Introduction: the history of tracheotomy

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Case presentation

In 1799, Elisha Cullen Dick, a former pupil of Benjamin Rush, was called to help attend to George Washington. Dr. Dick and two other physicians used copious bleeding in addition to other medical procedures. Dr. Dick suggested that a tracheotomy be performed to relieve the General’s obstructed airway. This suggestion was overruled and Washington died of obstruction from an upper airway infection.

Introduction

Tracheotomy is one of the oldest surgical procedures described, with written descriptions dating back to ancient Egypt and India. Its safety and necessity have been controversial for centuries. The indications and techniques for tracheotomy have changed and expanded over time. Today, due to advances in intensive care medicine and the widespread use of mechanical ventilation, tracheotomy is one of the most commonly performed surgical procedures. Owing to its increased prevalence, it is encountered on a regular basis by physicians in all fields of medicine.

The extensive history of tracheotomy can best be divided into five periods.

The period of legend (3100 BC to AD 1546)

It is impossible to know exactly when the first tracheotomy was attempted, but there is evidence from hieroglyph slabs belonging to King Djer in Abydos and King Aha in Saqqara that tracheotomy was performed in ancient Egypt at about 3100 BC [1]. Tracheotomy is also mentioned in the Rig Veda, a sacred book of Hindu medicine written between 2000 and 1000 BC. These writings describe “the bountiful one who without ligature, can cause the windpipe to reunite when the cervical cartilages are cut across, provided that they are not entirely severed” [2]. The Ebers Papyrus, an ancient medical reference from 1550 BC, refers to opening the windpipe through a neck incision [3] and in the eighth century BC Homer referred to an operation to relieve choking persons by cutting the trachea [4]. In the fourth century BC, Alexander the Great is said to have saved the life of a soldier who was choking from a bone lodged in his throat by “puncturing his trachea” with the point of his sword [4].

The first elective tracheotomy is credited to Asclepiades of Bithynia in AD 100 [3]. This operation was described by the renowned physician Claudius Galen in AD 131 [5] who also contributed to the understanding of the tracheotomy by describing the anatomy of the head and neck [6]. In the same century, Aretaeus in his book, The Therapeutics of Acute Diseases, confirmed the work done by Asclepiades of Bithynia on the subject of tracheotomy, but he condemned it on the grounds that “cartilage wounds do not heal” [7]. Later, in the fifth century AD, Caelius Aurelianus condemned the operation and stated, “Laryngotomia is a
The period of fear (AD 1546–1833)

The period between 1546 and 1833 marks the “period of fear” in the history of tracheotomy. During this era the procedure was considered irresponsible and barbaric, and only 28 successful tracheotomies were recorded in the literature [11]. In Bologna, Rolandi used tracheotomy to alleviate obstruction caused by laryngeal abscess [12]. In 1546, Antonio Musa Brasavola is quoted as saying “When there is no other possibility, in angina, of admitting air to the heart, we must incise the larynx below the abscess.” This account describes the use of tracheotomy to obtain an emergency airway in Ludwig’s angina (submental space abscess) [6,13] and although there are some records of tracheotomy for the treatment of Ludwig’s angina by Saliceto and Paré in France [12], this was not the treatment of choice by anyone’s standards at that time [6].

An Italian anatomist, Fabricius ab Aquapendente (1537–1619) also described the use of tracheotomy to bypass an obstruction of the airway, writing, “The terrified surgeons of our times have not dared to exercise this surgery and I also have never performed it; it is a scandal” [6]. Later though, he modified his feelings and successfully performed tracheotomies to relieve laryngeal obstruction due to foreign bodies. He used a vertical incision and a cannula with flanges. His pupil Casserius, introduced the curved cannula with stay tapes to hold it in position, but unfortunately this improvement in tube shape was quickly forgotten, and the straight tracheotomy tube remained in use for many years [7]. In 1590, Sanctorius used a trocar and cannula with a short, straight tube, the tip of which was placed against the tracheoesophageal wall and the cannula left in place for 3 days [14].

By the early 1600s, tracheotomy was considered acceptable for acute upper airway obstruction caused by foreign body ingestion, aspiration, and infection [7]. During the diphtheria epidemic in Naples, Severigno used tracheotomy as a symptomatic treatment (Julius Casserius 1599). Records from 1620 indicate that Nicholas Habicot of Paris did four successful tracheotomies leading him to suggest that the operation be used for inflammatory conditions of the larynx [15]. Interestingly, one of his tracheotomies was used to relieve the respiratory obstruction caused by the pressure of gold coins in the esophagus swallowed by a 14-year-old boy to protect his possessions from theft. The bag of coins became lodged in his esophagus impinging on his airway. Habicot used a novel tracheotomy tube that was flatter than usual to prevent pressure necrosis in the surrounding tissue [15]. In 1650, a renowned surgical pathologist named Theophilus Bonetus recommended the use of a tracheotomy for a 7-year-old child who had aspirated a piece of bone. This suggestion was rejected by the internist in accordance with the times and the child died [16].

There were other instances of physicians using tracheotomy for the symptomatic relief of respiratory infections. Renaus Moreau suggested its use in mumps [7], recommending that
the procedure be performed with the patient in the supine position, a recommendation that was ignored for nearly 200 years [17]. In 1765, Francis Home, a Scottish physician, recommended the use of tracheotomy to alleviate respiratory compromise in children suffering from croup [18] (called cynanche trachealis in the United States, with the direct Greek translation meaning dog-like choking). Despite the high prevalence of cases in the United States and Great Britain, fear and mistrust of the procedure prevented prevalent therapeutic use [18]. Professor Wendt of Erlangen, in 1760, described tracheotomy in a young patient via opening the trachea by dividing the first three rings and separating edges of the wound with blunt hooks [19]. In 1770, William Buchan’s handbook for physicians devoted a chapter to the management of drowning patients, one of which was on opening the trachea. This
material originated from the *Memoire sur la bronchotomie*, a text written by Louis who also advocated the use of tracheotomy for the extraction of foreign objects, which led to criticism from other practitioners.

The New World was heavily influenced by the medical thinking of Europe at this time. When Dr. Elisha Dick suggested a tracheotomy for his well-known patient, George Washington, Drs. James Craig and Gustavus Brown did not concur, instead treating him with blood-letting to release “evil humors” [20]. On December 14, 1799, the first President of the United States died of an acute upper airway obstruction secondary to a peritonsillar abscess [7]. His worsening symptoms happened within 36 hours of onset of sore throat and malaise, inability to speak, and difficulty breathing.

The terminology used to describe the procedure changed over time as well. Up until this time, the operation was known as a “Laryngotomy.” In 1707, Pierre Dionis wrote that it was wrong to use this term and it should be called “bronchotomy” [6]. In 1718, Lorenz Heister wrote in the prestigious *Chirurgie* that the operation should be called tracheotomy and all other names should be discarded [21,22]. It was not until the nineteenth century that this term became accepted.

The British surgeon, George Martin, introduced the double lumen cannula with the advantage of an inner cannula that could be removed and cleaned, thus preventing tube obstruction with mucus [9]. A tube with a flange allowed easy placement of tapes to keep the tube in place and another one with a loose flange allowed some flexibility with neck movement. This important advance in postoperative care was quickly discarded and forgotten [7].

**The period of dramatization (AD 1833–1932)**

During the third stage of tracheotomy, it was an operation of life or death, performed only in emergencies on acutely obstructed airways. McKenzie summarized the general feelings of those times, writing, “the question always arises in the mind of the young surgeon whether the symptoms are sufficiently urgent to render the operation necessary” [9]. Having performed more than two hundred tracheotomies, Trousselou reported happily that one-fourth were successful [23]. In 1837, Curling discussed the respiratory distress associated with tetanus, including laryngospasm and dysfunctional accessory respiratory muscles. Although the description of symptoms favored the use of tracheotomy as a symptomatic treatment, the procedure was never carried out [24]. Brodie carried out tracheotomy in 1843 to successfully remove a swallowed 20 mm coin that had been lodged in a patient [25]. In 1869, Dr. Erichsen described four complications of tracheotomy: exposing the air tube, hemorrhage, opening of air passage, and placing the tracheotomy tube. He further recommended that the tube be cleaned with a sponge and solution of silver nitrate [26]. In 1888, Prince Frederick of Germany had a tracheotomy for a malignant laryngeal lesion. His treatment was more palliative than curative, and he did not live past 4 months; however, this foreshadowed palliative use of this procedure that is still prevalent today.

Over time, tracheotomy became an accepted technique to bypass upper airway obstruction caused by infection or foreign bodies, and to rest the larynx in chronic tuberculosis or syphilis. Veheient arguments ensued in the literature over indications and technique. In 1860, the New Sydenham Society published over 38 papers devoted to discussing various techniques and indications for tracheotomy. The operative technique of tracheotomy was studied, refined, and described by Chevalier Jackson in 1909 [27]. Jackson defined factors
that predisposed to complications, such as a high incision, using an improper cannula, poor postoperative care, and splitting of the cricoid cartilage. He designed a metal double lumen tube of proper length and curvature with just the right fitting to avoid excessive pressure on the anterior or posterior wall of the trachea and reduce the risk of ulceration and tracheal erosion. Jackson also developed a “J” tube with a long shaft that could bypass mid or lower tracheal obstruction, and he favored a vertical incision from the thyroid notch to the suprasternal notch for best visibility of the surgical field [27]. Jackson’s teachings significantly reduced the complication rate and mortality rate of tracheotomy.
During the American Civil War from 1861 to 1865, tracheotomy was used by Union Army physicians to relieve respiratory distress in gunshot wounds of the head and neck. Despite improvements in technique, however, the First World War witnessed hesitation and even opposition to tracheotomy in war wound management.

Early in the twentieth century, diphtheria became controlled by immunization, while the discovery of sulfonamides helped curb other upper respiratory infections. The need for emergency tracheotomy became less common. For a brief period, tracheotomy was the only means of securing airways through general anesthesia, but the increasing popularity of endotracheal intubation replaced the need for tracheotomy. “The period of dramatization” was ending, although new antibiotics provided better prevention and control of infection in tracheotomy cases where the procedure was inevitable.
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**Figure 4** George Washington on his death bed: diagnosed with quinsy (peritonsilar abscess).

**Figure 5** Durham Flexible Pilot (introducer) Lobster tail Tracheotomy tube, inner canula and introducer (circa 1890s). Photo Courtesy of Mr. Cedric Russell.
The period of enthusiasm (AD 1932–1965)

During the fourth stage in the history of tracheotomy the saying, “If you think tracheotomy ... do it!” became popular. During this period, indications for tracheotomy were actively sought and the surgical and medical world became strong advocates for it. This period began in 1932 during the outbreak of bulbar poliomyelitis. Wilson suggested the use of tracheotomy to prevent impending pulmonary infection in poliomyelitis, as patients affected are unable to cough and raise secretions. He suggested that tracheotomy would provide an adequate airway and the patient could be managed by intermittent negative pressure respiration if provided with a cuffed tracheotomy tube and placed in an “iron lung.” Thus, for the first time, tracheotomy was considered as an elective procedure [28]. Polio remained an epidemic until the early 1950s when the invention of positive pressure respiration together with tracheotomy greatly reduced mortality [29]. However, like diphtheria in previous years, the rate of poliomyelitis decreased to almost nil with the onset of universal vaccination.

Tracheotomy was openly advocated for tetanus, head, chest, and maxillofacial injuries, drug overdose, and following major surgery where airway patency was compromised [7]. During the Spanish Civil War in 1936–1939, the rules of triage for soldiers with maxillofacial injuries were modified. While they were waiting for surgery, the soldiers had high rates of aspiration and frequently suffered from respiratory distress. The use of tracheotomy decreased mortality rates for soldiers waiting for such surgeries [30]. This approach continued through the Second World War, where tracheotomy became an integral part of the management of soldiers with chest injury, burns, blast injuries, and traumatic wounds that caused retained pulmonary secretions to obstruct upper airways [31]. In 1943, Thomas C. Galloway recommended the use of tracheotomy for removal of bronchial secretions in myasthenia gravis and tetanus [29]. Carte and Guiseppi recognized the physiological benefits of tracheotomy, namely the reduction in dead space ventilation. This understanding led to the use of tracheotomy for chronic obstructive lung disease and severe pneumonia [32]. Tracheotomy became more prevalent as intensive care and post-anesthetic care units were established in the 1950s, with better care for tracheotomy patients [33].

The indications for tracheotomy were changing. Many infectious diseases that had previously caused upper airway obstruction were now controlled. As late as 1961, Meade, in a series of 212 cases showed that 41% of tracheotomies were still carried out on patients with upper airway obstruction due to tumor, infectious disease, and trauma, and 55% were performed to assist in mechanical ventilation [34].

The period of rationalization (AD 1965 to the present)

In 1965, it became apparent that oral or nasal endotracheal intubation was quicker and safer than tracheotomy, with a lower complication rate. So began the “period of rationalization,” during which the merits of tracheotomy versus intubation have been debated. Improvements in tracheotomy tubes (e.g., the double lumen tube), improvement in cleaning and suction techniques, and use of biocompatible materials contributed significantly to the safety of the procedure. High-volume, low-pressure cuffs decreased the incidence of tracheal injury that can lead to scarring and stenosis by ensuring a stable airway seal without compromising perfusion pressure [35]. The flexible fiberoptic endoscope allowedatraumatic oral or nasal intubation in situations, such as cervical spine injuries, which previously necessitated tracheotomy.
Acute obstruction with impending asphyxia is no longer an indication for tracheotomy because alternatives, such as endotracheal intubation or cricothyroidotomy, are available. In fact, the emergency tracheotomy has become rare indeed. In a recent study of 1130 tracheotomies, Goldenberg et al. showed that 76% of tracheotomies were prophylactically performed on patients requiring prolonged mechanical ventilation while only 6% of patients were tracheotomized due to upper airway obstruction. Only 0.26% were performed on an emergency basis [36].

Percutaneous dilational tracheotomy (PDT) is an alternative to open tracheotomy because it can be comfortably performed at the bedside. In 1953, Seldinger introduced the technique of percutaneous guidewire needle placement for arterial catheterization [37]. Soon after, the guidewire technique (known as the “Seldinger technique”) was adapted to percutaneous tracheotomy. The first modern PDT was reported by Shelden et al. in 1955, but the complication rate was very high due to perforation of the trachea and lacerations of adjacent structures [38]. In 1969, Toy and Weinstein developed a tapered straight dilator for performing percutaneous tracheotomy over a guiding catheter [39].

The technique of PDT using serial dilators over a guidewire was first described in 1985 by Ciaglia et al. [40]. In 1989, Schachner et al. developed a dilating tracheotomy forceps over a guidewire [41]. Studies of this new technique concluded that it was safe in elective circumstances, various medical personnel are able to carry out this procedure at the patient’s bedside, there is reduced risk of infection, and the intercartilaginous membrane of the trachea heals well [42].

In 1990, Griggs et al. developed another guidewire dilating forceps for percutaneous tracheotomy [43]. The simplicity of this technique made tracheotomy more flexible and less traumatic. This technique is recommended and remains worthwhile in intensive care units [44,45]. As evolving medical literature debates the details, PDT is rapidly gaining acceptance as an alternative to the open tracheotomy in the treatment of patients requiring prolonged mechanical ventilation.

Conclusions

For more than 5000 years, tracheotomy has undergone changes in indications and techniques much like evolution in the practice of medicine itself. It could have potentially saved the life of the first American President if Dr. Elisha Dick had not faced opposition from his more senior colleagues. At times, dreaded, scorned, and carried out with extreme hesitancy, and in other instances, a noble and dramatic life-saving procedure, tracheotomy remains one of the most important and commonly performed surgical procedures to this day. It is a procedure carried out routinely in the operating room, intensive and intermediate care units, and in locations with minimal medical support during acute emergencies.

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