Balloon Dilation Techniques

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Contents

Abstract

Airway stenosis has many causes and can cause significant symptoms in some patients. Once identified, many interventions are available. A simple, safe, direct, inexpensive, repeatable, and rapidly effective option is balloon dilation, also called balloon bronchoplasty. A variety of different balloon options are available, but all can be readily performed with the aid of bronchoscopy. Attention to the airway and experience combined with appropriate application of readily available equipment can lead to immediate symptomatic improvement. Dilation alone may prove sufficient but can also be combined with other modalities such as stenting, laser, other thermal therapies, or local medications. At the least, dilation can improve the airway sufficiently to allow the time and stability to move on to more invasive techniques should they be required.

Keywords

Balloon dilation · Laryngeal mask airway · Airway patency · Rigid bronchoscope · Airway stenosis

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1 Introduction

Airway stenosis has many causes and has been treated in many ways. Various classification systems have been proposed [1]. The most basic approach is the bronchoscopic dilation of the area of narrowing. While this can be accomplished by various mechanisms, a simple, direct, and minimally traumatic approach is the use of balloons for dilation or balloon bronchoplasty. This chapter reviews the patient presentations, technique and equipment, and outcomes expected.

2 Patient Characteristics

Airway stenosis can be idiopathic or secondary to an underlying disease process (Table 1). Patients typically present with dyspnea and may have a focal wheeze on exam. Patients are often misdiagnosed with asthma or other causes of dyspnea, and the diagnosis is often delayed. Return of initial symptoms, which may be slowly progressive in some instances, may be a sign of recurrent stenosis in those with prior treatment. A high index of suspicion is required, and this may be assisted by ancillary studies such as imaging (CT with reconstruction better than standard radiographs or tomograms), flow volume loops, and clinical exam.

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However, the best method for evaluating the presence, degree, and extent of an airway stenosis is direct visualization via bronchoscopy. Bronchoscopy can assist in establishing the underlying etiology and be therapeutic. Both flexible and rigid approaches apply and will depend on planned intervention, operator and institution experience, and airway stability needs.

Table 1 Causes of airway stenosis

Intubation
Surgical anastomotic (i.e., sleeve resection, transplant)
Infectious (i.e., tuberculosis)
Inflammatory (i.e., sarcoidosis, eosinophilic granulomatosis with polyangiitis, and relapsing polychondritis)
Malignant
Idiopathic
Radiation
Inhalational injury
Trauma

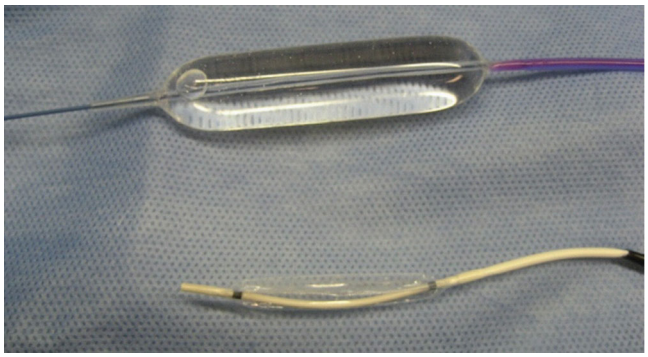

Fig. 1 Examples of nonconformal balloons. Above: dilated with saline and over a wire. Below: a different deflated balloon with radiopaque markers at balloon ends. (Boston Scientific, Marlborough, MA)

3 Balloon Characteristics

The main characteristic of balloons (Fig. 1) used should be that they are of sufficient length to straddle the stenosis, are of a diameter sufficient to dilate the stenosis, are nonconformal, and generate adequate pressure for dilation. Pressure is generated by a dedicated syringe or inflation device allowing the filling of the balloon with solution (water or saline and may be radiopaque) and measurement of pressure (Fig. 2). As for length, the balloon should ideally be able to center over the stenosis with sufficient overlap, approximately $\geq$1 cm on either side of the stenosis, and minimize funneling while inflated. The initial diameter should be small enough to start with a gentle dilation and large enough to dilate beyond the initial diameter of the stenosis. Serial larger diameter balloons may be needed with the largest chosen being several millimeters larger than the desired final diameter of the airway. These serial dilations may be accomplished by several different balloons of unique diameters or using balloons that have several inherent diameters depending on inflation pressure. A nonconformal balloon is one that dilates to the desired configuration and diameter without molding to the shape of the stenosis. The pressure required for dilation is balloon specific and relates to that needed to achieve the diameter desired.

4 Technique

As with all patients, attention to airway stability is paramount. Appropriate monitoring and sedation are required. Patients typically require some form of established airway which can be a laryngeal mask airway, endotracheal tube, or rigid bronchoscope depending on location, experience, and planned intervention. Ideally, the practitioner is skilled in all

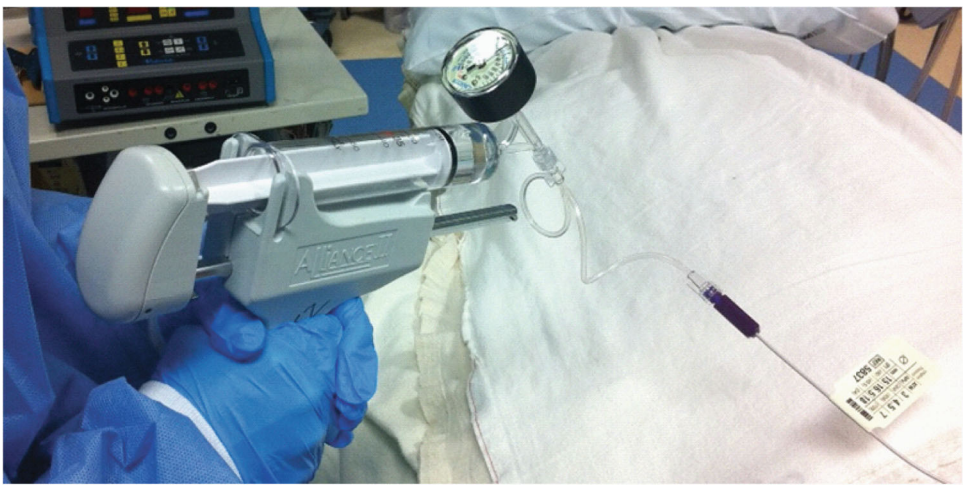

Fig. 2 Example of an inflation syringe system with built-in pressure gauge. (Boston Scientific, Watertown, MA)

of these options so the approach chosen can be patient specific. With the exception of a very distal stenosis, patient comfort during dilation necessitates a deep degree of sedation or anesthesia. That is, the typical procedure is done with the assistance of anesthesia support and is preferred with all.

Once the degree and type of stenosis is determined, the approach is chosen. Patients appropriate for balloon bronchoplasty may have this as their only technique used or may have this done in conjunction with other interventions such as airway laser, other thermal therapies, local medications, or stenting. In fact, stent deployment or seating may be assisted by the use of a balloon. While there are a number of roles for airway balloons (Table 2), the scope of this chapter focuses on balloon dilation.

Many balloons are available on the market for use. Balloons specifically designed for airway use as well as others designed for vascular or gastroenterologic uses have been employed. Balloons for gastroenterologic or bronchosocpic use are often less expensive than those developed for vascular use. Although the pictures in this chapter show product from one company (Boston Scientific, Marlborough, MA), this is not an endorsement of one product set or company. Multiple high-quality options are available from different companies. Some fit through the working channels of flexible bronchoscopes (Fig. 3), while others require placement via a larger channel either directly or over a wire (Fig. 4). The larger channel may be a rigid bronchoscope or other airway. The independent passage of a wire and then balloon with image guidance to an area of stenosis and subsequent dilation without bronchoscopic guidance should be discouraged.

Once an airway is established, the bronchoscope is advanced to the area of stenosis. Depending on the balloon and scope used, the balloon is advanced through the working channel of the bronchoscope or over a wire and fed across the stenosis. Bronchoscopic observation of positioning and dilation is ideal. If placed over a wire or directly via a rigid bronchoscope, the balloon can be observed using a telescope or sufficiently small bronchoscope. While fluoroscopic imaging can also be used, it is rarely necessary as Mayse has demonstrated [2]. Once positioned straddling the lesion, the balloon is inflated to the desired diameter for 1 min and then deflated. Adequate preoxygenation should be established prior to dilation. The 1 min interval is typically repeated at the chosen diameter for a total of three dilations [3]. If limited resistance is encountered, the next larger dilation diameter can proceed before three dilations at a particular level are reached. Different dilation times have been used, but none have been analyzed for superiority. One minute is a reasonable middle ground with the time interrupted if not tolerated. The balloon is then deflated and the airway observed for significant finding such as tear or bleeding.

Table 2 Other balloon uses

Stent deployment
Tamponade of bleeding
Deliberate airway occlusion
Foreign body removal

5 Outcomes

Initial outcomes are excellent with long-term efficacy often requiring repeat procedures (Fig. 5).

Fig. 3 Example of a balloon catheter passed via the working channel of a flexible bronchoscope which is itself inserted into the airway via a laryngeal mask airway

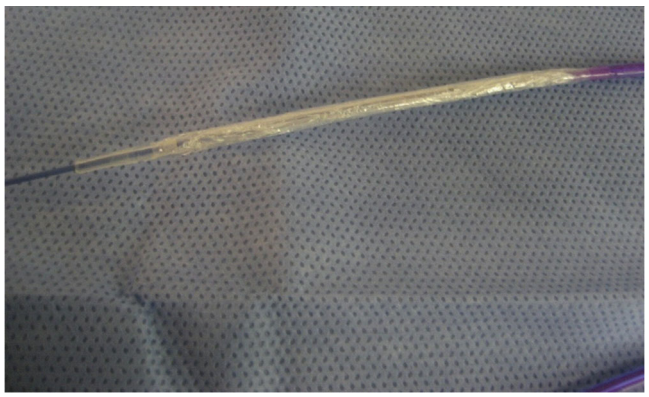

Fig. 4 Deflated balloon in its initial state when removed from its package shown with a wire. (Boston Scientific, Marlborough, MA)

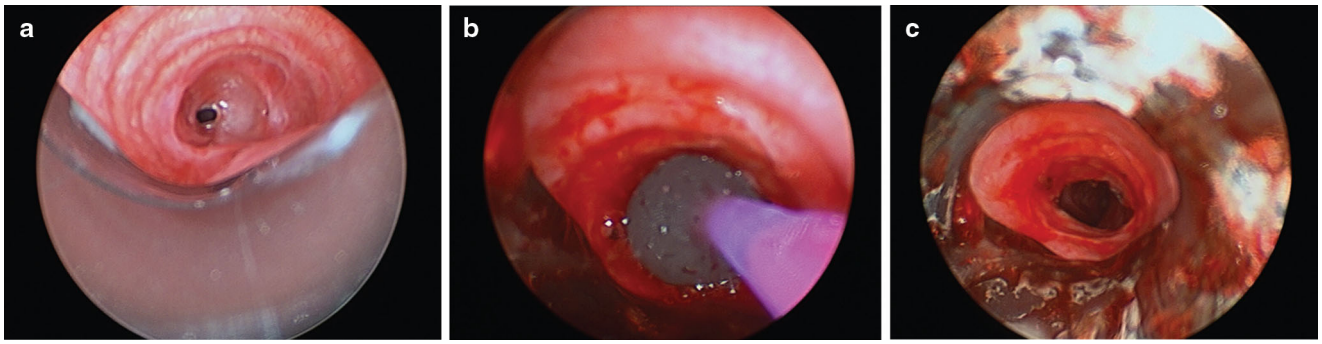

Fig. 5 Tracheal stenosis: Before (**a**); during (**b**); and after (**c**) balloon dilation

In a small series, Sheski and his colleague had success with an initial procedure in 10 of 14 patients [4]. Adjunct procedures, such as stenting or cryotherapy, and multiple procedures—up to 30 in an extreme case—were required in others. Hebra in a series in children showed a 90% initial and 54% long-term success in tracheal dilation with an average of four sessions [5]. Ferretti, using one to five repeat sessions, had a 68% initial success and a 56% long-term success [6]. The lower initial success might be explained by the dilation of some malacia patients in this group. The optimal number of balloon dilations for therapeutic efficacy is not well elucidated and may vary, though a study of Chinese patients with nonmalignant central airway stenosis has suggested lack of incremental improvement in efficacy beyond six treatment sessions [7]. In malignant stenoses, a larger series reported by Hautmann and colleagues showed improved diameter in 79% of stenoses with one procedure, reaching the intended outcome of symptom relief or stenting [8]. Stenting in this case served as an adjunct to other interventions or to lead to better tolerance of other interventions. In addition to symptom relief, there have been trend of improved lung function noted by FEV1 and FEV/FVC following dilation both immediately postprocedure and on follow-up at 1 month [9]. Stenosis due to inflammatory state such as due to underlying autoimmune processes or rejection in transplant patients may be more refractory or have less treatment response, which may prompt earlier consideration of adjunctive interventions in lieu of repeat balloon dilations.

Complications are rare and typically mild and self-limited (Table 3). Most interestingly, Kim and colleagues showed that for benign stenosis patients, laceration of the airway was associated with longer-term airway patency [10]. They found that approximately half of dilations led to some degree of airway laceration with the vast majority of these superficial. Few were deep, and none were through and through. Some tears had associated mild chest pain, blood-tinged sputum, or even pneumomediastinum, but these all resolved spontaneously at 24 h. The tears themselves healed spontaneously in 1 month when superficial and up to 9 months when deep. All were managed conservatively. Patient with tears had an average of 24 months of patency as compared to 4 months for those without a tear. Importantly, the main etiology of these stenoses was tuberculosis, and the responsiveness or stiffness of the tissue in post tuberculosis stenosis may not be generalizable to all causes.

Table 3 Potential complications of balloon bronchoplasty

Airway laceration
Bleeding
Pneumothorax
Pneumomediastinum
Mediastinitis
Chest pain

Lung transplantation represents a common cause of stenosis and indication for balloon dilation, often in association with stenting. Stenting may be reserved for the more difficult airway, but the approach likely varies with the institution. Abi-Jaoudeh and colleagues found that they used stents in somewhat more than half of their patients with posttransplant stenosis, and these patients had better symptomatic improvement, longer airway patency, better FEV1, and longer survival [11]. De Gracia also found good initial results in a posttransplant stenosis patient population with subsequent procedures required for an average of four dilation interventions and half ultimately requiring stents [12]. While balloon dilations often have transient relief in this population, there is preference to avoid stents due to the associated risk factors in lung transplant recipients and only those that require frequent balloon dilations of more than two per month are recommended for consideration of stent placement [13].

6 Conclusion

Balloon bronchoplasty is a safe, simple, quick, effective, and repeatable method to obtain greater airway patency. Symptomatic impact is immediate in most patients. The equipment is readily available, and supplies are inexpensive. The intervention may be all that is required or can be used as an

adjunct to other therapies. If not sufficient, it can at least allow for time to plan for the next levels of intervention.

Competing Interest Declaration The author(s) has no competing interests to declare that are relevant to the content of this manuscript.

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