanically ventilated patients and those breathing spontaneously without immediate distress [27].

Preventive measures against tracheostomy tube dislodgement are crucial to prevent life-threatening complications. These measures include securing the ties snugly, minimizing traction from the ventilator circuit, maintaining a midline and neutral position, and minimizing patient transport. Regularly checking tube security, especially before movement, is essential [27]. Moreover, newly established stomas, particularly those less than a week old, are susceptible to swift closure, posing a challenge for the reinsertion of the tracheostomy tube. In these instances, prompt intervention involving mask ventilation and subsequent orotracheal intubation becomes imperative to ensure airway maintenance [27].

For patients with a mature stoma over one week old, the rate of stoma closure depends on the duration of decannulation of the tube. If the tube is promptly replaced, the stoma can typically accommodate the tube without complications. However, prolonged decannulation can cause the stoma to narrow, requiring a smaller tracheostomy tube for reinsertion. To ensure a quick response, it is crucial to maintain a tracheostomy tube of the same size and one that is a size smaller readily accessible. Generally, mature stoma can close to 50% within 12hours and 90% within 24hours, complete closure average may occur within 2 weeks, for this reason it is important as stated earlier to ensure that tube size remains the same.

The process of reinserting the tracheostomy tube or tube replacement involves first removing the inner cannula and inserting the obturator into the outer cannula. The obturator serves as a protective guide for the tube's tip, minimizing trauma to the airway. In cases of a flexible tube, the obturator also provides rigidity and control during insertion. To minimize the risk of entering a false passage, the tube is initially

inserted at a 90-degree angle. Subsequently, the tube is angled downward another 90 degrees to bring it into its proper position, and the obturator is removed [38].

10.7 Cricoid cartilage injury

According to Walvekar *et al.,* before proper understanding of the tracheotomy procedure, mistakes involving the cricoid cartilage were common during tracheostomies, Chevalier Jackson, after refining the tracheostomy technique, emphasized the critical importance of preserving the integrity of the cricoid cartilage during the procedure. Improper understanding or carelessness during tracheostomy can lead to damage to the cricoid cartilage, resulting in chondritis that may progress to subglottic stenosis. [26]. Pearson also highlighted that tracheal stoma placement positioning in relation with the cricoid cartilage during tracheostomy can contribute to further post-procedure complications. He strongly advocated against allowing the tracheal stoma to rest on the cricoid cartilage, as this could cause necrosis and subglottic stenosis [3].

Walvekar *et al.,* also suggested that if the cricoid cartilage is accidentally injured during tracheostomy, the tube should be removed immediately, and a new stoma should be created at a lower point on the trachea. Unfortunately, this complication is often observed in patients who have undergone emergency tracheostomies performed by practitioners without specialized expertise, leading to inadvertent damage to this critical anatomical structure. The paradox of tracheostomy lies in its seemingly straightforward nature, yet it is associated with various serious complications.

10.8 Injury to the laryngeal nerve

The insertion of a tracheostomy can potentially damage neck structures associated with the larynx, particularly the recurrent laryngeal nerve. According the Salassa *et al.*, the recurrent laryngeal nerve, located in the tracheoesophageal sulcus, should remain unharmed during a tracheostomy as long as the dissection is confined to the midline [8]. Since this nerve innervates the vocal cord, its integrity in a patient with a tracheostomy can only be assessed through direct or flexible laryngoscopy. If the nerve is injured, laryngoscopy will reveal vocal cord paralysis.

Walvekar *et al.,* asserted that in cases when intraoperative procedures lead to the damage of the recurrent laryngeal nerve during a tracheostomy, a vocal cord medialization procedure should be conducted immediately during the procedure to align the vocal cord at the midline. Additionally, upon necessitation, a secondary procedure may be performed later. However, if the injury is suspected but not definitive, the patient should undergo periodic re-evaluation for at least six months postoperatively to monitor for the return of

vocal cord function. If no improvement is observed within this time frame, spontaneous recovery of the vocal cord is unlikely [26]. Pearson added that medialization procedure of the vocal cord is important not only in repair of the vocal function but also in facilitating the mobilization of pulmonary secretions and in the prevention of aspiration and subsequently pneumonia [3].

Additionally, When the extent of recurrent laryngeal nerve injury is uncertain, and the patient exhibits symptoms and endoscopic findings of nerve dysfunction such as a weak voice, with or without aspiration, gel foam has been effectively used for temporary medialization of the vocal cord without adverse effects [26]. The decision to use gel foam depends on the degree of aspiration, the patient's overall health, and their specific needs. Although other materials have recently been developed that are as effective as gel foam, such as a combination of gelatin, carboxymethylcellulose, and water, the choice of material typically depends on the specific protocols of each hospital [26]. In situations where the vocal cord functionality does not recover within six months, a thyroplasty or medialization procedure should be performed to restore voice function. Walvekar *et al.,* also has reported instances where bilateral recurrent laryngeal nerve injury occurs during tracheostomy, which results in the patient experiencing airway difficulties and a breathy voice, particularly during decannulation attempts. If spontaneous recovery does not occur within six months, medial arytenoidectomy or transverse cordotomy are effective options for increasing the glottic airway [26].

11. LATE COMPLICATIONS OF TRACHEOSTOMY

Grillo stated that although most of the later complications of tracheostomy seem unavoidable and inevitable at first, many of these complications are now largely avoidable. Despite considerable progress in their prevention, post intubation lesions continue to be the most prevalent surgical tracheal complications encountered. Enhancing awareness of their clinical features and nature is essential to avoid delays in recognizing these lesions and to ensure patients receive the best possible treatment [7]. Knowledge of the laryngeal lesions associated with intubation is important before the tracheostomy procedure. Some of the patients undergoing tracheostomy might have initially been ventilated through an endotracheal tube and this might have caused a laryngeal injury which might be long lasting and problematic.

Even when presenting with tracheal lesions or tracheostomies, these patients may have underlying laryngeal issues caused during endotracheal tube insertion and hence serious complications can arise if tracheal repairs are conducted without confirming laryngeal integrity [7]. For instance, an unrecognized inadequate glottis, masked by a preoperative tracheostomy and only discovered after tracheal reconstruction,

might necessitate further endotracheal intubation or another tracheostomy to ensure a functional airway until the glottis is corrected. Intubation from this could jeopardize the healing of a newly repaired trachea.

11.1 Obstructive Lesions of the Trachea Following Tracheostomy

Obstructive lesions of the trachea after tracheostomy can occur at four distinct depending on the underlying cause of the injury. The levels are the site where inflatable cuff was positioned, level of the stoma, the segment between the stoma and the cuff location, and the stomal level. According to Copper and Grillo the opening created by tracheostomy inevitably leads to some scarring during the healing process, and after healing, an asymptomatic narrowing of the tracheal may occur and in certain instances the narrowing might expand up to 50% of the tracheal cross-sectional area or even more. The lesions associated with obstruction are granuloma, anterolateral stenosis, and a posterior depressed flap of the tracheal wall above the stoma [39].

Complications involving granulation tissues are typically associated with tracheal stenosis. These issues usually develop during the healing process. Granulomas may appear weeks or months after the tracheostomy tube is removed and as the healing progresses, exuberant granulation tissue can accumulate on the inner surface of the trachea at the stoma site, potentially becoming large enough to obstruct the airway. This papillomatous granulation tissue often forms alongside deformities at the healing stomal site. If a sizable granuloma is present, removing the tracheostomy tube can lead to immediate airway obstruction [7], [13]. According to Strietz and colleagues, as granulation tissue matures, it gradually becomes fibrous and is covered with a layer of epithelium. The formation of fibrosis leads to stenosis, causing the anterior and lateral parts of the tracheal wall to narrow at the level of the stoma [40].

11.2 Tracheal stenosis

Tracheal stenosis is the most frequent serious late complication of tracheostomy, characterized by an abnormal narrowing of the tracheal lumen caused by granulation tissue or fibrosis. The development of tracheal stenosis is primarily driven by inflammation and the formation of granulation tissue [6]. Factors that increase the risk of tracheal stenosis include trauma from the tracheostomy, mucosal ischemia caused by excessive cuff pressures, and chronic mucosal irritation, all of which can result in ulceration and inflammation of the cartilage. This inflammation triggers the development of granulation tissue, which gradually transforms into a fibrous tissue layer covered by epithelium, leading to tracheal stenosis. [6]. Other risk factors include gender (with males being more predisposed), advanced age, stomal infections, and the use of tight or oversized cannulas.

Although all patients with a tracheostomy might experience some degree of tracheal stenosis, which typically only becomes symptomatic when more than 50% of the lumen is affected. According to Lee *et al.,* the incidence of clinically significant tracheal stenosis post-tracheostomy ranges from 3–12%, and the condition can be identified while the patient is still on mechanical ventilation, as it can cause difficulties in weaning off the ventilator. Other associated symptoms, including dyspnea, stridor, or respiratory failure, appear within two months after decannulation, though the onset can vary from days to months [6].

According to Pearson, the incidence of tracheal stenosis has become less prevalent due to the usage of compliant tracheal cuffs. These cuffs can reduce the incidence of pressure-induced cartilaginous damage. But in some instances, even those low-pressure cuffs can cause injury if overinflated [3]. Copper and Grillo added that patients with stenotic lesions are now more likely to have comorbid conditions and laryngotracheal involvement, often due to cricoid injury [39]. Also, the association between the method of tracheostomy and the risk of stricture remains unclear. Grillo continued that tracheal stenosis is tangential to the tracheostomy opening or stoma and the area of the balloon cuff and in some cases, both regions may occur simultaneously [7].

As enumerated earlier Grillo attested as well that the introduction of compliant, extensible, large-volume latex cuffs has significantly reduced the incidence of post cuff stenosis. However, stenosis at the stomal site is still common, especially when a large stoma, superimposed infection, or rigid connecting systems are used, leading to pressure erosion. The tracheal wall may exhibit fibrosis, granulation tissue, and sometimes calcium depositions which predisposes patients to the condition. According to Klemm and Nowak, the correct classification of stenosis is essential to determine appropriate management usually with rigid bronchoscopy [41].

They observed that tracheal stenosis requiring interventions usually occurs when there is between 60 to 70 % to total occlusion of the trachea lumen. It is also regarded as either grade III or grade IV lumen occlusion [41] and usually requires prompt hospitalization and surgical intervention. Additionally, they confirmed that stenosis is synonymous with tracheostomy tube narrowing, buttressing the work of Grillo and Pearson [3], [7]. The reasons for stenosis according to Klemm and Nowak are multifaceted, often stemming from a blend of tracheal trauma, inflammation, and irritation from foreign bodies which leads to the formation of tissue granulation in susceptible areas surrounding and adjacent to the stoma, resulting in the deterioration of the original tracheal tissue layer through fibrosis [41].

Klemm and Nowak added that cartilaginous rings are extremely sensitive to traumas and injuries, often resulting in the recurrence of tracheal stenoses which is usually triggered by an overactive regeneration process, characterized by the expression of osteoid by osteoblasts and subsequent

mineralization in an acidic environment. Other researchers like Walvekar *et al.,* attributed the pathogenesis of stenosis to high-pressure low-volume cuffs leading to a cascade of events including mucosal ischemia, ulceration, chondritis, cartilage necrosis, and ultimately, scar formation. The historical prevalence of these complications spurred a significant redesign of tracheostomy tubes. Today's tubes utilize high-volume, low-pressure cuffs, dramatically reducing the incidence of such injuries [4].

According to Walvekar *et al.,* subglottic stenosis often arises after prolonged endotracheal intubation or high tracheostomy placement, to the cricoid cartilage. The cricoid cartilage represents the narrowest point of the airway, making them more susceptible. The proposed mechanism is believed to have been developed through a series of events starting with ischemia of the airway mucosa and progressing to inflammation of the cricoid cartilage caused by pressure injury. Subsequently, bacterial infection then set in, damaging the cricoid cartilage, and weakening its supportive structure. As the body attempts to heal, scar tissue forms, narrowing the airway [26].

Streitz *et al.,* described the effect of granulation tissue maturation in the pathogenesis of tracheal stenosis. According to them, as the granulation tissue matures, it transforms into a fibrous mass covered by epithelium. Although initially seen as beneficial in the healing process, the development of fibrosis narrows the front and side walls of the trachea at the stoma, causing the airway to constrict [40]. Supra stomal stenosis has been reported in various articles as a more prevalent complication of percutaneous dilatational tracheostomy [40].

In conclusion, research done by Klemm and Nowak on trachea stenosis as a complication reported that between 1996 and 2016, a total of 102 patients aged between 17 and 89 with an average age of 60years were diagnosed with tracheal stenosis, required various treatment, and were monitored at the University Teaching Hospital Dresden-Friedrichstadt. These individuals, sourced from 20 different clinics, presented with respiratory difficulties several weeks after undergoing tracheostomies. Recurrent stenosis was observed in 75 cases of percutaneous dilatational tracheostomies and 27 cases of open surgical tracheostomies [41].

11.3 Tracheoesophageal Fistula

Pearson suggests that tracheoesophageal fistula commonly results from the compression caused by a rigid nasogastric tube and the tracheal tube cuff, leading to necrosis of the intervening membranous portion and esophageal wall. This condition typically presents suddenly with symptoms such as an air leak escaping

through the mouth and abdominal distension. There is also a risk of aspiration of esophageal contents, which can result in pneumonia. To prevent this complication, it is recommended to replace the nasogastric tube with a gastrostomy tube at the time of tracheostomy or shortly after [3].

Lee *et al.,* observation is agreeable with Pearson's that transesophageal fistula is a rare but life-threatening complication, primarily seen in patients with nasogastric tubes. Lee further explained that a tracheoesophageal fistula can develop due to elevated tracheostomy cuff pressures, which lead to ischemia of the tracheal mucosa [6]. Prolonged ischemia may result in necrosis, ulceration, and perforation of the tracheal wall, eventually causing an erosion into the esophagus. Additional risk factors include damage to the posterior tracheal wall during stoma creation, intubation, or from excessive cuff pressure eroding through the posterior tracheal wall. Lee *et al.,* also observed that immediate management of transesophageal fistula involves placing a long-cuffed tube beyond the fistula level. Surgical correction timing is challenging, as mechanically ventilated patients are not suitable candidates for surgery [6].

For patients who are stable and no longer require ventilation, surgery can be conducted to separate the esophagus from the trachea and repair any resulting defects. This typically involves using a muscle flap to protect the repaired area. For those not suitable for surgery, palliative measures may include a combination of tracheal and esophageal stenting [6]. Streitz *et al.,* researched that tracheoesophageal fistula occurs in less than 1% of patients. [40]. Sanwal *et al.,* attributes it to mucosal ischemia or abrasion secondary to prolonged intubation, and use of high cuff pressures [42]. Tracheoesophageal fistula resulting from tracheal cuff-related injuries typically presents symptoms within four weeks. In non-ventilated patients, common signs include persistent coughing after swallowing (Ono's sign), difficulty breathing, recurrent pneumonia, and unexplained weight loss [43].

11.4 Tracheo innominate Artery Fistula

Pearson researched that trachea innominate artery fistula is a rare but life-threatening complication determined by the anatomical position of the artery and its proximity to the tracheal stoma, he added that a low-positioned stoma increases the risk of pressure on the artery, which should be avoided. Acute bleeding from this condition is usually severe and necessitates immediate control through compression, followed by an urgent sternotomy and division of the innominate artery [3]. Lee *et al.,* observed that this complication is a rare, but potentially fatal, typically occurring 3–4 weeks after a tracheostomy and affecting less than 1% of patients. They reported that the condition arises when the tracheostomy tube erodes into the innominate artery, often due to high cuff pressure or direct contact between the tube's distal end and the artery. Other contributing factors include low placement of the tracheostomy and repetitive head movements [6].

In cases of a suspected trachea-innominate fistula, applying digital pressure to the anterior stoma wall can serve as a temporary measure. However, definitive treatment requires urgent surgical intervention in the operating room. A rigid bronchoscope is employed to assess the stoma and anterior wall, after which the tracheostomy tube is removed. If severe bleeding occurs, an emergency median sternotomy with ligation of the innominate artery and tracheal wall repair is required. To reduce the risk of developing a vascular fistula, it is essential to ensure proper placement of the tracheostomy tube between the first and second or second and third tracheal rings. The risk is heightened if the tube is positioned lower in the trachea.

11.5 Tracheo cutaneous Fistula and Persistent Tracheal Stoma

Tracheo cutaneous fistula is a complication of prolonged tracheostomy which usually occurs because of epithelial growth into the tracheotomy tract that prevents closure and healing. Patients with this condition often experience issues like aspiration, skin irritation from secretions, and voice problems [44]. Continuous leakage from the fistula onto the neck, along with the expulsion of mucus during coughing, is a common issue. This complication tends to arise more frequently in patients who have had a tracheostomy for an extended period. Additionally, it is often accompanied by a noticeable depressed scar. This scar adheres to the trachea and becomes noticeable as it moves when the patient swallows. Significant weight loss can increase the risk of developing trachea-cutaneous fistula as it reduces the distance between the skin and the trachea due to loss of subcutaneous tissue in the neck [44].

A persistent tracheal stoma occurs when the stomal tract becomes covered with epithelium after prolonged intubation, preventing proper healing. To close the stoma, the tract is separated from the skin, and a strap muscle is interposed between the tract and the skin closures. Persistent tracheal stoma can lead to various complications such as recurrent aspiration, infections, ineffective coughing, skin irritation, and social or cosmetic concerns [44].

11.6 Tracheomalacia

Tracheomalacia is an uncommon complication that involves the weakening of the cartilage in the tracheal wall, resulting in dynamic expiratory collapse and airway obstruction. During forced expiration, the trachea's cross-sectional area can decrease by more than 50%. This uncommon condition can be triggered by several factors, including ischemia caused by high tracheostomy tube cuff pressures and frequent episodes of gastroesophageal reflux during mechanical ventilation. These factors lead to

inflammation of the tracheal rings, and prolonged inflammation can weaken the rings, causing airway deformities, increased compliance, and hyperdynamic collapse of the airway during expiration [33].

The clinical manifestations of tracheomalacia typically include shortness of breath during physical exertion, persistent coughing, frequent respiratory infections, and coughing up blood, with these symptoms potentially emerging months or even years after decannulation. One key clinical indicator is unexplained difficulty in weaning from the ventilator, which may require re-intubation following decannulation. Dynamic flexible bronchoscopy remains the gold standard for diagnosis, although CT scans and pulmonary function tests can provide additional diagnostic insight. In cases of severe tracheomalacia, treatment options may involve posterior membrane tracheoplasty or surgical procedures, such as localized tracheal resection and subsequent reconstruction [33].

12. CONCLUSION AND RESEARCH LIMITATION

Tracheostomy, a vital airway management procedure, carries a range of potential complications, both immediate and long-term. Despite advances in surgical techniques, immediate risks such as hypoxia, hemorrhage, and injury to critical structures like the recurrent laryngeal nerve and great vessels persist, often influenced by the procedure's urgency and anatomical challenges. Long-term complications, including infection, tracheal stenosis, and tracheoesophageal fistula, can significantly affect patient outcomes. As tracheostomy techniques evolve, balancing risk reduction with the needs of patients requiring prolonged airway support remains crucial for enhancing patient care.

This review primarily focused on complications associated with tracheostomy but did not address complications specific to percutaneous dilatation tracheostomy. Additionally, it did not cover other relevant tracheal procedures such as endotracheal intubation, mini-tracheostomy, and cricothyrotomy.

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14. WARRANTY

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Vardas, pavardė: Ayodeji Ojo
Padalinys: Medicinos fakultetas
Studijų programa: Medicina
Darbo pavadinimas: Complications after tracheostomy: literature review
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