SURGERY IN POST-INTUBATION TRACHEAL STENOSIS -MANAGEMENT AND RESULTS

A DISSERTATION SUBMITTED TO THE TAMIL NADU DR.M.G.R. MEDICAL UNIVERSITY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF M.Ch – CARDIO-THORACIC SURGERYGOVERNMENT OF TAMIL NADUMADRAS MEDICAL COLLEGE AND GOVERNMENT GENERAL HOSPITALCHENNAI – 600003

CERTIFICATE

This is to certify that this dissertation titled **"SURGERY IN POST-INTUBATION TRACHEAL STENOSIS – MANAGEMENT AND RESULTS"** is a bonafide record of the work done by **DR. SUDHAN NAGARAJAN** in the Department of Cardio-Thoracic Surgery, under our supervision, during the period of his postgraduate study for M.Ch – Cardiothoracic Surgery, from June 2003 to February 2006.

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CONTENTS

INTRODUCTION

Tracheal surgery has been one of the last specialties mastered by thoracic surgeons. The 1960s saw the rapid development of the surgical techniques in treating tracheal disorders. Surgery of the trachea and bronchi still remains a challenging subdivision and is done routinely only in experienced centres.

Post-intubation tracheal stenosis remains the most common indication all over the world for surgery on the trachea. Despite the wide research done on the issue of prolonged mechanical ventilation and the advantages of large volume, low pressure cuffs, tracheal stenosis still persists as a major consequence in patients on endotracheal tube or tracheostomy tube, though the incidence has decreased considerably over the decades.

The management of patients presenting with post-intubation tracheal stenosis can be urgent or elective, depending on the clinical picture and investigations. The principles of surgical management have been clearly established through several studies in the past. We have encountered patients with post-intubation tracheal stenosis referred to us on a regular basis. Hence we decided to analyse the characteristics and surgical management of such patients in our hospital.

REVIEW OF LITERATURE

HISTORY

Despite the antiquity of tracheostomy, tracheal surgery was the last anatomic subdivision of cardiothoracic surgery to develop. The 1960's proved to be the decade when the advances in tracheal surgery quickened [1]. In 1950, Belsey observed, "The intrathoracic portion of the trachea is the last unpaired organ in the body to fall to the surgeon, and the successful solution of the problem of its reconstruction may mark the end of the expansionist epoch in the development of surgery" [2]. Tracheostomy found application in general anaesthesia, but was soon displaced by endotracheal intubation [3].

REPAIR AND HEALING

An ancient concern that cast a shadow on tracheal surgery into the twentieth century was that cartilage healed poorly. Hippocrates had cautioned, "The most difficult fistulae are those which occur in the cartilaginous areas……." [4]. The Rig Veda, a book of Hindu medicine dating from between 2000 to 1000 B.C. noted that "The trachea can reunite when the cervical cartilages are cut across, provided they are not entirely severed" [5].

Ambrose Pare described suture of tracheal lacerations in the mid 1500s in three patients, the first from a sword wound and the latter two from knife wounds [6].

END TO END TRACHEAL AND BRONCHIAL ANASTOMOSIS

Gluck and Zeller, in 1881, demonstrated healing after end to end tracheal anastomosis in

dogs and believed the technique could be applied in man [7]. Primary anastomosis of the cervical trachea, after limited resection for post-traumatic tracheal stenosis, followed in 1886 by Kuster, apparently the first in man [8]. Complex methods for repair of cervical tracheal defects, with skin or fascia lata, were also explored in the early twentieth century by Nowakowski in 1901, by Levit in 1912, among many others [9, 10].

Bronchial repair after trauma proved the feasibility of airway reconstruction. Sanger described bronchial repair in patients during the World War II [11]. Earlier, cautious enlargement of bronchial stenosis by wire-supported dermal grafts was replaced by resection and reconstruction [12].

PRESUMED LIMITS OF RESECTION

A more insistent concern was that only a very limited segment of the trachea could be removed and reanastomosis accomplished. Rob and Bateman, on the basis of cadaver dissection placed the limit at 2 cm [13]. Belsey believed that three or four rings, about 2 cm, were the limit in man [2]. Those presumed limits led to devising complex methods of cervical tracheal reconstruction with available time flaps and transfers, and further, to a century-long search for a means of tracheal replacement with autogenous tissues, foreign material transplantation and tissue engineering [14].

MAINTENANCE OF VENTILATION

An additional difficulty for reconstruction was the maintenance of safe, continuous and stable ventilation throughout the procedure, especially for intrathoracic tracheal operations. Stenoses from traumatic, iatrogenic or inflammatory causes were not seen frequently before 1960.

PRIMARY RESECTION AND REANASTOMOSIS – INITIAL EXPERIENCES

Despite continued concerns about the feasible length of tracheal resection and lingering doubts about cartilaginous healing, a number of successful anastomosis were described in the 1950s and early 1960s, most often for shorter, benign lesions such as strictures [15]. Improvements in diagnosis (endoscopy) and technical and ventilatory methods had served to widen the field beyond tracheostomy and endoscopic treatment alone.

ANATOMIC MOBILISATION OF TRACHEA

The "2 cm rule" which had served to inhibit advances in tracheal surgery, was now challenged by experimental studies reinvestigating the extent of trachea that could be removed, and approximation achieved by anastamotic tracheal mobilization, without the use of prosthetic replacement.

Michelson and colleagues, in an effort to increase the length of resectable trachea, freed the right main bronchus in dogs by incising the right pulmonary ligament and resecting the left main bronchus at the carina, and then reanastomosing it to the bronchus intermedius. They found that the human trachea could be stretched 4 to 10 cm by mobilization and an added 2.5 to 5 cm could be obtained by the manoeuvre described in dogs [16].

In 1959, Harris showed radiologically that neck extension elongated the trachea by 2.6 cm [17]. Grillo and colleagues reported in 1964, from autopsy studies in man, that one half of the adult trachea could be resected and continuity reestablished by full mobilisation of the limiting structures.

Steps in mobilization which aided in tracheal excisions upto an additional length of 6 cm

were (i) right hilar dissection and division of right pulmonary ligament, (ii) division of the left main bronchus and (iii) freeing the pulmonary vessels from the pericardium. Additional mobilisation was possible by the division of cervical trachea two to three rings below the cricoid, completing the anastomosis distally and cervical reconstruction at a second stage [18].

The appreciation of the possible degree of tracheal mobilization, based on anatomic principles like pretracheal mobilisation, cervical flexion, hilar dissection and mobility of detached main bronchi, made possible a systematic and aggressive approach to tracheal resection and reconstruction.

LARYNGEAL RELEASE

Division of the thyrohyoid muscles, the superior cornua of the thyroid cartilage and of the thyrohyoid membrane, with care to preserve superior laryngeal nerves, allowed the larynx to drop about 2.5 cm. Grillo observed clinically that laryngeal release did not transfer effective relaxation for lower tracheal or carinal resections [19].

TRACHEAL BLOOD SUPPLY

Grillo emphasized the entry of small segmental arteries via “lateral pedicles” of tissue attached to either side of the trachea [20]. Miura and Grillo precisely defined the blood supply to the upper trachea in 1966, usually from three principal branches of the inferior thyroid artery with the first branch most often predominant [21].

The arterial supply of the thoracic trachea was mapped to be from bronchial, supreme

intercostals, subclavian, right internal thoracic and innominate arteries [22]. Complete circumferential dissection, subsequent division and anastomosis have led to necrosis.

ANAESTHESIA FOR TRACHEAL SURGERY

Mc Clish and colleagues noted that the concern about anaesthesia for major airway reconstruction "stems from the complexity of simultaneously controlling the airways, maintaining satisfactory gas exchange, and ensuring good surgical exposure to the trachea" [23].

Cross table anaesthetic techniques were fully described by Grillo in 1965 and expanded in 1970 [24]. The potential use of two anaesthetic machines for complex carinal reconstruction was also noted. El Baz and colleagues favoured high frequency positive pressure ventilation for tracheoplasty to permit better visualisation and access [25].

Close communication and co-operation between the surgeon and the anaesthesiologist are uniquely demanded for this type of surgery - preoperatively, intra-operatively and optimally, postoperatively. The use of cardiopulmonary bypass, though controversial, has been useful in difficult reconstructions in a few experiences.

COMPLICATIONS OF TRACHEAL SURGERY

As tracheal surgery became more common, a pattern of complications inevitably appeared. These were analysed by Levasseur in 1971, Couraud in 1982 and by Grillo in 1986, along with their colleagues [26, 27]. Suture line granulations were common, but major complications like tracheo-innominate artery fistula and significant restenosis have occurred, not infrequently.

T-TUBES

The silicone rubber T tube developed by Montgomery proved widely useful in tracheal surgery; although it was initially developed with the false hope that prolonged stenting would resolve tracheal stenosis [28]. Cooper and colleagues in 1981 used it for temporary and permanent restorations of anatomic continuity (i) when the trachea was not reconstructible (ii) when a lesion was not removable or (iii) when a temporary airway was needed [29].Westaby and colleagues introduced a bifurcated T tube for the carinal problems [30].

POST-INTUBATION LESIONS

The poliomyelitis epidemics of the mid twentieth century introduced and led to an ever widening use of mechanical ventilators to treat respiratory failure. The iatrogenic lesions that resulted provided a whole new field of endeavour for the tracheal surgeon [31].

Gradually, a spectrum of lesions was recognised, attributable to ventilatory apparatus, endotracheal and tracheostomy tubes and the cuffs necessary to seal the trachea [20],[32],[33]. Principal among them were (i) circumferential stenosis that appeared at the level of the sealing cuff and (ii) anteriorly pointed, arrow shaped stenosis, which occurred at the stomal level.

Additionally, granulomas occurred at the point where a tube tip impinged on the tracheal wall [31]. Areas of malacia were seen less often at the cuff level and sometimes in the segment between the tracheal stoma and a cuff stenosis.

Tracheo-oesophageal fistulae occurred between the trachea and the oesophagus at the cuff level, usually with accompanying circumferential tracheal damage [31].

Tracheo-innominate artery fistulae, though rare, were disastrous when they occurred. These lesions proved to be of two types (a) one where a tracheostomy tube rested immediately on the innominate artery near the stoma and (b) the other, where the cuff, or less often, the tube tip, eroded through the trachea anteriorly into the innominate artery [31].

In the 1960s, numerous papers, often single case reports appeared in Europe and North America, describing surgical resection of post-intubation strictures [34-39]. Tracheomalacia instead of tracheal stenosis was also described, although a rare finding by Grillo [40].

Deverall, Pearson, Grillo, Couraud and their colleagues stressed the importance of allowing florid inflammation to subside prior to surgical correction [33, 41]. Their generally good results showed the superiority of definitive surgical resection and anastomosis over prior alternative methods of treatment, such as repeated dilatations, steroid injections and cryotherapy. Unfortunately, the lesson is being relearned today with uncritical use of laser surgery for these lesions and more lately, with much more disastrous results, the attempted use of stents to treat post-intubation stenosis [31].

Correction of post-intubation stenosis involving the subglottic larynx remains much more difficult than lesions confined to the trachea [31].

Reoperative tracheal resection and reconstruction for unsuccessful repair of post-intubation stenosis proved to be surprisingly manageable. In 1997, Donahue and colleagues tallied 97%

good or satisfactory results in 75 patients who had failed prior surgical repairs [42].

ETIOLOGY OF POST-INTUBATION LESIONS

The etiology was initially unclear. Among the factors thought to be implicated were irritation from the materials which made the tube and cuff, elution of chemicals by gas sterilization, age of the patient, debility, steroids, bacterial infection and direct irritation by the presence of the tube. Although some of these likely contributed to the injuries seen, pressure and necrosis from tubes and cuffs - whether endotracheal or by tracheostomy, with subsequent efforts at tissue repair and finally, cicatrisation proved to be the fundamental explanation [43].

Post-tracheostomy stenosis had been pointed out as early as 1886, when Colles found four strictures in 57 patients treated for diphtheria [44]. However, only with the growing use of ventilation, during and after the 1952 poliomyelitis epidemic, did post-intubation injuries become more frequent.

Bignon and Chretien, in 1962, described inflammation, metaplasia and stenosis at the tracheostomy site; pseudopolyps, ulceration and stenosis of the trachea at the cuff level; and sometimes softening of the tracheal wall [45]. They attributed these changes principally to the trauma from the cannula above and to ischemic compression by the cuff or erosion by the tip of the tube below. The severity of the lesions did not correlate with the length of ventilation.Florange and colleagues reconstructed the evolution of tracheal necrosis from mucosal inflammation to erosion

of the mucosa, loss of cartilage and localized $_2$mediastinitis [46]. Gibson concluded that the main factors in producing stenosis were cuff trauma and infection at the stoma.

Cooper and Grillo presented a detailed pathologic study of autopsy specimens from patients dying on respirators [47]. The lesions appeared within 48 hours and progressed from tracheitis to ulceration of the mucosa, to fragmentation of the cartilage, to the replacement of the tracheal wall with scar tissue. The location and nature of the lesions also correlated with surgically removed Stenotic lesions. The same erosive processes were observed to cause tracheo-oesophageal fistulae and tracheo-innominate artery fistulae.

PREVENTION OF POST-INTUBATION INJURY

Prevention quickly became the priority once the etiology of these lesions was evident. In 1957, Adriani and Philips found that most of the intra-cuff pressure necessary to inflate the then conventional cuffs (90 to 120 mm Hg) was expended on distending the cuff, and the pressure on the tracheal wall was low (10 to 15 mm Hg) in order to develop ventilatory pressures of 10 to 20 mm Hg [48].

Cooper and Grillo later pointed out that excessive pressures were necessary to seal the irregular shaped trachea by distending the relatively rigid, small volume cuffs that were then is use [49]. Knowlson and Bassett noted that small increments over the minimal occlusive volume necessary for the seal of conventional cuffs at 20 cm H_2O caused a rapid rise in the pressure exerted on the tracheal mucosa [50].

In 1943, Grimm and Knight had proposed that the ideal cuff “should have sufficient volume when inflated, without stretching, to fill the diameter of the trachea [51].

Cooper and Grillo reproduced severe stenosing cuff lesions in dogs in 1969, which were entirely parallel with the lesions in man [49]. Experimental large volume, thin walled latex cuffs produced seals at 20 to 40 mm Hg intraluminal pressure, and no mucosal damage followed.

Since this conclusively proved that tracheal lesions were due to cuff pressure, a large volume, compliant cuff was designed for clinical use by Grillo and his colleagues [52]. Their comparative clinical trial showed that any degree of injury severe enough to evolve into stenosis was produced by the standard (high pressure) cuff. The average intra-cuff pressure in the new cuff was 33 mm Hg, compared with 270 mm Hg in the standard cuff. In extensive clinical use, no tracheal lesions resulted from the use of this large volume, compliant cuff.

A variety of other seals including prestretched cuffs, flanges and alternating cuffs were also proposed as solutions, but they lacked the simplicity and effectiveness of properly used large volume cuffs. The light weight tracheal connectors used in Massachusetts, USA have led to a drop in the incidence of stomal stenosis from 17.5% to 6.9% [53].

AIMS AND OBJECTIVES

To analyse the characteristics and results of tracheal resection and reconstruction in patients presenting with post-intubation tracheal stenosis.

PATIENTS AND METHODS

This was a single institution, retrospective review of 82 patients who underwent tracheal resection and reconstruction for post-intubation tracheal stenosis from January 2000 to December 2004.

PATIENT SELECTION

Patients who were diagnosed to have tracheal stenosis following intubation and prolonged mechanical ventilation and underwent tracheal resection and reconstruction in our department were included in the retrospective analysis.

The records of the patients operated from January 2000 to December 2004 were procured from the Medical Records Department and the details noted.

PARAMETERS STUDIED

The parameters evaluated in each patient were:-

1. **Patient characteristics**:

   The age and gender of each patient was noted.

2. **Etiology:**

   The cause of tracheal stenosis was ascertained as to whether due to the balloon cuff of endotracheal tube, balloon cuff of tracheostomy tube or the tracheostomy site itself.

3. **Characteristics of the stenosis:**

The exact site of the stenosis, the involvement of the laryngeal apparatus, the multiplicity of the lesions, the presence of tracheo-oesophageal fistula or tracheomalacia and the details of any mode of treatment prior to the surgery were noted.

4. Surgical treatment:

The type and technique of anaesthesia carried out in patients with and without stoma were noted. The surgical approach, the type of anastomosis, the anastamotic technique, the suture materials used, the presence of any need for reinforcement of anastomosis or laryngeal release, details of concomitant oesophageal fistula repair if any, resection of malacic segments, the need for cardio-pulmonary bypass and the amount of the trachea resected in each patient were also noted.

5. Postoperative care:

The duration of Intensive Care Unit stay, the total duration of the postoperative hospital stay and the presence of the need for ventilatory support were recorded. 16

6. Follow-up:

The follow-up was mainly by Out-Patient Department visits. The details of the follow-up visits were carefully assessed. The results in each patient were assessed using a self-designed grading scale.

The grading of the results:

Good - (i) Able to perform normal daily activities and

(ii) Bronchoscopy reveals a normal airway.

Moderate - (i) Has difficulty on exertion or

(ii) Bronchoscopy reveals significant narrowing or vocal cord abnormalities

Poor - (i) Unable to perform even the basic daily activities

(ii) Bronchoscopy reveals significant narrowing and other complications which warrant re-operation.

7. Complications:

A careful note of the complications was made and the details of their management were included. The mortality rate was also calculated.

8. **Other interventions**:

Reoperation, creation of tracheostomy, temporary and permanent T-tube insertions and dilatations were included in the data collected.

OBSERVATIONS

A. PATIENT CHARACTERISTICS:

- A total of 78 patients underwent 84 tracheal resections and reconstructions for post-intubation stenosis.
- They included 51 male patients (65%) and 27 female patients (35%), with an age distribution ranging from 14 to 70 years. The most common age group affected was the 25-35 year age group (Table I).
- The balloon cuff of an endotracheal tube accounted for the lesions in 57 patients (74%) and the tracheostomy site or tube lesions were seen in 21 patients (26%) (Fig.1).
- All patients underwent X-ray imaging of the neck, CT scan and bronchoscopic evaluation (Fig.2,3&4).
- Of the 78 patients, 74 patients (95%) had principally tracheal lesions and 4 patients (5%) had laryngotracheal involvement.
- 23 patients (30%) had prior treatment in the form of tracheal dilatations or attempts at laser recanalisation before being referred to our Institute for surgical reconstruction. Three patients had expandable stents inserted prior to the referral and the stent had slipped in one patient, got obstructed in another and was the cause of erosion in another.

B. OPERATION DETAILS:

- A total of 84 resections and reconstructions were performed on 78 patients.
- The principles of anaesthetic technique that formed the protocol were:-
  - (i) If the residual airway was sufficient to maintain ventilation, the patient was intubated and ventilated and tracheal reconstruction was carried out under general anaesthesia.
  - (ii) If the residual airway was very narrow and there remained a doubt regarding the adequacy of ventilation, then a tracheostomy or tracheal dilatations using tracheal dilators were performed on-table prior to reconstruction in endotracheal tube cuff lesions (Fig.5). In the case of tracheostomy site lesions, the stoma was dissected under local anaesthesia and the distal airway was established using a flexometallic tube prior to definite reconstruction.

- The surgical approach used was cervical in 47 patients (60.2%), cervicomediastinal in 24 patients (30.9%) and 7 patients (8.9%) required a thoracotomy for primary access (Fig.7).
- The amount of trachea resected ranged from 1 cm to 5 cm and most often, 2 to 3 cm was resected (Table II).

- Anterior and posterior dissection was done in all cases to free the trachea upto the carina so as to enable a tension-free anastomosis, aided by cervical flexion. This manoeuvre avoided the vessels that supply the trachea through the lateral segmental branches (Fig.9 & 10).
- Laryngeal release was not done in any of the patients as there was no necessity and we wanted to completely avoid aspiration and the problems associated with deglutition. Laryngotracheal

lesions were resected with an oblique cut of the laryngeal cartilage, as shown in [Fig.15(a)].

- The anastomosis was tracheo-tracheal in 62 patients (78.8%) and cricotracheal in 12 patients (15.4%) and thyrotracheal in 4 patients (5.8%). The cricothyroid junction was always preserved in its posterior part to avoid injury to the recurrent laryngeal nerve.
- All four patients with thyrotracheal anastomosis had a temporary T-tube inserted at the end of the procedure. The suture material used for anastomosis has been 3-0 or 4-0 vicryl in all cases.
- A total of four patients had tracheo-oesophageal fistulae and all of them underwent repair as a single-stage procedure. Three of them presented as a result of post-intubation lesions extending to the oesophageal walls and one patient developed it secondary to tracheal reconstruction (Fig.30).

- Reinforcement of the anastamotic site was done using strap muscles in 10 patients, of which four underwent repair of tracheo-oesophageal fistulae and six patients had their innominate artery exposed during the surgery. Two out of these six patients had undergone tracheo-innominate fistula repair along with tracheal reconstruction (Fig.19-22).
- Tracheomalacia was seen in short segments adjacent to the Stenotic site in three patients, all of whom had these segments removed successfully, along with the resection of the stenotic sites.
- Cervical flexion was maintained in the postoperative period for 7 days by sutures that fix the submental crease of the chin to the presternal skin(Fig.16)
- Postoperative re-intubation was required in two patients and one each in this category belonged to the thyrotracheal and cricotracheal groups.

- No patient required a concurrent tracheostomy at the end of reconstruction. However, six patients needed T-tube insertions temporarily; one of them for a second high anastomosis when the low stenosis was reconstructed; four of them for the laryngotracheal anastomosis, and one was for high amount of tension in the anterior wall of the anastomosis(Fig.17)

C. RESULTS

- The average length of follow-up of the patients was two years.
- The results were good in 66 patients (78.6%), moderate in 11 patients (13.1%) and poor (failure) in 6 patients (7.1%) (Table III).
- The failure rate for the tracheo-tracheal anastamotic group was 6.5% and that for the cricotracheal and thyrotracheal anastamotic groups were 5.5% and 25% respectively (Table IV).
- The rate of overall good results in the tracheo-tracheal anastamotic group was higher than that of the other groups (Table IV).

D. COMPLICATIONS

- Major complications were present in 18 patients (23.2%) (Table V).
- Granulations were the most frequent of all complications (34%) (Table V). Four patients had major granulations which resolved with bronchoscopic removal.

- Major dehiscence or restenosis warranting further active intervention were present in six patients. Two had a successful reconstruction, and two had to have a permanent tracheostomy. One patient had tracheal necrosis at the anastomotic site in a low level lesion and we undertook omentoplasty which was successful. One patient developed acute respiratory obstruction at home and died.

- Laryngeal dysfunction was of minor degree in two patients and resolved spontaneously. Acute adductor palsy (severe dysfunction) was present in four patients, out of which three were managed successfully with temporary T-tubes. One patient, aged 70 years, the oldest in our series, had to undergo a permanent T-tube insertion.
- A total of three patients developed tracheo-innominate artery fistula, all during hospital stay in the first postoperative week, and presented with massive bleeding from the wound site and haemoptysis. Two patients were managed successfully with urgent exploration, tracheal reconstruction, graft interposition between the aorta and the right common carotid artery and ligation of the innominate artery. One patient died prior to surgical intervention, when urgent exploration was about to be carried out(Fig.19-22)
- One patient developed quadriplegia due to acute neck flexion in the postoperative period.
- Wound infection was present in three patients and one patient had severe deep infection with mediastinitis and underwent re-exploration, lavage and a second reconstruction.
- One patient in the cervicomediastinal group developed pneumothorax and was treated successfully with intercostal tube drainage.
- A total of three patients died; one each due to tracheo-innominate artery fistula, acute severe restenosis and septicemia.

DISCUSSION

ETIOLOGY AND PREVENTION:

The etiology of post-intubation tracheal stenosis has been well established and it is mainly due to prolonged ventilation, use of inappropriate pressure in the cuffs of the endotracheal or tracheostomy tube and also due to the interventions done along with intubation (47, 53).

Prevention is possible to a high degree by the use of large volume, low pressure cuffs (52) and careful management of stomal tubes. However, the lesions continue to appear, most likely because of overinflation of non-elastic plastic cuffs and leverage on tracheostomy tubes.

Balloon cuff lesions were the most common cause of stenotic lesions in our series (74%). This was comparable with the other published series (58, 59).

DIAGNOSIS:

The patients usually present with difficulty in breathing, most often misdiagnosed as asthma, and with or without a stoma. And, in our series, the patients were generally referred to our Institute with an established diagnosis based on radiologic imaging.

EXTENT OF INVOLVEMENT:

In our series, only 5% of the lesions had laryngotracheal involvement and the rest were principally tracheal in nature. 30% of our patients had received conservative treatment prior to being referred for definite reconstruction. However, we were not able to analyse the failure rates in this subgroup of patients who underwent prior treatment. Grillo et al have found that prior treatment can lead to increased failure rates (59).

CONSERVATIVE MODALITIES:

A host of conservative treatments are available like dilatation, local and systemic steroids, cryosurgery, fulguration, laser treatment and prolonged or permanent stenting with T-tubes and other stents. These modalities have proved successful and without excessive complications only for highly selected patients (54-56).

TRACHEAL DILATATION:

It offers two major benefits. One is the establishment of a definite airway just prior to resection and reconstruction. The other benefit is that this allows safe deferral of operation in order to treat the concurrent medical problems, to clear obstructive pneumonia and to gradually reduce the dosage of steroids, if they are being given.

The procedure is usually done under general anaesthesia. Deep inhalational anaesthesia is given and the patient is allowed to maintain respiration. Rigid bronchoscopy is done and tracheal dilators (Fig.5) of various sizes are passed through the stenotic segment and then the bronchoscope is

manoeuvered gently through the obstruction. Distal secretions are thoroughly cleared with suction. Four patients in our series underwent this procedure and were taken up for definite reconstruction in the same sitting.

T-TUBES:

These tubes developed by Montgomery still play a vital role as an adjunct in tracheal surgery. Temporary T-tubes are required when a temporary airway was needed prior to definite reconstruction (for example, in case of second stenosis) or to tide over a crisis (for example, postoperative laryngeal dysfunction) (28). Nine patients in our series required temporary T-tubes.

Permanent T-tubes are indicated when the trachea is not reconstructible and such a situation was met in two of our patients. For patients with extensive tracheal damage that defy surgical reconstruction, permanent T-tubes maybe the best solution (55). One patient in our series developed acute respiratory distress due to T – tube blockage and underwent emergency re-intubation(Fig.18). He subsequently had to be on permanent tracheostomy.

STENTS:

Expandable stents can cause problems such as slippage, obstruction or extrusion. Though they have a few select indications (56), we have no experience of stent insertion as primary treatment in our series.

SEGMENTAL TRACHEAL RESECTION:

The largest series in the world, published by Grillo et al, has established the benefits of tracheal resection and reconstruction as the preferred definitive mode of treatment op post-intubation stenosis.

Basic principles of tracheal reconstruction introduced in the 1960s and 1970s, served to reduce the incidence of many complications. These principles include the avoidance of excessive anastamotic tension, good mobilisation using anterior and posterior dissections and laryngeal release when required, maintenance of tracheal blood supply and interrupted suture techniques. Laryngeal release was never required in our patients.

Majority of the patients required a tracheo-tracheal anastomosis (78.8%) and 5.8% patients required a thyrotracheal anastomosis which was done by preserving the

cricothyroid junction posteriorly to avoid recurrent laryngeal injury [Fig.15(a-f)]. We had to insert temporary T-tubes in all patients who underwent laryngotracheal anastomosis, since our experience is limited.

Cervical flexion was maintained for an average of seven days in all patients. One patient developed a rare complication of quadriplegia following acute neck flexion which has been reported earlier (59).

Reinforcement of the anastomotic site was done only with strap muscles which we found were easily accessible and ideal. Other published series have also used thyroid isthmus, pericardial fat and have had good results (59). We have reinforced the anastomosis when the innominate artery is exposed during dissection around the trachea, the anastomosis lies in proximity to the artery and also in cases of tracheo-innominate artery and tracheo-oesophageal fistulae(Fig.23).

The failure rates were relatively higher in the laryngotracheal anastomotic group though the numbers of patients who have undergone this procedure are low. This finding has been proved to be of statistical significance in other published series (59).

The results were good in almost 80% patients and were comparable with other studies of the same kind. Grillo et al achieved good results on 87.5% of their patients and it was a larger series than ours.

3.85% of our patients died. This was within acceptable limits of a centre doing tracheal surgery on a routine basis.

COMPLICATIONS

- Granulations were the most common complication in our series. This was the same as experienced by Grillo et al (59). However, the most frequent complication in the series of Rea et al was vocal cord dysfunction (58).
- Laryngeal dysfunction was experienced in four patients and only one required a permanent T-tube for airway.

- Anastomotic tension is a greater concern in tracheal surgery, since sudden dehiscence can lead to massive surgical emphysema and respiratory distress. Immediate postoperative dehiscence happened in two patients in our series, which required a second reconstruction. We have never felt the need for laryngeal release procedures in any of our patients. Complications were generally more in the subset of patients requiring laryngeal release, though the overall results

have been equivalent (60).

- The etiology and management of tracheo-innominate artery fistula have been well established (61). In our series, we successfully managed two patients with the same principles of control of bleeding, exploration using cervicomediastinal approach (Fig.20), isolation and ligation of the innominate artery and tracheal

reconstruction. Though it has been claimed that there is no significant increase in the incidence of neurologic dysfunction after ligation of the innominate artery (61), we have preferred Gortex graft reconstruction, the graft being interposed between the ascending aorta and the right common carotid artery in both patients. After the proximal anastomosis is completed, we used a Prohit-Inhara shunt (Fig.21) connected between the distal end of the graft and the right common carotid artery when the distal anastomosis was being carried out (Fig.22). No infective or neurologic complications have occurred in both patients.

- Patients with tracheo-oesophageal fistulae are treated best by a single stage repair of the trachea and the oesophagus and that has been achieved in all such patients in our series(Fig.30).

SUMMARY

- Post-intubation tracheal stenosis remains the most common indication for tracheal resection and reconstruction.

- Endotracheal tube cuff lesions were the most frequent of non-neoplastic tracheal stenosis.

- Tracheal lesions were more common than the complex laryngotracheal lesions, which are seen only in a small subset of patients.

- All patients require proper clinical evaluation, radiologic imaging and endoscopic assessment, if possible, prior to definitive surgery.

- Tracheal dilatations prior to tracheal reconstruction were needed for ventilation in a few selected patients.

- Cervical approach is sufficient for adequate resection and reconstruction in a majority of patients.

- With good anatomic mobilisation and avoiding devascularisation at the same time, upto 5 cm of the trachea could be resected and anastomosed.

- Laryngeal release is not mandatory for good reconstruction. Its role in reoperation has to be analysed in further studies.

- Laryngotracheal anastomosis may suggest the need for temporary T-tube, to avoid complications.

- Tracheo-oesophageal and tracheo-innominate artery fistulae are special situations where single stage repair can be successful and require reinforcements with soft tissues most often.

- Reinforcements of the anastomoses were required whenever the innominate artery is exposed during dissection or the surgeon is in doubt.

- Short segments of tracheomalacia adjacent to the stenotic sites can be resected successfully.

- Temporary T-tubes were required in doubtful cases and in patients who develop postoperative laryngeal dysfunction.

- Permanent T-tubes were required in severe lesions which defy reconstruction.

- Granulations remain the most common complication is our series.

- Failure rates were within acceptable limits when compared with other published series.

CONCLUSION

Tracheal surgery is undoubtedly one of the challenging subspecialties of Cardiothoracic Surgery. Non-neoplastic tracheal stenosis, most commonly post-intubation, is the most frequent indication for tracheal resection and reconstruction. Surgery may be required either on an elective or emergency basis.

Careful patient selection is of great importance and good anaesthetic backup is mandatory for a combined team effort. Meticulous surgical technique and adherence to strict surgical principles leads to lesser morbidity and mortality. Resection and reconstruction still remains the best option for post-intubation tracheal stenosis and it offers good results in majority of the patients.

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