Interventional bronchoscopy in the initial management of benign and malignant tracheal stenoses

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Introduction Management of tracheal stenoses is inconsistent. Interventional bronchoscopy (IB) is one of the therapeutic options used.

Aim The aim of the study was to investigate the role of IB in the initial management of tracheal stenosis, evaluating the treatment strategies used and complications encountered.

Patients and methods We prospectively recruited 30 patients presenting with bronchoscopically confirmed tracheal stenoses over 1 year. Twenty benign (six simple and 14 complex) and 10 inoperable malignant tracheal stenoses were studied. All except two patients underwent rigid IB with different modalities. Each patient was followed up for 6 months.

Results All simple, 12 complex (not eligible for surgery), and all malignant stenoses were treated with 17 (mean of 2.83 per patient), 52 (mean of 4.33 per patient), and 39 (mean of 2.83 per patient) IB procedures, respectively, including 1, 10, and 8 stent placements, respectively, with overall good therapeutic response after IB. Two patients with complex stenoses were sent for surgery. During the first 6 months after stent insertion, stent migration occurred in 27 and 12% and obstruction by mucus secretions occurred in 64 and 37% of benign and malignant stenoses, respectively. Granuloma formation occurred in 45% of benign stenoses. Tumor in-growth occurred in 37% of malignant stenoses. All complications were non-life-threatening stent-related complications that were easily managed. During follow-up, two malignant patients died of disease progression.

Conclusion IB is a useful option in the management of simple benign and inoperable complex benign and malignant tracheal stenoses associated with a relatively high rate of non-life-threatening stent-related complications that were easily managed. *Egypt J Broncho* 2015 9:146–153

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Introduction

Tracheal stenosis is narrowing of the trachea by benign or malignant processes. Patients with significant stenosis may present with dyspnea, wheezing, or stridor or may generate a life-threatening situation when the narrowing impedes flow and increases resistance within the airways [1].

Several malignant conditions may affect the tracheobronchial tree with subsequent obstruction due to either extrinsic airway compression, intrinsic airway tumor, or a combination of both [1]. The most frequent type of large airway benign stenosis is caused by iatrogenic events including intubation, tracheostomy, and lung transplant. It can also occur secondary to infections, systemic inflammation, and trauma, or may be idiopathic [1–3].

The management of tracheal stenosis is controversial because the role and efficacy of surgical techniques versus endoscopic procedures strongly depend on the experience of the center and on referral pattern as well as on the characteristics of the stenosis (location, type, and severity) [2,4]. Surgical resection is the preferred approach for benign strictures and resectable lesions with malignant tracheobronchial stenosis, but not all patients are appropriate surgical candidates [5]. In addition, scarring and recurrent stricturing at the surgical site remain an issue in 4–14% of patients with benign tracheal stenosis [6–8]. Thus, endoluminal approaches are often considered to relieve threatening symptoms and in managing patients not suitable for surgery or who experience failure after airway resection [5].

Bronchoscopic modalities in either benign or malignant tracheal stenosis include a combination of mechanical approaches, such as rigid bronchoscopy (RB) or balloon dilatation for opening the airway, heat or cold therapy to relieve endoluminal obstructions, and airway stenting to stabilize the airway for the longer term [1,9,10].

Although all endoluminal approaches have resulted in improvement in luminal patency, all have produced inconsistent results in this application and the durability of the therapy needs to be further tested [5]. In recent times there have been increasing referrals of tracheal stenosis to our unit. The aim of this study was to investigate the role of interventional bronchoscopy (IB) in the initial management of patients suffering from tracheal stenosis secondary to various etiologies, evaluating treatment strategies used and complications encountered.

Patients and methods

During the period between September 2012 and September 2013, we prospectively recruited all patients presented or referred to the Bronchoscopy Unit at the Pulmonary Medicine Department, Ain Shams University Hospital, with clinical presentation strongly suspicious for stenosis of the large airways (e.g. stridor, previous history of endotracheal intubation or tracheostomy, exertional dyspnea or cough) and/or computed tomography of the neck and chest showing images of tracheal stenosis.

To be included in the study population, all patients underwent a preliminary flexible videobronchoscopy (Pentax EB-1830T3 videobronchoscope; Asahi Optical Co., Tokyo, Japan) indicating the presence of tracheal stenosis. Stenosis was classified using a flexible videobronchoscope as described in detail by Freitag *et al.* [11]. The flexible videobronchoscope identifies the location of stenosis [upper-third of the trachea (I), middle-third of the trachea (II), lower-third of the trachea (III), right main bronchus (IV), or left main bronchus (V)], the type of stenosis [exophytic/intraluminal tumor or granulation, extrinsic, distortion or buckling, stenosis/stricture, saber sheath (scabbard), floppy, abrupt (web stenosis), tapered (hourglass stenosis)], and degree of stenosis (0, no stenosis; 1, ≤25% decrease in cross-sectional area; 2, 26–50%; 3, 51–75%; 4, 76–90%; or 5, 91% to complete obstruction).

Benign stenoses were further classified morphologically into simple and complex as previously described by Galluccio *et al.* [2]. Simple stenoses included granulomas, web-like, and concentrical scarring stenosis. All of these lesions were characterized by endoluminal occlusion of a short segment (<1 cm), absence of tracheomalacia, or loss of cartilaginous support. Complex stenoses were represented by a long lesion (>1 cm) with involvement of the tracheal wall and subsequent scarring contraction of the latter, in some cases also associated with malacia [2].

Simple stenoses were treated first with a RB using electrocautery-assisted mechanical dilatation. In case of recurrence, patients were subjected to a repeated bronchoscopic treatment. Surgery was considered after the second recurrence of simple stenoses or as the first choice in operable complex stenoses. After the second recurrence of inoperable simple stenoses or in case of inoperable complex stenoses, electrocautery-assisted mechanical dilatation was performed, along with Dumon silicone stent placement whenever needed. Periodical bronchoscopic follow-up was done every 3 months.

In inoperable symptomatic malignant stenoses with endobronchial exophytic lesions, rigid IB was performed with a combination of several treatment approaches including dilation, mechanical debulking, electrocautery, and argon plasma coagulator. In combined intrinsic and extrinsic lesions, electrocautery resection, dilation, and stent placement were carried out by RB.

The following data were recorded from patients: age, sex, causes of the tracheal stenosis (benign or malignant), the various treatment modalities used, treatment-related complications, mortality, and therapeutic effect of the IB according to criteria for evaluation of therapeutic effects as follows: good response (>50% increase in the caliber of the lumen), partial response (25–50% increase in the caliber of the lumen), no response (<25% increase in the caliber of the lumen), or progressive disease (≥25% increase in the size of one or more measurable lesions or the appearance of new lesions) [12]. In cases of benign postintubation or tracheostomy tracheal stenosis, the cause of original intubation or tracheostomy, duration of intubation or tracheostomy in days, and time of onset of tracheal stenosis after extubation or after tracheostomy closure in days were recorded.

All patients provided written informed consent for being subjected to the procedures, which were performed as part of the regular prebronchoscopic assessment, which consisted of medical history, current medications, physical examination, laboratory tests, radiological evaluation and analysis of the indication, and planning of the expected procedure, as well as anesthesiologist evaluation. The thoracic surgeon was consulted whenever needed. The study was approved by the Institutional Review Board.

Anesthesia

General anesthesia was established by the anesthesiologist in all cases using total intravenous anesthesia and controlled ventilation through the ventilation port of the RB. Anesthesia for IB was commenced as previously described in detail [13].

Bronchoscopic procedure

All procedures were performed using the proper-sized tube of RB according to the site of endoluminal lesion using a Bryan-Dumon RB (Bryan Corp, Woburn, Massachusetts, USA). The IB procedures were performed using one or more of the following modalities whenever indicated: mechanical debridement with bevel of the RB or optical forceps, electrocautery (Erbe, Tubingen, Germany), and argon plasma coagulator (HF-Unit Tekno TOM 212A; Tekno Medical Optik Chirurgie GmbH, Tuttlingen, Germany), bougie with successively larger RB, balloon bronchoplasty (CRE; Boston Scientific, Marlborough, MA, USA), and Dumon silicone stent (Tracheobronxane; Novatech, La Ciotat, France). Different IB procedures were performed following the standardized techniques described in detail by Bolliger *et al.* [10]. The flexible videobronchoscope was sometimes used through the rigid scope to improve distal airway visualization and to assist in aspirating blood and secretions.

In benign tracheal stenosis, electrocautery was applied first to the fibrous, scarring, or granulomatous prominent tissue, and after diminishing it the rigid telescope was introduced into the lumen to assess the stenosis. In web-like stenosis, electrocautery was used to make radial cuts through the entire length of the stenosis scar tissue (generally at 3, 9, and 12 O'clock position), as described by Mehta *et al.* [14]. The stenotic area was then dilated by repeated bougie with successively larger RB. Eventual bleeding was controlled by compression of the tracheal wall by the RB or by argon plasma coagulator application. Any remaining small exophytic residual tissues after this procedure were removed by optical forceps or by argon plasma coagulator. When indicated, the Dumon silicone stent was placed as previously described [15].

First presentation of all tracheal stenoses entered the study analysis. Follow-up data were restricted to 6 months after completion of the initial interventions.

Results

During the study period, 30 patients were recruited with tracheal stenosis. Twenty patients had benign tracheal stenosis and 10 patients had inoperable malignant tracheal stenosis. The benign and malignant tracheal stenoses were classified according to the classification system of central airway stenosis described by Freitag *et al.* [11] (Table 1).

Benign tracheal stenosis

The characteristics of benign tracheal stenoses as regards morphological classification, age, sex, and pathology of stenoses are shown in Table 2.

Among the 18 benign cases who needed intubation or tracheostomy, 60% were post-traumatic, 20% were required after major surgery, and 20% were necessary for medical causes (e.g. respiratory or acute heart failure). The mean duration of intubation or tracheostomy in days was 28 ± 18 days and the mean onset of tracheal stenosis after extubation or after tracheostomy closure was 21 ± 14 days.

For the treatment of simple stenoses an overall 17 bronchoscopic interventions were performed, with a mean of 2.83 per patient. One patient with granuloma needed two bronchoscopic interventions to radically treat it. The concentrical stenoses were treated by six bronchoscopic interventions with a mean of three per patient, and one stent implantation was needed. For the web-like stenosis nine bronchoscopic interventions were performed with a mean of three per patient (Fig. 1 and Table 3).

Table 1 Classification of benign and malignant tracheal stenosis

Stenoses	Benign stenosis	Malignant stenosis
Location[a]		
I	13	2
II	8	7
III	1	8
IV	–	1
Type		
Intraluminal	2	10
Extrinsic	–	8
Scar/stricture	15	–
Abrupt (web stenosis)	3	–
Degree of stenosis (%)		
26–50[b]	–	7
51–75[b]	16	2
76–90[b]	–	1
90 to complete obstruction	4	–

I, upper-third of the trachea; II, middle-third of the trachea; III, lower-third of the trachea; IV, right main bronchus. [a]Tracheal stenosis may be present in more than one location. [b]Decrease in cross-sectional area.

Table 2 Characteristic of benign tracheal stenosis

Characteristics	Simple (*n* = 6)	Complex (*n* = 14)	Total
Age (years)	46.5 ± 20	38 ± 24	
Sex (male/female)	3/3	9/5	12/8
Pathology			
PITS	5	12	17
Tracheostomy	–	1	1
Tracheal lipomatosis	–	1	1
Idiopathic	1	–	1

PITS, postintubation tracheal stenosis.

Table 3 Bronchoscopic treatment of benign stenosis

Types of stenosis	*N*	Interventions (*n*)	P/P	Type of intervention	Stent placement
Simple	6	17	2.83		–
Granuloma	1	2	2	EC + MD	–
Concentric	2	6	3	EC + MD+D	1
Web-like	3	9	3	EC + D	–
Complex	12	52	4.33	EC + MD + D	10

D, dilation; EC, electrocautery; MD, mechanical debridement; P/P, procedures per patient.

The 14 patients with complex stenosis were first evaluated for surgery: two immediately received a surgical tracheal resection with reanastamosis and the remaining 12 patients, not eligible for surgery because of their clinical/surgical contraindications [2], were addressed to IB therapy. The treatment of the 12 complex stenoses needed a total of 52 IBs with a mean of 4.33 per patient, with the application of 10 stents (Fig. 2 and Table 3). The stent was not intentionally removed in any of the patients during first 6 months.

The therapeutic effect of IB was good response (>50% increase in the caliber of the lumen) in all 14 cases in which complete recanalization was done (78%) and in four (22%) cases in which partial recanalization (up to two-thirds of the lumen) was performed.

Recurrence of stenosis was observed in the first 6 months after completion of initial interventions in one of each type of simple and complex stenoses. These two patients were subjected to a repeated therapeutic IB.

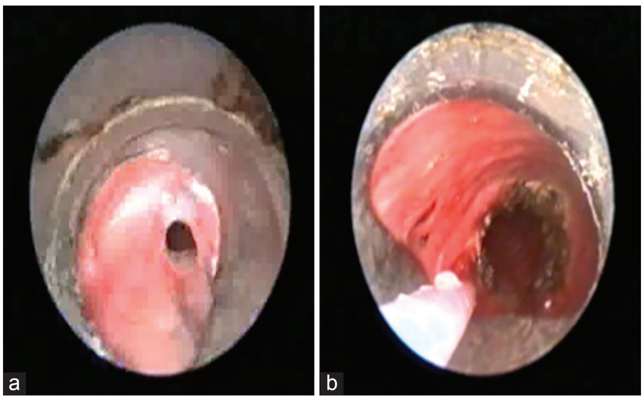
No intraprocedural complications or mortality were recorded. Postprocedural complications after completion of the initial interventions included the following: three stent migrations, which required either repositioning of the stent (n = 2) or placement of a stent of greater diameter (n = 1); retention of secretions in seven cases, which required bronchoscopic bronchial toilet and suction, together with appropriate medical treatment; and five excessive granulations tissue, which required argon plasma coagulation with or without electrocautery and endobronchial debridement. There was no recorded mortality during the first 6 months after completion of the initial interventions.

Malignant tracheal stenosis

The study included 10 patients with inoperable malignant tracheal stenoses. Their mean age was 48 ± 37 years; seven patients were male and three were female. The majority of lesions (70%) were present in the middle and lower-third of the trachea. The main carina was involved by the tumor in five patients, with extension to the right main bronchus in one patient. The length of stenosis and degree of stenosis varied between 2 and 5 cm and 30 and 80%, respectively. For the treatment of malignant tracheal stenoses an overall 39 bronchoscopic interventions were performed, with a mean of 3.9 per patient, with the application of eight stents (Fig. 3). All cases showed good therapeutic response (>50% increase in the caliber of the lumen) after IB treatment (Table 4).

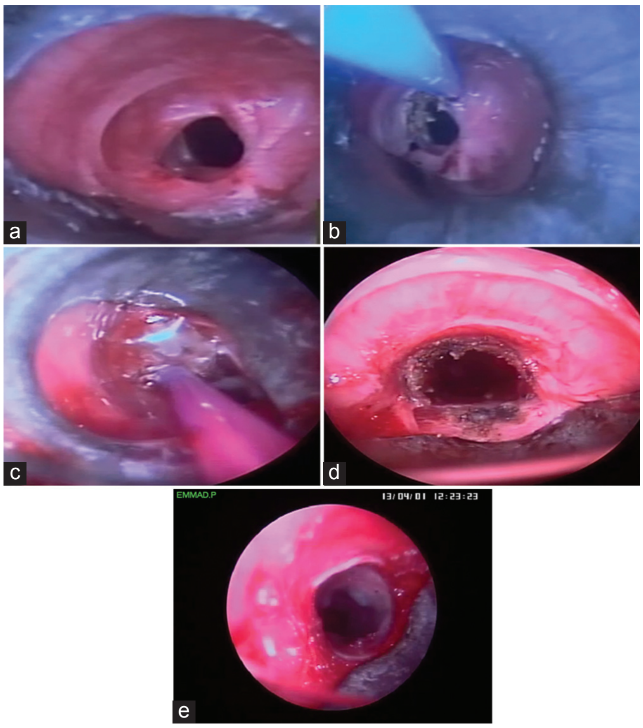
No intraprocedural complications or mortality were recorded. Postprocedural complications during the first 6 months after the initial intervention included one stent migration, which required placement of a stent of greater diameter, three cases of retention of secretions, among whom one had total lung collapse, which required another bronchoscopic session with bronchial toilet and suction, together with appropriate medical treatment, and three cases of tumor in-growth, which required argon plasma coagulation and endobronchial debridement. During the first 6 months after the initial intervention, two patients died of disease progression at 3 and 4 months, respectively.

Fig. 1



(a, b) Web-like stenosis before and after electrocautery-assisted mechanical dilatation with bougie with a successively larger rigid bronchoscope.

Fig. 2



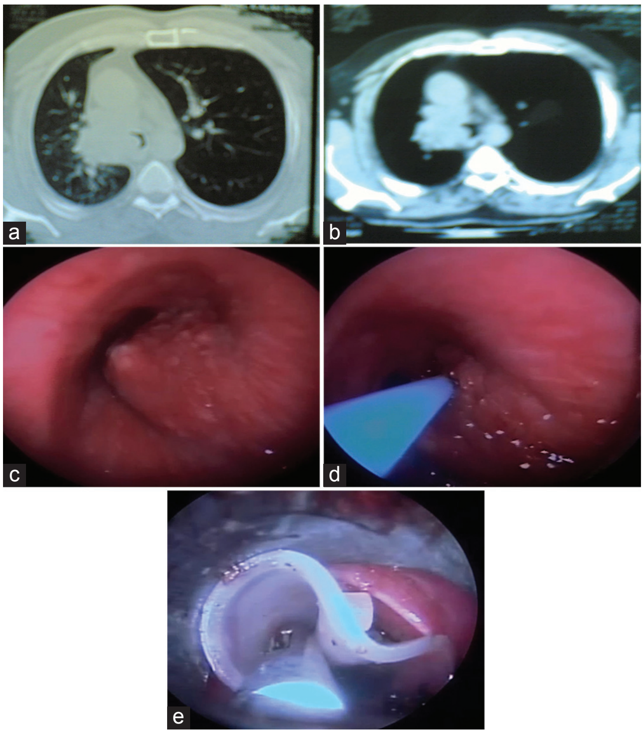
A case of complex benign tracheal stenosis (a) that has undergone electrocautery-assisted mechanical dilatation (b) with balloon bronchoplasty and bougie (c, d) with a successively larger rigid bronchoscope, followed by stent placement (e).

Discussion

Both malignant and benign diseases may cause focal narrowing of the trachea. Surgical resection for tracheal stenosis remains the gold standard management when feasible. With the development of interventional pulmonology in the last 20 years, definitive management of tracheal stenoses using minimally invasive endoscopic methods has become a possibility [3,16].

IB procedures could have a crucial role in the management of tracheal stenoses to relieve life-threatening symptoms and to manage patients not suitable for surgery or who experience failure after surgical airway resection [5].

Fig. 3



(a–e) A case of combined extrinsic and intraluminal malignant tracheal stenosis that has undergone a combination of electrocautery resection, mechanical debulking, dilation, and stent placement.

Current study data have shown good therapeutic response (>50% increase in the caliber of the lumen) after IB procedures in selected patients with benign and malignant tracheal stenosis with a relatively high rate of non-life-threatening stent-related complications that were easily managed.

The therapeutic algorithm of benign tracheal stenoses is controversial, and optimal treatment remains undefined. Surgical approach was considered the treatment of choice in some studies [8,17,18]. These studies considered IB management as an important supportive alternative therapy when surgery was not possible. Conversely, some bronchologists are convinced that most benign stenoses may be cured by IB [2,14,19]. In contrast, other bronchologists ascertain that IB does not preclude future surgery in most cases and may optimize potential surgical candidates [20]. A multidisciplinary management protocol integrating both operative and nonoperative bronchoscopic strategies was proposed by other authors [2,21,22]. We applied this multidisciplinary approach with collaboration between pulmonologists and surgeons to define the best method of management.

Postintubation tracheal stenosis was the most common cause (85%) of benign tracheal stenoses in the current study as well as in other similar studies [23,24]. Postintubation injury usually results from a pressure caused by the balloon or the tip of the endotracheal tube lying on the mucosa leading to mucosal ischemia followed by granulation tissue and fibrosis [25]. Using a low-pressure high-volume endotracheal tube cuff may decrease such injury. However, it is still a significant issue for a patient who needs long-term endotracheal

Table 4 Characteristics of the malignant tracheal stenosis patients

N	Age/sex	Etiology	Stenosis				Treatment	Therapeutic response
			Location	Type	Length (cm)	Degree (%)		
1	11/F	Spindle cell carcinoma	II + III	Intraluminal	3	40	MD + EC	GR
2	58/M	Squamous cell carcinoma	II + III	Intraluminal + extrinsic	4	50	MD + EC + D + S	GR
3	65/F	Papillary carcinoma of thyroid	I	Intraluminal + extrinsic	2	50	MD + EC + D + S	GR
4	85/M	Papillary carcinoma of thyroid	I	Intraluminal + extrinsic	2	80	MD + EC + D + S	GR
5	66/M	Squamous cell carcinoma	II + III	Intraluminal + extrinsic	4	70	MD + EC + D + S	GR
6	42/M	Adenocarcinoma	II + III	Intraluminal + extrinsic	4	70	MD + EC + D + S	GR
7	28/M	Malignant pleomorphic adenoma	II + III	Intraluminal + extrinsic	4	40	MD + EC + D + S	GR
8	48/M	Squamous cell carcinoma	II + III	Intraluminal + extrinsic	3	30	MD + EC + D + S	GR
9	59/M	Squamous cell carcinoma	III + IV	Intraluminal + extrinsic	5	30	MD + EC + D + S	GR
10	33/F	Adenoid cystic carcinoma	II + III	Intraluminal	3	50	MD + EC + APC	GR

I, upper-third of the trachea; II, middle-third of the trachea; III, lower-third of the trachea; IV, right main bronchus; APC, argon plasma coagulation; D, dilation; EC, electrocautery; F, female; GR, good response; M, male; MD, mechanical debridement; S, stent placement.

intubation, as experienced in the present study [26]. Among our study candidates, the mean duration of intubation was prolonged up to 28 ± 18 days. Upon removal of the tube, the transmural weakness in the trachea undergoes cicatricial healing, which results in a tight circumferential stenosis that manifests 3–6 weeks after tube removal [3]. This matched with our finding that the mean onset of tracheal stenosis after extubation was 21 ± 14 days.

We analyzed the mean number of treatments necessary to cure each subgroup of stenoses. For the web-like stenosis, a mean of three procedures per patient was needed. Similarly, Mehta *et al.* [14] treated endoscopically web-like stenoses, obtaining good results after one to three therapeutic sessions per patient. The concentric stenoses required a mean of three procedures per patient and stent placement in one case. Galluccio *et al.* [2] reported that concentric stenoses necessitated 2.35 procedures per patient and that stent placement was the most common in this subgroup of simple stenoses.

In complex lesions, we followed the strategy of Galluccio *et al.* [2] for complex stenoses in considering surgery as the first option and performing accurate selection of cases not eligible for surgery for IB. In the current study, complex stenosis required more number of procedures (4.33 per patient) to cure and stents were used in the majority (83%) of patients.

Tracheal neoplasms account for less than 1% of all malignancies. Despite their low incidence, these tumors represent a potentially lethal obstructive phenomenon [17]. There was predominance of the involvement of the lower-third of the trachea by a malignant process in the present study as this part is usually additively liable to direct invasion of the trachea by the adjacent lung or thyroid carcinomas [28].

There is no randomized controlled trial on the use of tracheal intervention in malignant disease because of the ethical challenges in patients requiring life-saving intervention or palliation [20]. Similar to other previous reports [29,30], we applied various therapeutic bronchoscopic modalities, including airway stenting, to achieve successful palliation of airway obstruction and relieve any respiratory distress in inoperable malignant tracheal stenosis. The choice of interventional procedures in the current study as well as in previous studies depends on the type of lesion (intrinsic, extrinsic, or combined) [29,30]. Mechanical core-out of tumor and endobronchial electrocautery applied for endoluminal tumor component and dilatation and airway stenting were carried out in extraluminal compression.

In two of our cases, IB and airway stenting were applied to relieve tracheal extrinsic compression and tumor in-growth secondary to malignant thyroid disease. IB procedures including tracheal endoprosthesis (stents) may provide longstanding airway patency, as has been reported in some case series of tracheal compression or invasion by thyroid cancer [31,32].

Among different airway stents available, the Dumon silicone stent is the most widely used [30,33]. We used the Dumon stent in the current study for the following benefits: it is available in different sizes, lengths, and configurations; it can be easily placed, removed, and repositioned; it has external studs to prevent migration; it is relatively inexpensive; and most importantly it can be applied in both malignant and benign tracheal stenoses.

Stent migration occurred in 27 and 12% of benign and malignant stenoses, respectively, and stent obstruction by mucus secretions occurred in 64 and 37% of benign and malignant stenoses, respectively. Granuloma formation occurred in 45% of benign stenoses. Tumor in-growth occurred in 37% of malignant stenoses. However, none of the stent-related complications were life threatening and all were reversibly managed. Comparable to our study results, stent-related complications occur more frequently in patients with benign causes of airway obstruction compared with those with malignancies [34,35]. This relatively high rate of stent-related complications has been previously reported in series of silicone stent insertion in patients with benign expiratory central airway collapse; these included 26 stent-related complications (12 mucus plugs, eight migrations, and six granulation tissues) seen in 10 of the 12 patients studied [36]. Continuous friction between silicone stents and the airway wall of patients with expiratory central airway collapse resulting from tracheobronchomalacia (as in patients with complex tracheal stenosis in our study population) increases the risk for stent migration and granulation tissue formation [36].

The higher frequency of stent migration in the current study may be because the majority of benign stenoses were in the upper one-third of the trachea (13 occasions), which has high mobility because of its close proximity to highly mobile vocal cords. This can be reduced by the use of a dedicated hourglass silicone stent [37] or by external fixation [38,39].

The higher rates of granuloma formation in our series could be also explained by burrs present at the edge of the stent after cutting it to shorten its length when the required length is not available. This cutting abolishes one of the advantages of Dumon stents – that is, its rims are polished to remove burrs to reduce the risk of granuloma formation [34]. The excessive mucus secretions recorded in our patients could be because silicone stents interfere with the mucociliary mechanisms and increase the risk of mucous adherence [40], in addition to negligence of good hydration and saline nebulization by some of the patients, which lead to thickness of secretions and difficulty in expectoration.

The duration that a stent should remain in place is not known and likely depends on the clinical scenario. Patients with malignant stenosis often die with the stent in place [25]. Benign stenosis may require long-term placement, from 12 to 18 months, after insertion because the inflammatory lesion would probably have stabilized, although one should be alert to the possible recurrence of stenosis or the emergence of malacia [23,24,41].

The study has certain limitations. The main limitation of this study is the small number of cases and short duration of follow-up. Although the current study focused on the initial management of tracheal stenosis, extending the follow-up period from 6 months to 12 or 18 months would have helped estimate the final outcome of our interventions through estimation of median survival in malignant cases and evaluation of restenosis especially after removal of stents in benign cases. Geographic considerations of the patients and advanced disease of some patients limited the practicality of returning for follow-up care, as previously experienced by Korraa *et al.* [15].

In conclusion, IB procedures applied by pulmonologists are a useful option in the management of simple benign and inoperable complex benign and malignant tracheal stenoses and are associated with a relatively high rate of non-life-threatening stent-related adverse events that can be easily managed. Further long-term prospective studies are needed to address the ideal stent for such patients and to better determine the place of IB in the therapeutic algorithm of management of tracheal stenoses.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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