Original Article

Surgical intervention is safe, feasible, and effective in tubercular tracheobronchial stenosis

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ABSTRACT

Objectives: Posttubercular tracheobronchial stenosis is a troublesome sequela of tracheobronchial tuberculosis. Surgical resection is the treatment of choice when repeated bronchoscopic dilatations fail. Herein, we aim to present our surgical experience in the management of this problem and also to evaluate factors affecting the surgical outcomes. **Materials and Methods:** This is a retrospective analysis of a prospectively maintained database at a dedicated thoracic surgical unit in New Delhi, India, over 8 years. An analysis of demographic characteristics, perioperative variables including complications were carried out. The occurrence of postoperative complications, and/or hospital stay of >7 days was considered as "poor" surgical outcomes. Various parameters were analyzed to assess the factors predicting surgical outcomes. **Results:** A total of 20 patients were surgically managed in the study period. Two patients had tracheal stenosis. The left main bronchus was involved in 16 patients. In these 16 cases, 12 cases underwent lung preserving surgery (bronchial sleeve resection and sleeve lobectomy) and rest of 4 cases required pneumonectomy. All postoperative complications occurred in 5 (25%) patients. Prolonged air leak was the most common postoperative complication. On univariate analysis, surgical outcomes were poor in patients who had longer duration of symptoms ($P = 0.03$) and with >2 episodes of preoperative balloon dilatations (<0.001). On multivariate analysis, "total number of dilatations <4 times," emerged as a significant predictive factor for lung preservation surgery. **Conclusions:** Surgical intervention is safe, feasible, and effective in tubercular tracheobronchial stenoses which fail to respond to bronchoscopic interventions. Early referral for surgery favors lung preservation.

KEY WORDS: Bronchial stenosis, surgery, tracheal stenosis, tubercular

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INTRODUCTION

Tracheobronchial stenosis is troublesome long-term sequelae of tracheobronchial tuberculosis (TBTB) which occurs due to fibrosis and consequent stricture formation. In patients with TBTB, around 68% develop some degree of stenosis at 4–6 months, which may increase up to 90%, beyond this initial time period.[1,2] This can cause significant obstruction to the airways which results in recurrent infections, pulmonary function derangement, and severe limitation in the exercise capacity. Interventions, such as bronchoscopic balloon dilatation, laser fulguration, and silicon stenting, can offer immediate symptomatic relief. Nevertheless, recurrence rate of stenosis after such methods is high for which repeated procedures may be

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required.[3,4] The protocols for managing such complex problems are not standardized and mostly these are managed on a case-to-case basis.[5] The duration for which silicon stent should be kept *in situ* is also unclear. Surgical correction is considered when medical therapy and interventional methods fail.[6] Extent of surgery may vary from tracheal resection and anastomosis, bronchoplastic procedures, bronchial sleeve resection, sleeve lobectomy to pneumonectomy depending on the site of stenosis, length of stenosis, and status of underlying lung parenchyma. This study aims to present the surgical experience of managing tubercular tracheobronchial stenosis at a dedicated thoracic surgery center and evaluate various factors influencing the surgical outcomes.

MATERIALS AND METHODS

Preoperative evaluation

This is a retrospective analysis of a prospectively maintained data base of 20 operated cases of tubercular tracheobronchial stenosis at a tertiary care center in New Delhi, India, from March 2012 to March 2020. Institutional ethics committee approval was sought. All patients who underwent surgery for tubercular tracheobronchial stenosis were included in the study. Demographic data, details of the present illness including duration of symptoms, and history of anti-tubercular treatment (ATT) were recorded. History of previous interventions including the frequency was also noted in detail. After a detailed clinical examination, contrast-enhanced computed tomography (CT) of chest was performed to assess extent of bronchial stenosis and condition of distal lung parenchyma. CT of the neck was also included in patients with tracheal stenosis [Figure 1]. Flexible bronchoscopic examination was done and the tracheobronchial tree was inspected thoroughly in all cases. In cases of tracheal stenosis, site and length of stenosis, total length of trachea, distance of stenosis from vocal cords and carina were calculated and recorded. In cases of TB bronchial stenosis, along with site and extent of stenosis, distance of stenosis from carina was also assessed. In the left main bronchus (LMB) stenosis, attempt was made to pass the bronchoscope distal to distal end of stenosis to assess the openings of left upper and lower lobes, which help in making appropriate surgical decision.

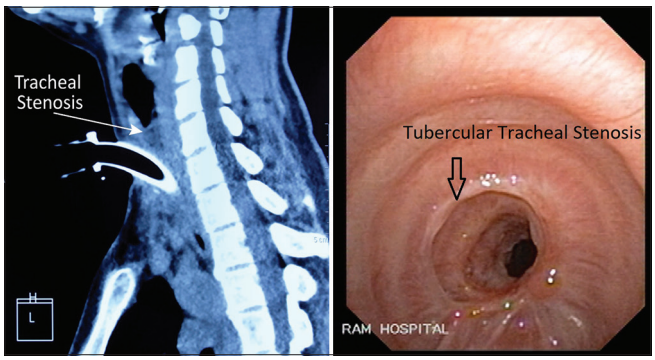

Figure 1: Upper one-third tubercular tracheal stenosis with bronchoscopic view

Indications, prerequisites, and principles of surgery

The presence of severe recurring stenosis with completely collapsed lung, persistent stenosis with continuing troublesome symptoms (cough, recurrent suppurative expectoration, dyspnea, and hemoptysis) and failure of medical therapy and bronchoscopic intervention (>2 times) to relieve obstruction were considered indications of surgery. Prerequisites for the surgical intervention were (1) adequate preoperative antituberculous therapy (ATT) (at least 6 months), (2) no evidence of active TB, (3) cardiopulmonary fitness, and (4) control of underlying risk factors and achieving adequate nutritional status preoperatively. Our principles of surgery were to preserve the lung parenchyma as far as possible and to achieve macroscopically clear margins (healthy mucosa-to-mucosa) for tension-free anastomosis and cover the anastomosis with autologous tissue (in sleeve resection).

Surgical details

All the procedures were performed under general anesthesia. In patients with tracheal stenosis, awake intubation was done under bronchoscopic guidance. Thereafter, patients were placed in supine position with neck extension. Procedure was started with horizontal cervical incision. However, partial sternal split was required in middle one-third tracheal stenosis to get better access. After lateral retraction of strap muscles, thyroid isthmus was divided in midline to reach anterior tracheal surface. Dissection was continued with bipolar cautery staying very close to tracheal cartilage. By this technique, stenotic tracheal segment was delineated. Stenotic segment was looped circumferentially taking care not to injure the anterior esophageal wall and recurrent laryngeal nerves. Vertical mid line incision was given over narrowed segment and extent of stenosis was assessed from inside. Complete resection of stenotic segment was carried out till healthy margins were seen. Along with trachea, cricoid cartilage internal diameter was also assessed. If cricoid cartilage was found stenotic, midline anterior cricoid split was given and a costal cartilage graft was placed in the gap to increase the diameter of the cricoid

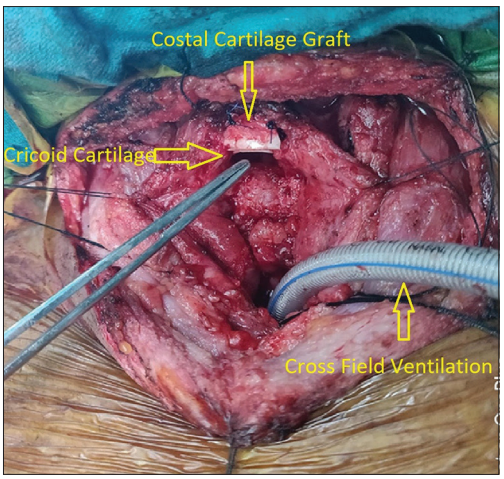

Figure 2: Anterior cricoid split with costal cartilage graft *in situ*

cartilage [Figure 2]. This was followed by end-to-end tracheo-tracheal/cricotracheal anastomosis.

In surgery for bronchial stenosis, single lung ventilation was achieved with a double lumen tube placed under bronchoscopic guidance. Patients were placed in lateral decubitus position with involved side up. Posterolateral thoracotomy was the surgical approach of choice. Complete mobilization of the lung was done after which the main bronchus was carefully dissected and looped circumferentially. Underlying lung was carefully assessed. In cases of main bronchus stenosis, if the whole lung was bronchiectatic and destroyed, pneumonectomy was performed. In patients with main bronchial stenosis with preservation of distal bronchi and lung parenchyma, a bronchial sleeve resection was performed [Figure 3]. If the main bronchus stenosis was extending till one of the lobar bronchus opening, sleeve lobectomy was performed [Figures 4 and 5]. In cases where "lobar bronchus only" was involved with destroyed, collapsed distal lobe, lobectomy was done without necessity of sleeve resection. In sleeve bronchial resection and sleeve lobectomy, 3–0 PDS was used for end-to-end anastomosis. In pneumonectomy and lobectomy, bronchus was divided with surgical stapler. Bronchial stump and anastomosis were always reinforced with pericardial fat/intercostal muscle flap. Lung expansion was checked, and the anastomosis was checked for any air leak. Two chest drains were placed and connected to Thopaz™ digital chest drainage system (Medela, Switzerland) with a negative pressure of 10 cm of H2O. In case of pneumonectomy, single drain was placed and connected to underwater seal. Patients were extubated on the table whenever possible, monitored in the recovery room overnight and shifted to floor the next morning. Patients who required ventilation were kept in intensive care unit till they were extubated, and then shifted to high dependency unit for further observation and transferred to ward once stabilized.

Postoperative care

Supervised, vigorous chest physiotherapy was continued to maintain good lung expansion and adequate nutritional support was ensured. The chest drains were removed when there was no air leak, the drainage was not purulent/hemorrhagic, and drainage was <100 ml in 24 h. Patients were discharged from hospital either after drain removal or with drains if they had prolonged drainage or air leak. The duration of postoperative air leak (>7 days), duration of chest tube, hospital stay, anastomotic dehiscence, wound infection, and other complications during hospital stay were monitored and recorded. The occurrence of any kind of postoperative complication(s), and/or hospital stay of >7 days was considered as "poor surgical outcomes." After discharge, patients were monitored to check for status of lung expansion and any other complication.

Follow-up

The follow-up was done on outpatient basis at 1st week after discharge and every month thereafter for 6 months. All patients had a chest X-ray and pulmonary function test at 6 months to assess the status of lung function. Check bronchoscopy was performed at 3 months and at 1 year after surgery.

Statistical analysis

Statistical testing was conducted with the statistical package for the social science system version SPSS 17.0 (IBM Inc, USA). Continuous variables were presented as mean ± standard deviation or median (interquartile range). Categorical variables were expressed as frequencies

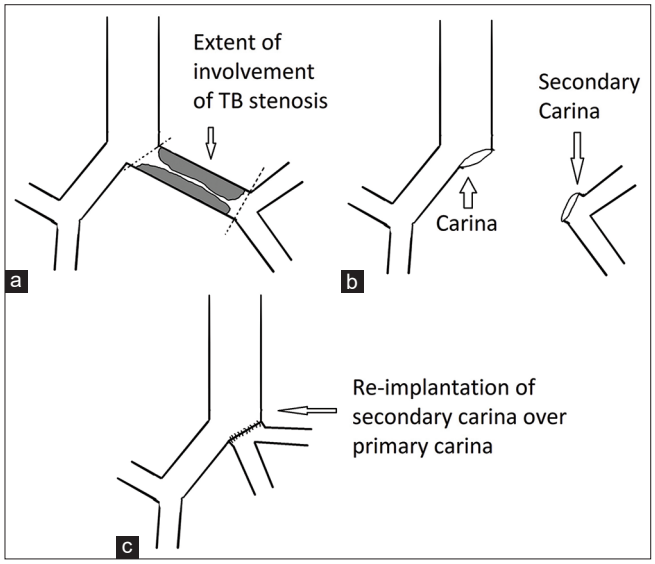

Figure 3: Pictorial representation of left main bronchus sleeve resection (a) Extent of stenosis involvement (b) Airway cut-ends after resection of stenosed segment (c) Method of reconstruction

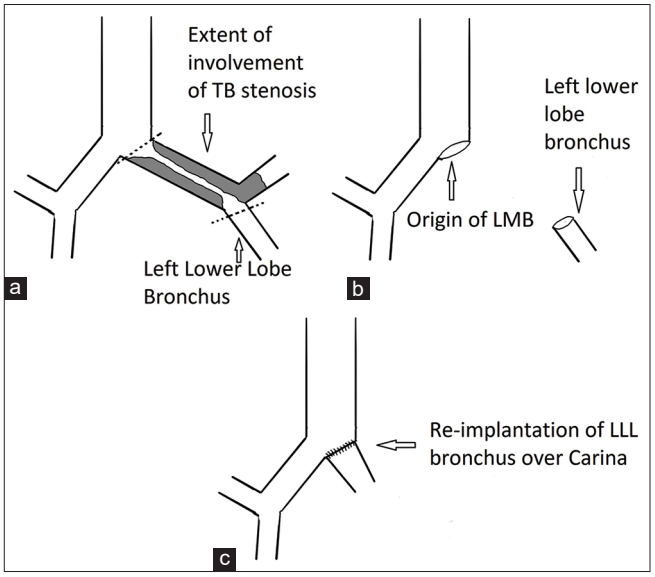

Figure 4: Pictorial representation of left upper lobe sleeve resection (a) Extent of stenosis involvement (b) Airway cut-ends after resection of stenosed segment (c) Method of reconstruction

and percentages. The comparison of normally distributed continuous variables between the groups was performed using Student's *t*-test. Nominal categorical data between the groups were compared using Chi-squared test or Fisher's exact test as appropriate. Nonnormal distribution continuous variables were compared using Mann–Whitney U-test. Multivariate analysis was done using linear regression model. For all statistical tests, a $P < 0.05$ was taken to indicate a significant difference.

RESULTS

Demography and preoperative variables

A total of 20 patients with tubercular tracheobronchial stenosis were treated at our center in the study period. LMB was the most commonly involved (80%). The patients were predominantly females (80%). Cough and shortness of breath were the most common symptoms. The median symptom duration was 6 months (range 2–21 months). All of patients had undergone balloon dilatation at least once with frequency ranging from 1 to 7 times. Only 7 (35%) patients had history of silicone stent placement. Detailed demographics are presented in Table 1.

Perioperative variables

In tracheal surgery, cervical approach was preferred. In case of bronchial involvement, posterolateral thoracotomy was the surgical approach of choice. For right side involvement, the right posterolateral thoracotomy was used and vice versa. Intraoperative bronchoscopy was employed to help locate the exact site and extent of stenosis. Of 16 cases of LMB involvement, in 12 (75%) cases, lung preserving surgery (bronchial sleeve resection and sleeve lobectomy) was done. Rest of 4 cases (25%) required pneumonectomy in view of completely destroyed, bronchiectatic lung. In bronchial sleeve resection, a sleeve of cicatrized bronchus was resected, cut edges of the bronchial ends were freshened and an end-to-end tension-free anastomosis was done. Of 8 such bronchial sleeve resections, 7 required re-implantation of healthy distal LMB directly over carina in view of proximity of stenosis to carina. However, in sleeve lobectomy, along with sleeve of LMB, the involved lobe was also resected and remaining lobar bronchus was re-connected to proximal LMB or re-implanted directly over the carina. Postoperative complications occurred in five patients. Prolonged air leak followed by surgical site infection were the most common postoperative complications. Anastomotic complication occurred in 1 patient, which was managed conservatively without need of re-exploration and with good outcome [Table 1]. No patient had recurrence of symptoms in the follow-up. Bronchoscopy and chest X-ray revealed good anastomotic healing and good lung expansion. Forced expiratory volume in one second (FEV1) was significantly improved in all the 16 patients who underwent lung preservation surgery (preoperative FEV1%-57.8 ± 10.6 vs. postoperative FEV1%-74.2 ± 5.5) ($P < 0.001$).

Table 1: Demography and operative details of patients with tubercular tracheobronchial stenosis (*n*=20)

Characteristics	Number (%)
Male	4 (20)
Female	16 (80)
Age in years (median, range)	29 (16-44)
Symptoms	
Cough	20 (100)
Dyspnea on exertion	20 (100)
Chest pain	7 (35)
Hemoptysis	5 (25)
Fever	2 (10)
Duration of symptoms (median) in months	6 (2-21)
Location of stenosis	
Upper one-third trachea with cricoid involvement	1 (5)
Mid one-third trachea	1 (5)
LMB	16 (80)
LMB alone	12 (60)
LMB with left lower lobe opening	3 (15)
LMB with left upper lobe opening	1 (5)
Right bronchus intermedius opening	1 (5)
Right upper lobe bronchus opening	1 (5)
Preoperative interventions	
Balloon dilatation	20 (100)
Silicon stent placement	7 (35)
Frequency of interventions	
Balloon dilatation (median, range)	2 (1-7)
Silicon stent placement (median, range)	1 (0-2)
Perioperative details	
Surgical approach	
Cervical approach with partial sternal split (for tracheal resection)	2 (10)
Right posterolateral thoracotomy	2 (10)
Left posterolateral thoracotomy	16 (80)
Surgical demographics and type of reconstruction	
Tracheal resection	2 (10)
End-to-end tracheotracheal anastomosis	1
End-to-end cricotracheal anastomosis	1
Left main bronchus sleeve resection	8 (40)
Re-implantation of LMB over carina	7
End-to-end anastomosis of cut ends of LMB	1
Left upper sleeve lobectomy	1 (5)
Re-implantation of left lower lobe bronchus over carina	1
Left lower sleeve lobectomy	3 (15)
Re-implantation of left upper lobe bronchus over carina	3
Left pneumonectomy	4 (20)
Right lower bi-lobectomy	1 (5)
Right upper lobectomy	1 (5)
Operative time (mean±SD) in minutes	232±81
Mean blood loss (mean±SD) in ml	298±122
Duration of ICD (mean±SD) in days	6.5±5.9
Postoperative complications	
Pneumonia	1
Anastomotic dehiscence	1
Surgical site infection	2
Prolonged air leak (>7 days)	4

LMB: Left main bronchus, SD: Standard deviation, ICD: Intercostal drain

Determinants of surgical outcomes and predictors of lung preservation surgery in patients with left main bronchus stenosis

On univariate analysis, surgical outcomes were poor in patients who had longer duration of symptoms ($P = 0.03$, with >2 episodes of preoperative balloon dilatations (<0.001) [Table 2]. On multivariate analysis, "total number of dilatations <4 times," emerged as a significant predictive factor for lung preservation surgery [Table 3].

Table 2: Univariate analysis of factors influencing surgical outcomes for tubercular left main bronchus stenosis (*n*=16)

	Poor surgical outcomes (*n*=5)	Good surgical outcomes (*n*=11)	*P*
Age (mean±SD)	26.1±5.4	29.6±5.2	0.4
Duration of symptoms (mean±SD) in months	6.8±2.8	4.1±1.4	0.02
≤2 preopeartive balloon dilatations	0	9	<0.001
>2 preoperative balloon dilatations	5	3	
Preoperative haemoglobin (mean±SD)	12.1±2.1	13.0±1.5	0.4
Preoperative albumin (mean±SD)	3.1±1.2	3.6±1.2	0.8
Pneumonectomy	3	1	0.06
Lung preservation surgery	2	10	

SD: Standard deviation

Table 3: Multivariate analysis of factors predicting lung preservation surgery in the left main bronchus tubercular stenosis (*n*=16)

Variables	Variable type	β coefficient	SE	*P*	95% CI
Age	Continuous	−0.007	0.06	0.30	−0.02-0.007
Sex	Dichotomous	−0.205	0.08	0.06	0.40-0.008
Duration of disease	Continuous	−0.023	0.02	0.29	0.71-0.024
<4 number of dilatations	Continuous	0.326	0.06	<0.001	0.17-0.45

CI: Confidence interval, SE: Standard error

DISCUSSION

Tubercular tracheobronchial stenosis develops due to healing of mucosal ulceration and necrosis which eventually leads to fibrosis, cicatrization, and stenosis.[7] LMB is more frequently involved than right main bronchus or trachea.[8] This increased vulnerability of LMB to develop infection faster is due to its anatomy where it is compressed between the aortic arch and the left mediastinal lymph nodes.[5] Similar observation was noticed in this series also, where 80% (16/20) of patients had LMB involvement.

The two important objectives of treating TBTB are: eradication of tubercle bacilli and prevention of stenosis.[9] ATT is effective in eradicating the tubercular infection, however, it cannot prevent the development of stenosis.[10-12] Oral corticosteroids (prednisolone equivalent >30 mg/d) also failed to reduce the incidence of persistent tracheobronchial stenosis. Age >45 years, fibrostenotic type of endobronchial Tuberculosis and symptom duration of >90 days were found to be the factors predicting persistence of tracheobronchial stenosis.[13]

Airway stenosis may lead to significant airway obstruction, which causes impairment of pulmonary function and also recurrent infections. Unfortunately, in TB endemic areas, patients may not be aware that they had contracted tuberculosis previously. Hence, it is not uncommon in these countries, where patients with tubercular stenosis are mismanaged.[14] In this series, the median symptom duration was 6 months ranging from 2 to maximum 21 months.

In the recent times, several bronchoscopic interventions have emerged as less traumatic and effective measures.[15] The various techniques described are balloon dilatation alone, stent placement following balloon dilatation,

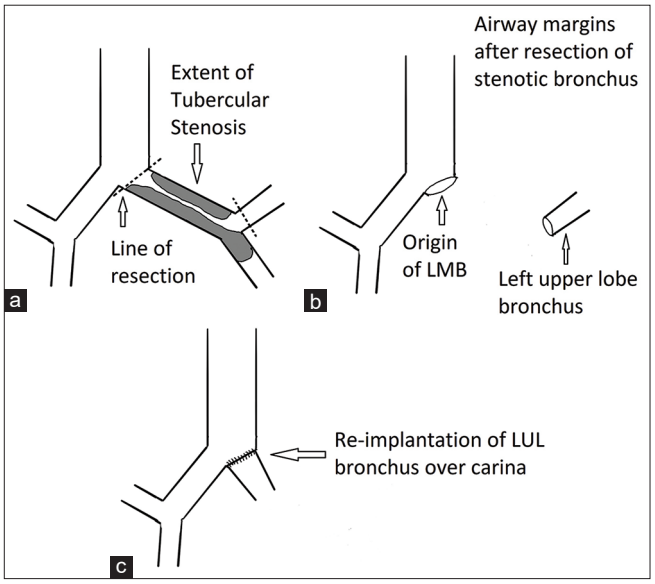

Figure 5: Pictorial representation of left lower lobe sleeve resection (a) Extent of stenosis involvement (b) Airway cut-ends after resection of stenosed segment (c) Method of reconstruction

laser photocoagulation, argon plasma coagulation, and cryotherapy.[16,17] However, there are many controversies in the bronchoscopic intervention therapy. There is no standardization and usually patients are managed on a case-to-case basis. Patients require repeated interventions which mean repeated hospital visits and admissions. Repeated forceful dilatations themselves may trigger further stenosis. Technically, dilatation is not feasible for airways distal to lobar bronchi and upper lobe bronchi dilatation is also technically difficult.[14] Silicone stenting of the airway after dilatation addressed few of the mentioned issues. However, these stents can also trigger airway inflammation and other complications[18] such as stent migration, excessive granulation tissue formation, erosion, continuous irritating cough, and hemoptysis.[19] The duration of stent

placement is another controversy. There are various durations reported from as early as 6 months to 5 years.[20] In the present series, all of the patients underwent balloon dilatations, frequency ranging from 1 to 7 times.

Surgical therapy is considered a useful therapeutic option when bronchoscopic interventions fail. Preoperative investigations aim to assess the length, extent of stenosis, and the condition of underlying lung, which influences the surgical decision. It is not uncommon to see patients with underlying destroyed lungs due to recurrent infection/TB, where no alternative exists except pneumonectomy. Twenty percent patients, in the present study, had this situation where whole left lung was destroyed. All these patients had bronchoscopic dilatation ≥4 times without stent placement. In another 20% of patients, along with LMB, one of the lobar bronchi was involved with destroyed lobe. Sleeve lobectomy was done in those cases. In most of situations, the stenosis involved the whole length of LMB. Hence, an anastomosis between distal LMB and carina had to be performed in these situations. These procedures are technically demanding and best results are obtained at high-volume specialist centers, which are experienced in airways surgery.[21]

Some authors have reported that the presence of remnant disease at the surgical margins is acceptable, with reported re-stenosis rate of anastomosis of 13.9% (5/36 patients).[22,23] However, we strongly recommend to achieve macroscopically disease-free margins as far as possible to achieve a tension-free anastomosis between two healthy bronchi. No anastomotic re-stenosis occurred in our series. Minor anastomotic dehiscence happened in a patient with tubercular tracheal stenosis with cricoid involvement who had undergone a cricotracheal anastomosis. However, conservative management with early wound exploration and regular dressings resulted in successful outcome with no long-term sequelae. In patients who underwent lung preservation surgery, pulmonary function was significantly improved. Similar observations were reported in previous studies.[22,24]

None of the previous studies evaluated the factors determining surgical outcomes and predictors of lung preservation surgery in patient undergoing surgery for tubercular stenosis. In this study, prolonged duration of symptoms and number of dilatations >2 times was significantly associated with poor surgical outcomes with longer duration of air leak, hospital stay, and need for intercostal drain. As frequent recurrence of stenosis was repeatedly managed by dilatation alone, there were multiple episodes of infection of lung parenchyma which caused dense adhesions of lung to the chest wall and mediastinum which required extensive adhesiolysis. This is the reason for prolonged peripheral air leaks leading to prolonged intercostal drain (ICD) and hospital stay. On multivariate analysis, repeated balloon dilatations <4 times was found to be a predictive factor for lung preservation surgery in LMB stenosis. These findings reinforce the fact that, physicians should be vigilant for surgical referral, if symptoms of stenosis are persisting even after 2 attempts at bronchoscopic interventions.

CONCLUSIONS

Surgical intervention is safe, feasible, and effective in tubercular tracheobronchial stenoses which fail to respond to bronchoscopic interventions. The ideal surgical candidate should have a short segment stenosis of the trachea, main bronchi, or lobar bronchi. Lung preservation surgery was possible only when healthy lung tissue was presented distal to the stenosis. Patients with multifocal stenosis and very long stenotic segments are usually not good surgical candidates. Early referral for surgery offers better chance of lung preservation.

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Conflicts of interest
There are no conflicts of interest.

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