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A Retrospective Review of the Short-Term Outcomes of Tracheal Resection for Laryngotracheal Stenosis at Chris Hani Baragwanath Academic Hospital

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"A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Medicine in Otorhinolaryngology."

Johannesburg, 2019

Declaration

I, Prince Ratshili Makaulule, declare that this research report is my own work. It is being submitted for the degree of Master of Medicine in Otorhinolaryngology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other university.

DR PRINCE RATSHILI MAKAULULE

On this 11th day of April, 2019 Signature_____

Dedication

I dedicate this work to my mother, Nkukeng Makaulule, my sister, Lorraine Maluleke and my fiancée, Boitumelo Pitse. Their constant love and support has been my pillar of strength and has kept me motivated throughout this project. To God Almighty, this opportunity would not have been possible without Him.

Publications and Presentations

This work has never been published nor presented at any local or international congress.

Abstract

INTRODUCTION:

Laryngotracheal stenosis is rare but has become a well-recognized pathological otorhinolaryngological condition. It develops when scar tissue forms in the trachea and larynx. Laryngotracheal stenosis can cause significant morbidity and the management of it is often complex. Tracheal resection with end-to-end anastomosis is a well-recognized surgical procedure performed for treatment of larygotracheal stenosis and has been shown to have great success.

AIM:

To review the short-term outcomes of tracheal resection for larygotracheal stenosis at the Chris Hani Baragwanath Academic Hospital Otorhinolaryngology Department.

METHOD:

This was a retrospective study, reviewing 24 patients with larygotracheal stenosis who underwent segmental tracheal resection with end-to-end anastomosis at the Chris Hani Baragwanath Academic Hospital, performed between 2005 and 2015.

RESULTS:

The study included 24 patients with ages ranging from 18 to 64 years. There were 15 (62.5%) males and 9 (37.5%) females. The causes of larygotracheal stenosis were prolonged intubation in 22 (91.7%) and inhalation burns in 2 (8.3%) patients. Eleven patients (45.8%) had postoperative complications, of which 4 (36.4%) were minor complications and 7 (63.6%) were major complications. The outcomes of surgery were excellent in 13 (54.2%), satisfactory in 8 (33.3%) and unsatisfactory in 3 (12.5%).

CONCLUSIONS:

Prolonged intubation was found to be the most common cause of larygotracheal stenosis. Tracheal resection for larygotracheal stenosis has been shown to have satisfactory to excellent short-term outcomes in terms of successful decannulation, voice quality, and low morbidity. In our study, the surgery was successful in 21 (87%) patients, which is comparable to success rates shown in the literature. Preoperative tracheostomy and higher degree of stenosis Meyer Cotton (III and IV) were associated with high post-operative complications. Irrespective of the cause, tracheal resection is a good surgical option, for the treatment of patients with severe stenosis and those who have failed treatment from other alternative surgeries.

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Acronyms

CHBAH	Chris Hani Baragwanath Academic Hospital
COPD	Chronic Obstructive Pulmonary Disease
CT	Computed tomography
ET	Endotracheal tube
HPT	Hypertension
LTR	Laryngotracheal resection
LTS	Laryngotracheal stenosis
LRTI	Lower respiratory tract infection
MI	Myocardial infarction
MVA	Motor vehicle accident
OP	Organophosphate poising

PDS	Polyglycolic acid suture
CM	Centimetres
TBI	Traumatic brain injury

1. Introduction

1.1. Introduction

The respiratory system is composed of the nasal passages, pharynx, larynx, trachea, and bronchi. The function of the upper and lower respiratory system is to transport humidified respiratory gases and to clear secretions from the human body. [1] Although the respiratory system is important, it is not exempt from trauma such as those caused by viruses, chronic diseases as well as tracheal stenosis which is propagated by intubation – which forms the basis of this report.

Laryngotracheal stenosis (LTS), over the last few decades, has become a well-recognized pathological otorhinolaryngological condition,[1,2] which develops when there is scar formation in the trachea or larynx. [2] The prevalence of LTS is ever increasing which can be directly attributed to the increased use of cuffed endotracheal tubes (ET) during patient treatment. [2]

The increased utilization of cuffed endotracheal tubes is attributed to the significant improvements in intensive care units which has subsequently led to an increased number of patients being intubated, and a proportionate increase in the rate of LTS. [2] The stenosis in LTS can differ in its location, severity, duration, and can exacerbate the extent of functional impairment thus leading to significant morbidity. [1,2,3]

LTS can be an intricate and difficult ailment to manage. [2,3] The Otorhinolaryngology Department at Chris Hani Baragwanath Academic Hospital in Soweto regularly treats patients with LTS, using various surgical techniques such as: dilatation, laser therapy, stent placement as well as tracheal resection – the latter of which is the subject of this report. The complexity and increasing number of cases of LTS encountered by the Department of

Otorhinolaryngology at CHBAH have prompted the undertaking of this retrospective review of tracheal resection as a definitive treatment option of larygotracheal stenosis. Knowledge of the anatomy of the larynx and the trachea is essential in the understanding and long-term management of LTS. [1,2,3]

1.2. Anatomy of the larynx and trachea

The functions of the larynx, which is located within the anterior aspect of the neck at the level of C3 to C6 are: to protect the airway, phonation, coughing, valsalva manoeuvre, and control of ventilation of the lungs. [15] The laryngeal framework is composed of three unpaired cartilage (cricoid, thyroid, epiglottis), three paired cartilages (arytenoids, corniculate, cuneiform) and intrinsic muscles. [15] The cavity of the larynx is divided into three parts by the true vocal cords and false cords. The three parts are the supraglottis, glottis, and subglottic space. [15]

The laryngeal cavity is lined by a mucous membrane with mucus glands in all parts except on the free edges of the vocal cords. [15,19]. The epithelial lining of the Glottis consists of; stratified squamous epithelium which lines the true vocal cords, as well as the upper parts of vestibule whilst the rest of the larynx, is lined by columnar ciliated epithelium. [15]

The superior and inferior thyroid arteries supply blood to the larynx whilst the superior laryngeal and recurrent laryngeal nerves are responsible for the nerve supply. [15] The inferior end of the larynx is at the level of C6 and the trachea starts immediately below it. [15]

The trachea, which extends from the level of C6 to T5, is a tube made up of cartilage and membrane and measures approximately 10 to 11 centimetres in adults. [15] The tracheal tube is composed of 16-20 incomplete cartilaginous rings anteriorly and a muscular layer

posteriorly. [15] At the level of the sternal angle, the trachea divides into two main bronchi which are connected to the lungs. [15]

The wall of the trachea is made up of four distinct tissue layers. The first lining is the respiratory mucosa which contains pseudostratified ciliated columnar epithelium, followed by the submucosa which contains loose connective tissue, blood vessels, neurons, and glands. [19] External to the submucosa is a cartilaginous layer containing stiff C-shaped cartilaginous rings which are bordered by the outer layer, which itself constitutes of a band of loose connective tissue that loosely binds the trachea to the oesophagus and other nearby organs. [19]

Blood supply is mainly from the inferior thyroid artery and nerve supply is from the recurrent laryngeal nerve and sympathetic trunk. [15] The mucosal lining of the larynx and trachea is commonly exposed to external foreign materials thus making it susceptible to trauma.

1.3. Pathophysiology

Laryngotracheal stenosis results from scar tissue formation in the larynx and trachea which can be result from a variety of causes such as: prolonged nasal and orotracheal intubation, tracheostomy, external trauma to the neck, inhalation injuries, radiation, Wegener's granulomatosis, and idiopathic cause. [4-7] Of these aforementioned causes; prolonged nasal and orotracheal intubation, as well as tracheostomy, are known to be the most common causes of LTS.[1-4]

1.3.1. Common Causes of LTS

The underlying pathology for the common causes of LTS, result from the formation of scar tissue secondary to trauma to endotracheal tissue. The Laryngotracheal injury is secondary

to ischaemic pressure necrosis of the mucosa around the cartilaginous rings which results from high cuff pressure as well as the tube size of the endotracheal tube. [5-7] Irritation of the endotracheal tissue by the endotracheal tube causes oedema and inflammation, which can, in turn, progress to ulceration and granulation tissue formation.[5-9]

The resultant healing from the irritation occurs with fibroblast proliferation causing scar formation and ultimately leading to a stenosis within the trachea, which is the most commonly affected area, although the larynx can also be affected.[2,5,6]

In summation, the factors that can predispose a patient to the development of LTS are endotracheal tube size, duration of intubation and laryngeal movement during intubation. Co-morbid illnesses such as diabetes mellitus, congestive heart failure, and stroke have also been associated with the development of LTS. [8-14]

1.4. Epidemiology

The common causes of Laryngotracheal stenosis are: prolonged nasal and orotracheal intubation as well as tracheostomy. The incidence of post-intubation larygotracheal stenosis is approximately 1 in 200 000 adults per year. [2] LTS in adults has been gradually increasing, and this is directly attributable to the increased number of patients who are intubated, and improvements in, and an increased number of, intensive care units. [2-5] In patients who are intubated, the incidence of LTS is proportional to the number of days of endotracheal intubation and has been shown to range from 10 - 15 percent in patients who have required intubation for more than 7 – 10 days. [2]

In a study series conducted in Egypt by El-Fattah et al, an incidence of 0.6 to 21 percent was reported. [2] In contrast, Raynham et al reported an incidence as high as 17.5 percent in South Africa. [4] These contrasting but high prevalence rates may be attributed to a variety

of factors such as: the practitioners who are responsible for the care of patients with endotracheal tubes not being adequately educated and trained, as well as the absence of stringent management protocols. [15-17] Patients who have had prolonged intubations should be monitored for the development of LTS because they are at risk. [17]

1.5. Presentation and assessment

LTS is suspected in patients who present with signs of upper airway obstruction (stridor) following a recent history of intubation, tracheostomy or inhalation burns. [11]

1.5.1. Clinical Presentation

The symptoms of LTS depend on the degree of airway obstruction and can range from asymptomatic to severe airway obstruction. Obtaining a comprehensive medical history is of utmost importance in relation to treating and managing LTS. The main features to inquire about during the medical history assessment are: airway obstruction, change in voice, difficulty in swallowing and any coexisting medical conditions like Diabetes mellitus, vasculitis, chronic obstructive pulmonary disease chronic obstructive pulmonary disease and/or asthma. [1]

1.5.2. Clinical Findings

Upon suspicion of LTS, the clinical examination is aimed at assessing the degree of stridor or respiratory distress. [1-3, 6] A useful apparatus for executing the clinical assessment is flexible endoscopy which aids in identifying the level of stenosis if visualized.[1,2,9] Apart from locating the stenotic region, there is visualization, documentation of vocal folds movement and evidence of laryngopharyngeal reflux. [1]

Direct laryngoscopy under general anaesthetic, using rigid instruments, has been shown to be superior to flexible nasolaryngoscopy.[1,2,6,9] This modality allows the medical practitioner

to define the site, degree, length and maturity of the stenosis.[1-2, 10-11] Whilst the maturity of the stenosis is identified using observation, the length and site are measured in centimetres, and the degree is graded using the Meyer-Cotton classification depicted in Figure 1.1.[1-2,9-12] The Meyer-Cotton classification encompasses the following grades of stenosis; (1) 0-50% of obstruction, (2) 51-70%, (3) 71-99% and (4) complete obstruction.[1,2,5,11-12].

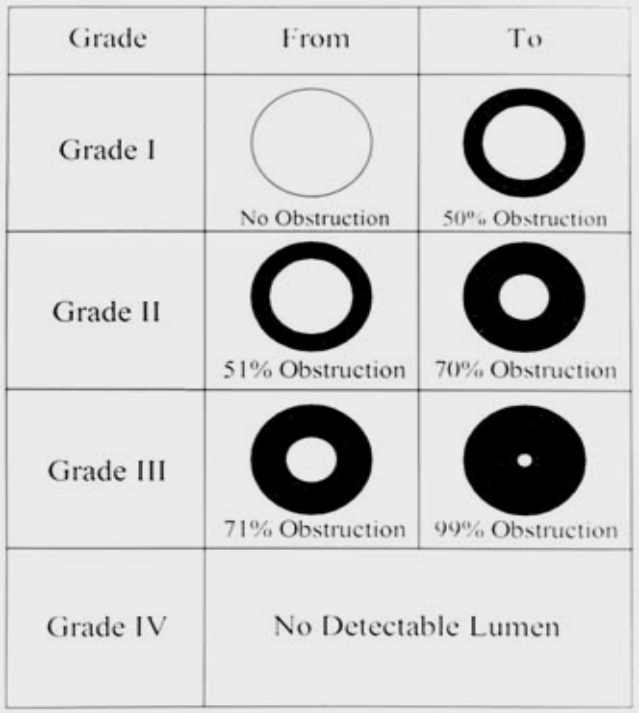


Figure 1.1. Meyer- Cotton classification. [15]

1.5.3. Diagnostic Investigations

To confirm the clinical diagnoses of LTS, there are other adjunctive investigations that can be utilized. These include: the use of flow volume loops, plain radiographs and computed tomography of the neck and chest which can assist in confirming the diagnosis. [1-2] Post diagnosis there are multiple surgical options to consider for the treatment and management of LTS, which have varying invasiveness and success.

1.6. Management of tracheal stenosis

Once the diagnosis is established and confirmed, the goals of management are to re-establish an adequate airway and enable eventual de-cannulation in patients with tracheostomy, with the preservation of laryngeal functions of airway protection, phonation, and sustained glottic closure. [2,5,13,14] When considering the management, several factors should be taken into account, namely: the location, dimensions and quality (soft or hard) of the stenosis, vocal folds mobility and functional impairment.[2,5,13-14] The aforementioned factors should be considered because they may have an impact on the choice of treatment modality as well as its success.

The treatment modalities include procedures with varying degrees of invasiveness. Less invasive procedures include sequential airway dilatation, micro-surgical debridement, local mitomycin application, laser treatment, and stent placement.[2,5,13,15] Although they are well tolerated and safe, less invasive procedures usually result in temporary relief of symptoms, thus resulting in the need for repeat procedures due to the absence of a definitive cure. [1-3,5-6]

Tracheostomy is another surgical procedure which is used to secure the airway when less invasive procedures cannot be performed in an emergency setting.[2,10-11]

Notwithstanding the usefulness of tracheostomy, the most definitive surgical procedure is resection and reconstruction. [1-2,10-11] This procedure can be performed as an initial procedure, after the failure of less invasive procedures and also in patients who have had a tracheostomy. [10-11] Both the invasive and less invasive procedures are discussed below.

1.6.1. Less Invasive Surgical Procedures

1.6.2.1 Dilatation

Dilatation is done endoscopically, using either a balloon expansion devise or tapered laryngeal dilator or a bougie.[11,16] The main difference between these aforementioned techniques is the amount of force with which the apparatus is introduced. Although balloon dilatation has become popular, its biochemical effect is poorly understood. [16] Currently, an angioplasty balloon with nominal diameter and gauge meter is used during surgical procedures aimed at managing LTS. [16]

1.6.2.2 Microsurgical debridement

This technique is done endoscopically. It combines the use of flexible forceps and a microsurgical debrider with video-endoscopic control. [13] The debrider has a powered rotating blade and suction so that soft tissue lesions are aspirated into the tip of the blade and cleanly cut. [13] The micro-debrider is used for many laryngeal lesions, manoeuvring of the rigid telescope with the laryngeal shaver promotes camera steadiness and good visualization of the blade tip relative to the lesion as it is removed. [13]

1.6.2.3 Laser therapy

The forgone decades have seen the growing popularity of carbon dioxide (CO2) laser.[11,13] Laser offers the advantages of delayed formation and maturation of collagen in wounds, thus allowing re-epithelialization before scar formation as well as minimal deep tissue injury.[13,16] Laser has enabled precise control of the areas removed and haemostasis with the aim of preserving existing mucosa that may be utilized for the repair.[13,16]

The procedure is done endoscopically and microscopically. Limitations of laser include the risk of airway fire, the danger of the laser plume for the surgeon and hospital staff if they

are working with infectious lesions.[11,13] The advantage of this approach is that, if performed carefully and meticulously, open repair can be avoided. [13]

1.6.2.4 Local application of Mitomycin C

Topical Mitomycin C may be useful for the treatment and prevention of subsequent re-stenosis and scar formation in the larynx and trachea. [13] Mitomycin C is an antineoplastic antibiotic that is applied directly onto the scar and acts as an alkylating agent which inhibits DNA and protein synthesis. The use of Mitomycin C remains controversial, with some studies showing good results and other studies, in contrast, showing no clinical improvement. [13]

1.6.2.5 Stent placement

If surgery is not possible and dilatation or laser has only a temporary effect, the next treatment option to be considered is stent placement. [13] This option is the most debated procedure; questions about the indications, optimal stent type and the duration of stenting remain largely unanswered. [13] There are several types of stents, of which silicone stents are known to have the best safety record. [13]

For high tracheal stenosis, a Montgomery T-tube is the safest option; the procedure requires a tracheotomy.[7,12,16] A Montgomery T-tube enables breathing, speaking and suctioning. The most common complications of stenting are ~~the~~ migration of the stent, mucus plugging, and granulation tissue formation. [16]

1.6.2. Invasive Procedures

1.6.2.1 Tracheal Resection

Tracheal resection is well established as the definitive treatment for LTS in carefully selected patients. The procedure has good success rates (89% to 96%) with low morbidity (3% to

25%) and mortality (1.5% to 9%).[12,14] Knowledge of this surgical procedure has vastly improved in recent years with some studies ~~d~~denoting that an average length of 6.4 cm or up to 58 percent of the total tracheal length, can be resected and primarily anastomosed with the aid of cervical flexion and releasing manoeuvres.[1-3,5,6] The advantage of releasing manoeuvres results is the reduction in anastomotic tension. [2]

The drawbacks of tracheal resection are complications, which are grouped as minor or major. The minor complications include superficial wound infection, surgical emphysema, and anastomotic granulation, whilst major complications include anastomotic dehiscence, vocal cord paralysis, restenosis, swallowing dysfunction and tracheoesophageal fistula. [2-3,5-8] The rate of minor complications ranges from 3 to 23 percent and that of major complications from 3.5 to 25 percent. [2-3,5-8] The mortality rate has been reported to range from 1.5% to 9%. [2-3,5-8]

Due to its invasive nature, tracheal resection is performed under general anaesthesia with orotracheal intubation. In patients with a tracheostomy, an intubation tube is left in the larynx using a reinforced tube.[12-14] The patient is positioned in a supine position with the neck in mild extension.[5] The stenosis is reassessed and measured by doing a direct laryngoscopy and bronchoscopy.[5,7,12-14] A collar skin incision is made and superior and inferior sub-platysmal flaps are raised.[12-14] The strap muscles are lateralized and the thyroid isthmus is separated in the midline to expose the thyroid, cricoid and tracheal cartilages.[12,13,14] The trachea is then mobilized as far as possible into the mediastinum. [5] The recurrent laryngeal nerves are not routinely exposed, but the courses of the nerves are kept in mind and injury is avoided.[5,7,12,13] The stenotic segment is identified and resection of the stenosis is done using a step by step process. The stenotic segment is resected to where normal airway, both on the superior and inferior stump, is observed. [5,7,12]

During resection of the stenotic segment, care is taken not to injure the oesophagus posteriorly.[12-14] When anastomotic tension is anticipated, tracheal mobilisation and laryngeal release techniques are employed; this is commonly done when there is a gap of greater than 3cm in tracheal continuity.[13] Tracheal mobilisation can be performed by making an incision on the annular ligaments.[13]

The laryngeal release is done by an infrahyoid release which involves transecting the sternohyoid, omohyoid and thyrohyoid muscles at the level of the superior border of the thyroid cartilage.[13] Stay sutures are placed on the lateral aspects of the superior and inferior stumps using polyglycolic-acid sutures.[12-14] The anastomosis is performed using a polydioxanone suture, and the posterior aspect is repaired first.[13] Care is taken to tie the sutures on the outer surface of the trachea and to keep the sutures submucosal.[12,13] Post repair, a Valsalva manoeuvre is performed on the patient by the anaesthetist to confirm a tight seal on the anastomosis. [12-14]

After the execution of the Valsalva manoeuvre, a 6mm vacuum drain is inserted and, strap muscles and subcutaneous tissue are approximated and the skin is closed.[13,14] Guardian sutures are placed on the lower end of the chin and sternum to safeguard against the patient hyperextending the neck and disrupting the anastomosis, although this is not always necessary.[14] The stitches then remain in-situ for 5 to 10 days.[14] Patients are extubated postoperatively in the operating theatre.[13-14] If airway swelling is anticipated, patients are kept intubated for 24 hours.[12-14] All the patients are admitted in ICU and monitored for 24 to 48 hours.[12,13,14] Postoperatively the patients are given intravenous corticosteroids (dexamethasone), prophylactic antibiotics (amoxicillin-clavulanate), analgesia and proton

pump inhibitors.[13,14] Flexible endoscopy is done to assess vocal cord mobility on day 3 to 4 postoperatively.[14]

1.6.3. Prevention of tracheal stenosis

Laryngotracheal stenosis is considered a preventable disease. The prevention of this ailment can be maximised by ensuring that the practitioners responsible for the care of patients with endotracheal tubes are adequately educated and trained. Moreover, stringent management protocols should be instituted and observed at all times.[17]

In patients with endotracheal tubes and tracheostomy for artificial ventilation, the protocol should recommend that the cuff pressure should not exceed 35cmH2O. Cuff pressure should be measured and documented frequently whilst utilizing high-volume, low-pressure cuffs.[18-19]

In patients requiring ventilatory support, airway pressures are to be kept low and micro-trauma during intubation and during maintenance should be prevented, whilst haemodynamic stabilization should be swift.[17] For patients with anticipated prolonged intubation, a tracheostomy should be considered and a policy on the type of tracheotomy technique should be adopted. [17]

Frequent observation of patients after prolonged intubation is necessary to detect early signs of stenosis formation. [17] In early stenosis, endoscopic treatment undertaken in proper time results in reducing the rate of stenosis as well as circumvents the emergence of urgent situations and improves the surgical conditions in the tracheal resection.[17]

In light of both the invasive and non-invasive techniques described above, tracheal resection has been shown to have good success, with reported success rates ranging from 89 to 96 percent in patients followed-up after 1 month up to 13 years post-surgery.[1-3, 5-8] Because of the low morbidity and high success rate as well as the increasing number of patients,

tracheal resection is slowly becoming a commonly performed procedure for LTS at the CHBAH Otorhinolaryngology Department. The weighing up of cost and benefit make tracheal resection a safe and reliable procedure for LTS treatment.

1.7. Aims and objectives

1.7.1. Aims and Objectives

This report aims to review the short-term outcomes of tracheal resection for larygotracheal stenosis in adult patients at the CHBAH Otorhinolaryngology Department. Furthermore, the report will review the morbidity and mortality of tracheal resection as well as determine the rate of successful decannulation before the patient is discharged.

2. Materials and Methods

2.1. Study design

This was a retrospective chart review.

2.2. Study setting

The study was done at the CHBAH Otorhinolaryngology Department. CHBAH is a tertiary hospital situated in the low-to-middle income township of Soweto, in the Gauteng province of South Africa, which is home to an estimated 1.5 million people. Chris Hani Baragwanath Academic Hospital is the biggest hospital in South Africa and the third largest hospital in the world, with 3,400 beds and 6,760 staff members[32]

2.3. Study sample

The study population included; all adult male and female patients (individuals 18 years and older), with benign Laryngotracheal stenosis, who were operated upon at CHBAH Otorhinolaryngology Department during the period January 2005 to January 2015.

2.4. Inclusion criteria

The patients who were included in the study are the adult male and female patients with benign Laryngotracheal stenosis who had segmental tracheal resection and anastomosis performed at CHBAH in the Otorhinolaryngology Department during the set dates of consideration. The inclusion of the patients depended on the availability of their medical records - detailing their diagnoses and surgical procedure.

2.5. Exclusion criteria

- Patients younger than 18 years.
- Stenosis resulting from non-benign causes.
- Patients who were managed by other departments e.g. cardiothoracic.
- Patients who had surgery other than segmental resection with end-to-end anastomoses, such as tracheostomy (as a definitive measure).

2.6. Data collection

The data for this study was obtained using two sources, namely; The Otorhinolaryngology theatre register and the notes in the patient's medical files for all the patients that met the inclusion criteria. The files were manually and electronically searched from the CHBAH records department using a patient-specific file number, but no personally identifiable information was collected for confidentiality preservation.

Each patient was given a unique study number and a tick sheet was used to collect the data (Appendix B). The data collection sheet was used to collect the following general information:

- Age at the time of surgery,
- Sex and race,
- Comorbidity,
- Length and degree of stenosis as defined by the Meyer-Cotton stage,
- Tracheostomy and length of trachea resected,
- Post-operative complications as well as the requirement of additional interventions or airway surgery.

The collected data was used to review the success of the operation. The success of the operation was based on successful decannulation and a secure airway after the operation. Short-term outcomes were assessed from the time of completion of surgeries to hospital discharges.

The success was classified in three classes, namely;

- Excellent (no complications),
- Satisfactory (with complications but with successful decannulation)
- Unsatisfactory (complications and unsuccessful decannulation).

2.7. Data analysis

All the data was captured from the data collection sheet and recorded electronically using Microsoft Excel and Microsoft Access applications, using a password protected database. Microsoft Access 2013 was used for data storage, retrieval and selection and Microsoft Excel 2013 for data analysis.

Mean, standard deviation, median, interquartile range, and ranges were used as descriptive statistics to summarize the study data. The skew formula was used, a value between -1.0 and 1.0, indicates normal distribution. For a normal distribution, the mean and standard deviation were used; median and range were used for normal distribution.

3. Results

3.1 Demographics and co-morbidities

In the ten-year period, between January 2005 and January 2015, 24 tracheal resections were performed at the CHBAH Otorhinolaryngology department. From the 24 patients, 15 (62.5%) patients were males and 9 (37.5%) were females. The ages ranged from 18 to 64 years, with a median age of 29 years . One mortality (4%) was recorded in the study, and this was secondary to post-operative complications.

Three (12.5%) of the patients had co-morbidities. The documented co-morbidities were; HIV in 1 patient (4.1%), hypertension in 1 patient (4.1%) and both hypertension and mitral valve stenosis in 1 patient (4.1%). Pre-operative tracheostomy was already performed in 15 (62.5%) patients at the time of surgery. The summary of patient demographics and comorbidities is tabulated in table 3.1.

Table 3.1. Patient demographics and co-morbidities (N=24)

	Number(%)
Sex	
Male	15(62.5)
Female	9(37.5)
Patient co-morbidities	
No co-morbidity	21(87.5)
With co-morbidities	3(12.5)
HIV	1(4.1)
HPT	1(4.1)
HPT and Mitral valve stenosis	1(4.1)
Tracheostomy	
With tracheostomy	15(62.5)
No tracheostomy	9(37.5)

3.2. Causes of LTS and Indications for Intubation

The causes of LTS within the selected patients varied, and were identified as follows; prolonged intubation in 22 patients (91.7%) and inhalation burns in 2 patients (8.3%). The major indications for intubation were; major trauma secondary to motor vehicle accident as well as severe body burns. The indications for intubation are summated in table 3.2 below and on the next page.

Table 3.2. Indications for endotracheal intubation (n=22)

Indication(s)	Number(%)
Motor vehicle accident	8(36.5)

Burns	4(18.5)
Organophosphate poisoning	3(12.5)
Traumatic brain injury	2(9.5)
Myocardial infarction	1(4.6)
Appendicitis	1(4.6)
Lower respiratory infection	1(4.6)
Suicide attempt	1(4.6)
Tetanus	1(4.6)

3.3. Intra-operative Findings

The pre-operative assessment of LTS was done using the distance of the stenosis below the vocal cords in centimetres, length of stenosis in centimetres and degree of stenosis or obstruction according to Cotton Meyer classification. The distance below the vocal cords was between 1.1 - 2 cm in 3 patients (12.5%), 2.1 - 3cm in 14 patients (58.4%) and 3.1 - 4cm in 7 patients (29.1%). The skew was 0.8, with a mean of 2.4cm, median length of 2cm, standard deviation of 0.5 and the range was 1.5 to 3.5 cm.

The length of stenosis was 0.1 - 1cm long in 4 (16.4%), 1.1 - 2cm long in 11 (46.1%) and 2.1 - 3cm long in 9 (37.5%) of the patients studied. The median length was 2cm, with a mean of 1.9cm, standard deviation of 0.6 and a range of 0.6 to 3cm. The degree of stenosis or obstruction found in patients according to Myer-Cotton classification were: Grade 1 stenosis in 1 patient (4.2%), grade 2 stenosis in 2 patients (8.4%), grade 3 stenosis in 16 (66.6%) patients and grade 4 in 5 (20.8%) patients. The position, length, degree of stenosis and length of trachea resected are tabulated in table 3.3 below.

Table 3.3. Position, length, and degree of stenosis (N=24)

	Number (cm)/(%)
The position of stenosis below vocal cords	
1.1-2m	3(12.5)
2.1-3cm	14(58.4)
3.1-4cm	7(29.1)
Length of stenosis	
0.1-1cm	4(16.4)
1.1-2cm	11(46.1)
2.1-3cm	9(37.5)
Degree of stenosis	**Grade**
Grade 1	1(4.2)
Grade 2	2(8.4)
Grade 3	16(66.6)
Grade 4	5(21.8)

3.4. Post-operative Findings and Additional Surgery

Postoperatively, all the patients were admitted to the ICU, extubation was performed slowly; immediately post-operatively on the theatre table or in ICU after 24 hours. All patients were given three doses of dexamethasone, a proton pump inhibitor for 7 days and three doses of antibiotics (amoxicillin-clavulanate). The silk braided suture holding the lower-end of the chin to the sternum was removed after 5 to 10 days.

All the patients had a flexible endoscopy done at day 4 to 5 post-operatively to assess vocal cord mobility and voice. Twenty-one (87.5%) patients were extubated in theatre and 3 (12.5%) patients were extubated after 24 hours in ICU. The length of trachea resected

ranged from 2cm to 5cm, with a mean length of 3cm. The mean length resected was 3.1cm for patients with tracheostomy and 2.8cm for patients without tracheostomy.

Postoperatively, there were no complications in 13 (54.2%) patients and there were complications in 11 (45.8%) patients. The postoperative complications were classified as minor and major complications. From the 11 patients with complications, 4 (36.4%) patients had minor complications and 7 (63.6%) patients had major complications.

The prevalent minor complications following resection of LTS were: neck surgical emphysema in 1 patient (4.1%), neck hematoma in 2 patients (8.5%), and wound sepsis in 1 patient (4.1%). The major complications included: left vocal cord palsy and restenosis in 1 patient (4.1%), right vocal cord palsy and neck surgical emphysema in 1 patient (4.1%), neck surgical emphysema and breakdown of anastomosis in 1 patient (4.1%), neck haematoma and breakdown of anastomosis in 1 patient (4.1%) and restenosis in 3 patients (12.7%).

Furthermore, 72.5% (8) patients with pre-operative tracheostomy developed postoperative complications compared to 27.5% (3) without tracheostomy. For patients with tracheostomy, 4 had minor complications, and 4 had major complications. The effect of tracheostomy on surgery outcome was not statistically significant, with a p-Value of; 0.720.

There was a higher rate of complications noted in patients with Cotton 3 stenosis, with 6 patients having complications; 5 patients had major complications, and 1 patient had a minor complication compared to, 3 patients with Cotton 4 and 1 patient with Cotton 2 and Cotton 1 respectively. From the patients with Cotton 4 stenosis, two had minor complications, and one had a major complication. The postoperative complications are summarized and presented in table 3.4 below and on the following page.

Table 3.4. Post-operative complications (N=24)

Post-operative complications	Number(%)
Yes	11(45.8)
No	13(54.2)
Classification of complications	
Minor complications	4(36.4)
Major complications	7(63.6)

For patients who developed complications, an additional surgical intervention was required in 8 (72.7%). For minor complications, 2 (18.1%) patients required additional surgical intervention; evacuation of haematoma was performed on both patients. Six (54.9%) patients with major complications required additional surgical intervention. The types of additional surgical interventions for patients with major complications were; micro-direct laryngoscopy and laser of granulation tissue around the anastomosis in 1 of the patients in the study group, direct laryngoscopy and dilation of restenosis in 1 patient, direct laryngoscopy and T-tube insertion in 2 of the patients, and evacuation of haematoma and insertion of a tracheostomy in 1 patient. None of the patients required a repeat tracheal resection.

There was one mortality, wherein the patient developed a neck hematoma and breakdown of anastomosis which was later complicated by mediastenitis. For this patient, tracheostomy was inserted and the hematoma was evacuated. The additional surgical interventions are presented in table 3.5 below.

Table 3.5. Required surgical interventions (n=8)

Required intervention	Number
MDL and laser	1
DL and dilation	2
DL and T tube insertion	2
Evacuation of hematoma	2
Evacuation of hematoma and tracheostomy	1

3.5. Outcome Following Tracheal Resection

The length of stay for the admitted patients ranged from; 7 - 14 days, with a mean of 8.7 days. The length of stay was lengthened by postoperative complications. All the patients were followed up from the day of discharge to two months post tracheal resection. The voice was normal in 20 (83.3%) patients and 4 (16.7%) patients had hoarseness. The surgical outcome was excellent in 13 (54.1%) of patients, satisfactory in 8 (33.3%) of patients and unsatisfactory in 3 (12.6%) of patients.

For the patients with unsatisfactory surgery, two patients had Montgomery T-tubes inserted and one patient had a tracheostomy inserted. As it was noted, pre-operative tracheostomy and degree of stenosis not only predisposed patients to post-operative complications but also affected the success of the surgery. The two patients with unsatisfactory results had

Cotton 3 stenosis. Outcomes of surgery are presented in table 3.6 below and on the next page.

Table 3.6. A Summary of Patients who had Tracheal Resection and Surgical Outcome (N=24)

Patient	Cause of stenosis	Tracheostomy	Degree of stenosis	Complication (minor or major)	Voice at discharge	Outcome
1	Prolonged intubation for burns	Yes	3	None	Normal	Excellent
2	Prolonged intubation post MVA	Yes	3	None	Normal	Excellent
3	Prolonged intubation post MVA	Yes	4	Major	Hoarse	Satisfactory
4	Prolonged intubation post MVA	Yes	3	None	Normal	Excellent
5	Prolonged intubation post MVA	No	3	Major	Normal	Satisfactory
6	Prolonged intubation for burns	Yes	4	None	Normal	Excellent
7	Prolonged intubation for OP	No	3	None	Normal	Excellent
8	Prolonged intubation for OP	No	3	None	Normal	Excellent

9	Prolonged intubation post MVA	No	3	None	Normal	Excellent
10	Prolonged intubation for appendicitis	No	3	Major	Normal	Satisfactory
11	Prolonged intubation for burns	Yes	2	None	Normal	Excellent
12	Inhalation burns	Yes	3	Major	Had a T-tube, hoarse	Unsatisfactory
13	Inhalation burns	No	3	None	Normal	Excellent
14	Prolonged intubation post MVA	Yes	3	None	Normal	Excellent
15	Prolonged intubation for OP	Yes	3	Minor	Normal	Satisfactory
16	Prolonged intubation for TBI	Yes	4	Minor	Normal	Satisfactory
17	Prolonged intubation for Tetanus	Yes	3	Major	Hoarse	Satisfactory
18	Prolonged intubation post MVA	Yes	4	Minor	Normal	Satisfactory
19	Prolonged intubation post MVA	Yes	3	None	Normal	Satisfactory
20	Prolonged intubation for MI	Yes	1	Minor	Normal	Satisfactory
21	Prolonged	No	3	None	Normal	Excellent

	for LRTI					
22	Prolonged intubation for drug overdose	Yes	4	None	Normal	Excellent
23	Prolonged intubation for TBI	Yes	3	Major	Had a T-tube, hoarse	Unsatisfactory
24	Prolonged intubation for burns	No	2	Major	Tracheostomy – mortality	Unsatisfactory

4. Discussion

4.1. Aim

The management of LTS remains a challenge that requires a multidisciplinary team that possesses interdisciplinary knowledge and skills. This retrospective study was aimed at

reviewing the short-term outcomes of tracheal resection for LTS in patients who were treated at Chris Hani Baragwanath Academic Hospital.

The patients who were selected using an established framework as per the requirements of the research objectives were followed up until two months post-operation. The study hoped to prove or disprove that tracheal resection is a safe, effective and reliable procedure for patients with LTS.

4.2. Demographics and Co-morbidities

The ages of the patients included in the study ranged from 18 years to 64 years, with a mean age of 29 years. The gender distribution was 15 (62.5%) male patients and 9 (37.5%) female patients. This age distribution was expected in our study, it is comparable to most of studies that have been conducted previously. For instance, in a study by Marulli et al the median age was 35 years and the age distribution was 18-75yrs. [7] The population groups in both studies represent the most active groups of societies as well the bulk of economically active citizens who, based on these factors, contribute directly to the socio-economic development of their respective societies.

The burden of disease not only negatively affects the patient's life but that of their families and potentially the nation. Males are more commonly affected and this is consistent with the findings of this report. This is attributed to males being most likely to be involved in risky behaviour that may lead to trauma.

Only 3 patients from the 24 had co-morbidities. The co-morbid diseases have been postulated to influence the postoperative course in the literature consulted. In our study, co-morbid diseases had no effect on the postoperative course; however, the low number of patients with co-morbid diseases makes the analysis unreliable. Tracheostomy was

performed in 15 (62.5%) patients in our study. This is comparable to studies conducted by Rea et al and J. Grobbelaar, where 63% and 85% of their patients had pre-operative tracheostomies respectively. [5, 12]

4.3. Causes of Laryngotracheal Stenosis and Indications for Intubation

Laryngotracheal stenosis has, over the last few decades, become a well-recognized pathological Otorhinolaryngological condition. The expanding prevalence of Laryngotracheal stenosis can be attributed to the increased use of cuffed endotracheal tubes, particularly with the significant improvements in intensive care units and thus the increase in the number of endotracheal intubations. [2]

The causes of LTS in a study conducted by Marulli et al were prolonged endotracheal intubation in 75.7% cases and idiopathic in 24.3% cases. The indications for intubation were, traumatic in 17 (45%) patients, respiratory failure in 4 (11%) patients, suicide attempts in 4 (11%) patients and other causes in 3 (8%). [7] The causes of LTS and indications for intubation in our study are comparable to those denoted by Marulli et al.

Trauma-related injuries were the most common indication for intubation in our study; this can be attributed to the socioeconomic conditions in the area surrounding CHBAH, which has led to a high prevalence of patients needing intubation. Our patients with prolonged intubation were previously admitted in an ICU and high care facility, records on the length of intubation could unfortunately not be accessed. Tracheostomy was not documented to have directly caused LTS in our records.

4.4. Intraoperative Findings

Preoperative assessment is a crucial step in the surgical management of tracheal stenosis. [7,14] Before tracheal resection, all our patients were assessed in theatre under general

anaesthesia. A direct laryngoscopy and bronchoscopy were performed, and the precise dimensions of the stenosis were documented. In the procedure, the character, position, length, and degree of stenosis were assessed. All our patients had a pre-operative CT scan done and the findings were correlated with the theatre findings. Studies by Ulusan et al [14] and Marulli et al [7] suggested that the most reliable methods of assessing patients with LTS are rigid laryngoscopy, bronchoscopy, and CT scan.

Regarding the surgical technique, we adopted the standard procedure of tracheal reconstruction popularised by authors with significant experience.[7,12,14] The mean distance from the vocal cords was 3.41cm and the mean length of stenosis was 2.14cm in a study conducted by Ulusan et al. [14] The mean distance below the vocal cords and the length of stenosis in our study are comparable with those shown by Ulusan et al. [14]

The degree of stenosis was also comparable to the results shown in the literature. The length of the segment to be resected is one of the challenging problems in tracheal resection. The length that can be safely cut during tracheal resection is still controversial. [7,14] It is very important to avoid tension in the anastomosis, as this can predispose to breakdown and leakage of the anastomosis. [8,12]

The suprahyoid release is indicated when the length of trachea resected is greater than 3cm. [13] The length resected extended from 1.5 to 5.1cm with a mean of 2.5cm in the study conducted by Marulli et al. [7] Having a tracheostomy pre-operatively has been shown to complicate the surgery by increasing the length of the stenotic segment needed to be resected and theatre time. [14] Ulusan et al [14] compared tracheal stenosis associated with endotracheal intubation and that associated with tracheostomy, and found that the length of trachea resected was greater in patients who had tracheostomy; the mean length resected in the study was 3.3cm. [14]

The length is greater in patients with tracheostomy because the procedure involves resection of normal trachea between the stoma and the stenosis region. [7,14] The length of trachea resected was longer in patients who had tracheostomy compared to those without in our study. The overall length of trachea resected was like that shown by Marulli et al. [7] Suprahyoid release was performed in patients where the segment of trachea resected was above 3cm.

4.5. Post-operative complications and additional surgery

In our study, the postoperative complications were grouped into minor and major complications. Some patients had both minor and major complications coexisting together. The rate of major complications has been shown to range from 3.5 to 25% for major complications, and 3 to 23 % for minor complications. [2, 3, 5-8] Marulli et al. showed minor complication rates as high as 37.8%. [7]

In a study by Rea et al [12], the major complications included: anastomotic dehiscence, vocal cord paralysis, and restenosis. The minor complications included: superficial wound infection, anastomotic granulation tissue, and temporary vocal cord dysfunction. Our complication rates for both minor and major complications are comparable to those shown in the literature. Ulusan et al [14] showed that having a pre-operative tracheostomy complicated the procedure by increasing the length of trachea resected and the surgery time. In our study 8 (73%) who developed complications, had pre-operative tracheostomy thus indicating that a pre-operative tracheostomy made the surgery challenging.

It was noted that the greater the degree of stenosis the higher the complication rate, none of the studies in the literature directly compared the degree of stenosis with complication

rates. The peri-operative morbidity and additional surgical procedures performed in the study by Rea et al [12] where:

- Anastomotic dehiscence in four patients was treated successfully with surgical debridement and temporary Montgomery T-tube (E. Benson Hood Laboratories, Inc., Pembroke, MA);
- Vocal cord paralysis in two patients was managed with laser therapy in one case and with cortectomy in the other instance;
- Restenosis was treated with laser therapy in one patient.

The additional surgery performed and morbidities in our study are comparable to those seen in the literature. There was one (4%) mortality in our study, which is comparable to those shown in the literature.

4.6. Surgical Outcome

The goals of tracheal resection for Laryngotracheal stenosis, are successful decannulation and a good functioning voice. The success was assessed using the following classification;

- Excellent (successful decannulation without complications),
- Satisfactory (successful decannulation with complications) and
- Unsatisfactory (unsuccessful decannulation with complications).

Follow up with patients was short-term, ranging from 2 weeks to 2 months postoperatively. The local and international success rates have been reported as ranging from 89 to 96 %.[1-3, 5-8] The surgery was successful in 87% of patients in our study. The main difference in our study, in comparison the other existing bodies of work, is that the patients that formed part of our investigation were followed up from the day post-surgery to two months post discharge. The length of follow-up in other studies ranged from 1 week to 13 years. The

surgery was unsuccessful in 3 patients accounting for 12.6% of patient population; Montgomery T-tubes were inserted for two patients and a tracheostomy for one patient. The failure rate in our study is consistent with that shown in the literature.

The findings of this body of work have managed to show that tracheal resection has a high success rate, but it is important to note the post-operative complications that are associated with the procedure. Although the morbidity can be low, it can be potentially life-threatening. Even though tracheal resection is a definitive treatment option, additional surgery may be needed, more so in patients who develop stenosis post-operatively.

4.8. Limitations of the current study

- Finding records proved to be a challenging task, all records had to be searched manually and not all the records could be accessed.
- We only had 24 patients included in the study. This minimal number of patients limits the interpretation of results.
- The study only included short-term results, length of follow up could have been longer.
- This is a retrospective study that represents data from a single institution, any conclusions drawn from this data are limited.

5. Conclusion

The success rate and good functional results of tracheal resection with primary end-to-end anastomosis make tracheal resection an effective and reliable surgical procedure in the management of LTS. Our study suggests that tracheal resection can be used as a definitive treatment for patients with LTS and who have had failed treatment from other conservative

surgical techniques, like laser, dilation or micro-debridement. The procedure can cause significant postoperative morbidity, which at times can be life-threatening. Patients with preoperative tracheostomy were shown to have a longer length of trachea resected and a higher rate of postoperative complications. Higher degrees of stenosis Meyer Cotton stenosis (grade III and IV) were also associated with higher rates of post-operative complications.

Patients who are considered for tracheal resection should be meticulously selected and the treatment options should be discussed in detail. Selected patients should have a detailed description of the history, clinical examination, direct laryngoscopy, bronchoscopy, and CT scan.

The findings of this research have managed to show that tracheal resection has a high success rate. It is, however, important to note the post-operative complications that are associated with the procedure. Although the associative morbidity is low, it may be potentially life-threatening. Even though tracheal resection is a definitive treatment option for LTS, additional surgery may be needed, more so, in patients who develop stenosis post-operatively. Tracheal resection is a good surgical option, as a definitive measure, when less invasive surgical techniques have failed in treating patients with tracheal stenosis. The procedure continues to be performed at CHBAH with careful consideration of the complications associated with the procedure.

Appendix A: Ethics Clearance Certificate

R14/49 Dr Prince Ratshili Makaulule

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M161044

NAME: (Principal Investigator)	Dr Prince Ratshili Makaulule
DEPARTMENT:	Otorhinolaryngology Chris Hani Baragwanath Academic Hospital
PROJECT TITLE:	A Retrospetive Review of the Short Term Outcomes of Tracheal Resection for Laryngotracheal Stenosis at Chris Hani Baragwanath Academic Hospital
DATE CONSIDERED:	28/10/2016
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr Yahya Atiya
APPROVED BY:	Professor P Cleaton-Jones, Chairperson, HREC (Medical)
DATE OF APPROVAL:	31/10/2016

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 3D1, Third floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorised to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report.** The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed in October and will therefore be due in the month of October each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

Appendix B: Data collection sheet

Data collection sheet (tracheal resection)		
Study Number		
Age at time of surgery		
Sex	Male	Female
Comorbidities Type of comorbidity?	Yes	No
Tracheostomy?	Yes	No
The degree of stenosis (Meyer cotton)		
Length of stenosis (cm)		
Length of trachea resected		

Postoperative complications	Yes	No
Type(s) of complication(s)?		
Any required interventions or additional airway surgery	Yes	No
Additional surgery type		
Follow up post resection		
Outcome Excellent	Yes	No
Satisfactory	Yes	No

Unsatisfactory	Yes	No

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