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Balloon Bronchoplasty for the Treatment of Bronchial Stenosis After Lung Transplantation: A Single-Center 10-Year Experience

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Objective: To assess the safety and efficacy of balloon dilatation under dual guidance using fluoroscopy and bronchoscopy for treating bronchial stenosis following lung transplantation (LT), and to elucidate the factors associated with patency after the procedure.

Materials and Methods: From September, 2012, to April, 2021, 50 patients (mean age ± standard deviation, 54.4 ± 12.2 years) with bronchial stenosis among 361 recipients of LT were retrospectively analyzed. The safety of balloon dilatation was assessed by evaluating procedure-related complications. Efficacy was assessed by evaluating the technical success, primary patency, and secondary patency. Primary and secondary cumulative patency rates were calculated using the Kaplan-Meier method. The factors associated with patency after the procedure were evaluated using multivariable Cox hazard proportional regression analysis.

Results: In total, 65 bronchi were treated with balloon dilatation in 50 patients. The total number of treatment sessions was 277 and the technical success rate was 99.3% (275/277 sessions). No major procedure-related complications were noted. During the mean follow-up period of 34.6 ± 30.8 months, primary patency was achieved in 12 of 65 bronchi (18.5%). However, the patency rate improved to 76.9% (50 of 65 bronchi) after repeated balloon dilatation (secondary patency). The 6-month, 1-year, 3-year, and 5-year secondary patency rates were 95.4%, 90.8%, 83.1%, and 78.5%, respectively. The presence of clinical symptoms was a significant prognostic factor associated with reduced primary patency (adjusted hazard ratio [HR], 0.465; 95% confidence interval [CI], 0.220–0.987). Early-stage treatment ≤ 6 months (adjusted HR, 3.588; 95% CI, 1.093–11.780) and prolonged balloon dilatation > 5 min (adjusted HR, 3.285; 95% CI, 1.018–10.598) were associated with significantly higher secondary patency.

Conclusion: Repeated balloon dilatation was determined to be safe and effective for treating bronchial stenosis following LT. Early-stage treatment and prolonged balloon dilatation could significantly promote long-term patency.

Keywords: Bronchial stenosis; Balloon dilatation; Lung transplantation; Early-stage treatment; Prolonged dilatation

INTRODUCTION

Lung transplantation (LT) is the optimal treatment option for end-stage pulmonary diseases and patients' survival has improved with the development of immunosuppression and surgical techniques [1,2]. However, airway complications, which affect 7%–40% of patients, remain common and serious events following LT [3-6]. Among the various airway complications, airway stenosis is the most prevalent, with incidence rates varying from 1.6% to 24.4%, commonly developing 2–4 months after surgery [7,8].

Bronchial stenosis is primarily attributed to ischemia of the donor bronchus; however, anastomotic surgical techniques, infection, and reperfusion edema are known risk factors for bronchial stenosis. Stenosis usually occurs at the anastomotic site or distal sites of the lobar, segmental, and subsegmental

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bronchi. Bronchial stenosis can cause dyspnea, cough, wheezing, and obstructive pneumonia and may eventually lead to significant morbidity and mortality due to pulmonary infection, obstructive airway disease, and allograft dysfunction [5-9].

Balloon bronchoplasty under bronchoscopic guidance is the first-line treatment option for bronchial stenosis [8]. However, bronchoscopy-guided procedures are not technically feasible when the bronchial strictures are too tight for the bronchoscope to pass through. Therefore, dual guidance with fluoroscopy and bronchoscopy may be an effective alternative. However, information on the benefits of using the dual approach is limited [10-12]. Stent placement is also a treatment option for patients with severe bronchial stenosis refractory to balloon bronchoplasty [8]. Nonetheless, the use of stents for bronchial stenosis after LT remains controversial because of the high complication rate [13,14].

Therefore, this study aimed to assess the safety and efficacy of balloon dilatation under dual guidance using fluoroscopy and bronchoscopy in patients with bronchial stenosis after LT, and to elucidate the factors associated with bronchial patency after the procedure.

MATERIALS AND METHODS

Study Population

This single-center retrospective study was approved by our institutional review board (approval number: 4-2022-1077), which waived the requirement for informed consent. Of the 361 consecutive patients who underwent LT between September, 2012, and April, 2021, 106 (29.4%) developed bronchial stenosis. Among them, those who were treated for bronchial stenosis using balloon dilatation were eligible for inclusion in this study. The indications for bronchial intervention were as follows: 1) luminal narrowing ≥ 50% observed on chest computed tomography (CT) with three-dimensional reconstruction with or without clinical symptoms; 2) lumen was too narrow to pass through the stricture site using bronchoscope (6 mm in diameter), with or without symptoms; and 3) clinical symptoms including sputum, wheezing, dyspnea, and recurrent obstructive pneumonia, even if bronchial narrowing was < 50%. Patients with luminal narrowing < 50% without symptoms or acceptable for bronchoscope passage and those who were suspected of having malignancy were excluded. Bronchial narrowing ≥ 50% was determined to be severe and a treatment criterion based on previous studies [15-18]. Finally, 50 patients (65 bronchi) who were treated with bronchial balloon dilatation were included in this study (Fig. 1).

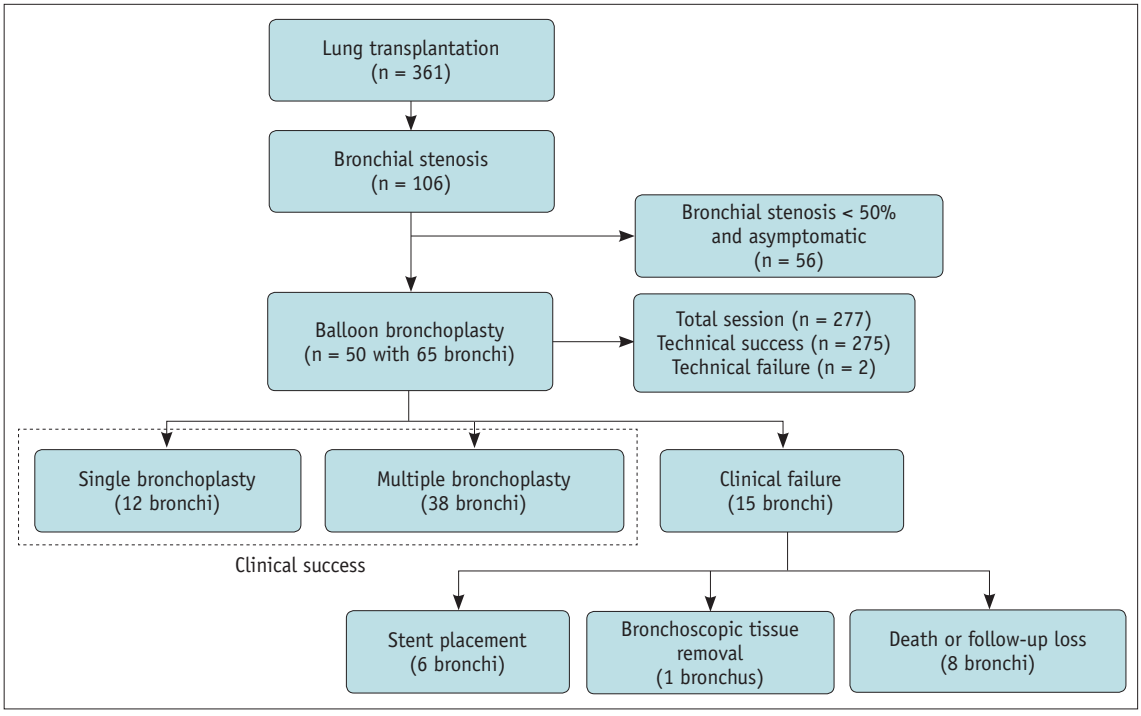

Fig. 1. Flow diagram of the study population.

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Bronchial Balloon Dilatation Procedure

Bronchial balloon dilatation was performed under dual guidance using both fluoroscopy and bronchoscopy. Routine intravenous administration of sedatives (0.05 mg/kg midazolam) was performed with oxygen saturation monitoring, and the pharynx and larynx were topically anesthetized using a 10% lidocaine aerosol spray. After bronchoscope insertion and bronchial stricture site identification by a pneumatologist, a bronchogram was obtained to identify the characteristics of the lesion and the proximal and distal normal bronchi using diluted water-soluble contrast material (Visipaque, GE Health). A 0.035-inch hydrophilic guidewire (Terumo) was passed through the side hole of the bronchoscope and positioned distal to the stricture site. The bronchoscope was removed, leaving the guidewire in place. Under fluoroscopic guidance, an angioplasty balloon catheter (Mustang, Boston Scientific) was passed over the guidewire and correctly positioned across the stricture site. Balloon insufflation was manually performed by one of the three interventional radiologists (with 7, 9, and 13 years of experience) until the balloon waist disappeared. The endpoint of balloon dilatation was residual stenosis < 10% on the bronchogram immediately after the procedure (Fig. 2). When oxygen saturation was below 90%, the balloon was deflated. After the saturation had recovered by > 95%, the balloon was reinflated. Balloons with diameters of 7–14 mm, oversized by approximately 10%–20% of the bronchus diameter, were used to achieve bronchial dilatation. Bronchoscopy was performed immediately after balloon dilatation to evaluate the degree of dilatation of the lesion. If suboptimal dilatation was observed, a repeat balloon dilatation was performed. A session was defined as any procedure performed in a single day. The total balloon dilatation time was measured in each patient by summing the balloon dilation times in a session.

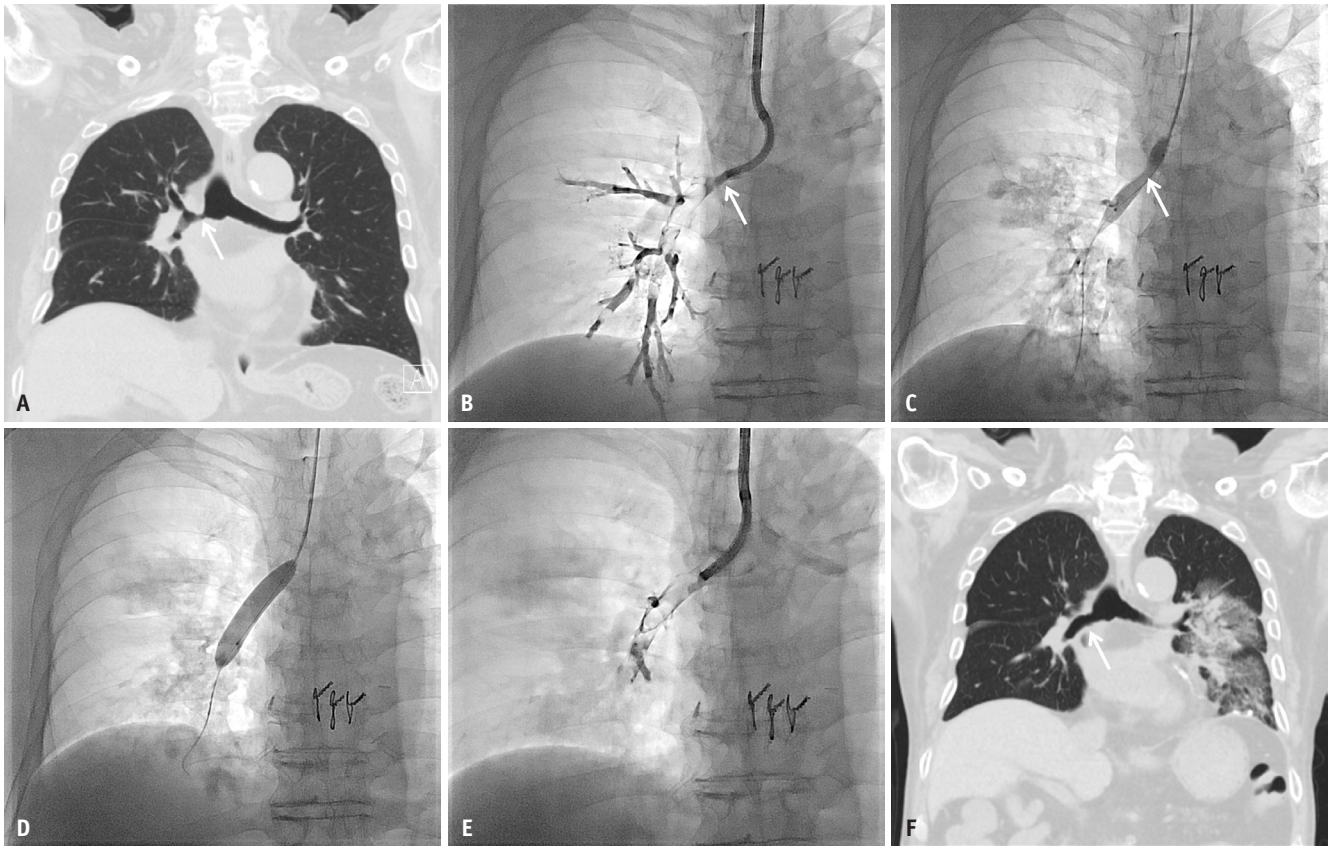

Fig. 2. A case of a 64-year-old male suffering from dyspnea after lung transplantation. **A:** Pre-procedure chest computed tomography (CT) shows stenosis of the right main bronchus (RMB, arrow). **B:** Bronchogram was obtained before balloon dilatation, and the RMB is significantly narrowed (arrow). **C, D:** Bronchial dilatation with 12 mm diameter balloon was performed until the balloon waist (arrow) disappeared. **E:** Bronchogram obtained immediately after balloon dilatation shows marked improvement of bronchial stenosis. **F:** Follow-up chest CT shows improvement of stenosis at the RMB (arrow). The ground glass opacity and consolidation observed at the left lung was due to viral pneumonia, unrelated to the procedure.

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Definitions

Technical success was defined as the successful passage of a balloon catheter through the stenosis with less than 10% residual stenosis at the time of balloon dilatation. Clinical success was defined as achievement of primary or secondary patency after the procedure. Primary patency was defined as maintaining luminal narrowing < 50%, acceptable for bronchoscope passage, and improvement of symptoms experienced before balloon dilatation, after one session of balloon dilatation without evidence of recurrence during the follow-up period or patient death. Secondary patency was defined as maintaining luminal narrowing < 50%, acceptable for bronchoscope passage, improvement of symptoms after one or repeated balloon dilatation, and no evidence of further recurrence without alternative treatment, such as stent placement or surgery. Primary and secondary cumulative patency rates after the procedure were also calculated. Complications related to balloon dilatation were classified as major or minor. Major complications were defined as events that caused additional hospitalization, permanent adverse sequelae, or death [19]. All other events were defined as minor complications.

Data Analysis and Follow-Up

Before the procedure, the characteristics of bronchial stenosis, including the stenosis site, length, and diameter, were measured by a radiologist on chest CT with three-dimensional reconstruction. Prolonged balloon dilatation was defined as a dilating time > 5 min to assess the association between the patency rate and balloon dilation time. Furthermore, the interval period from LT to initial balloon dilatation, which was less than 6 months, was determined to be the early stage, and the period beyond 6 months was determined to be the late stage.

For follow-up after the procedure, the patients underwent scheduled chest radiography, CT, or bronchoscopy immediately, 1–3 days, and 1 month after the procedure, and at 1–3 months intervals thereafter. Patients were asked to visit the hospital at any time if symptoms recurred. Patients with recurrent clinical symptoms, bronchial re-stenosis ≥ 50% on follow-up CT, or unacceptable bronchoscope passage underwent repeat balloon dilation. Other alternative treatments (for example, stent placement or tissue removal) were performed for refractory stenosis, which was defined as short-term recurrence of clinical symptoms or bronchial stenosis > 50% on follow-up CT or bronchoscopy within 1 month of repeat balloon dilatation.

Statistical Analysis

Continuous variables are expressed as mean ± standard deviation or median and interquartile range (IQR). Continuous variables were compared using independent *t*-tests, whereas categorical variables were compared using Chi-squared or Fisher's exact tests. The Kaplan–Meier method was used to calculate primary and secondary cumulative patency rates after the procedure, and the log-rank test was used to compare differences in patency according to the factors. Univariable and multivariable Cox proportional hazard regression analyses were performed for the 65 bronchi treated to identify the risk factors associated with primary and secondary patency. Factors associated with primary and secondary patency ($P < 0.2$) in the univariable analysis were included in the multivariable analysis. Outcomes are expressed as hazard ratios (HRs) and 95% confidence intervals (CIs). All statistical analyses were performed using SPSS 25.0 for Windows (SPSS Inc., IBM) and $P < 0.05$ was considered statistically significant.

RESULTS

Baseline Characteristics of Patients and Bronchi

The detailed patient characteristics and procedures are summarized in Table 1. A total of 65 bronchi were treated using balloon dilatation in 50 patients (mean age, 54.4 ± 12.2 years). Thirty-five patients (70%) had obstructive symptoms, including dyspnea (n = 27), sputum (n = 6), and obstructive pneumonia (n = 2). The remaining 15 patients (30%) were asymptomatic, but bronchial luminal narrowing ≥ 50% was observed on chest CT or bronchoscopy before the procedure. Bronchial stenosis was located in the main bronchus in 36 (36/65, 55.4%) patients and lobar or segmental bronchi in 29 (29/65, 44.6%) patients. The mean diameter and length of stenosis were 2.5 ± 1.3 mm and 9.3 ± 4.9 mm, respectively. There was no significant difference in the degree of bronchial stenosis between the patients with and without clinical symptoms (63.0% vs. 63.8%, $P = 0.849$). Of the 65 bronchi, 42 (64.6%) were treated with balloon dilatation in the early stage and 23 bronchi (35.4%) in the late stage. The total number of sessions was 277 (median, 4.0 per patient; IQR, 2–6). The mean diameter of the balloon was 10.2 ± 1.5 mm and the mean time of balloon dilatation was 8.2 ± 2.8 min.

Technical and Clinical Outcomes

Technical success was achieved in 275 of the 277 sessions

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Table 1. Patients' Baseline Characteristics and Procedure Details

Characteristic	Values
No. of patients	50
Age, yr	
Mean ± SD	54.4 ± 12.2
Median (IQR)	57.0 (44–65)
Sex	
Male	30 (60.0)
Female	20 (40.0)
Symptoms	
Dyspnea	27 (54.0)
Sputum	6 (12.0)
Obstructive pneumonia	2 (4.0)
Asymptomatic	15 (30.0)
No. of treated bronchus	65
Level of stenosis	
Right main bronchus	3 (4.6)
Left main bronchus	7 (10.8)
Right bronchus intermedius	26 (40.0)
Right lobar and segmental bronchus	11 (16.9)
Left lobar and segmental bronchus	18 (27.7)
Site of stenosis†	
Anastomotic	10 (15.4)
Non-anastomotic	55 (84.6)
Diameter of stenosis, mm	
Mean ± SD	2.5 ± 1.3
Median (IQR)	2.3 (1.4–3.1)
Length of stenosis, mm	
Mean ± SD	9.3 ± 4.9
Median (IQR)	7.9 (4.9–13.0)
Stage*	
Early stage ≤ 6 months	42 (64.6)
Late stage > 6 months	23 (35.4)
No. of procedure session	
Total	277
Per patient, median (IQR)	4.0 (2–6)
Mean diameter ± SD of balloon, mm	10.2 ± 1.5
Mean time ± SD of balloon dilatation, min	8.2 ± 2.8

Data are number of patients or bronchi with percentage in parentheses, unless specified otherwise. *Interval period from lung transplantation to initial bronchial balloon dilatation, †Bronchial anastomosis site during lung transplantation. SD = standard deviation, IQR = interquartile range

(99.3%). Two technical failures occurred in one patient because guidewire passage failed due to total occlusion of the bronchus. In this patient, the occluded segment was traversed with the backend of the guidewire in the next session and successful balloon dilatation was performed. No major procedure-related complications were noted. There was a spot of bleeding on bronchoscopy immediately after the procedure in 137 of 277 sessions (49.5%), but these spontaneously resolved and were considered minor complications.

During the mean follow-up periods of 34.6 ± 30.8 months (median, 28.8 months; IQR, 6.8–59.6 months), primary patency was achieved in 12 of 65 bronchi (18.5%). The median primary patency period was 25.6 months (IQR, 7.2–46.2 months). The 6-month, 1-year, 3-year, and 5-year primary patency rates were 87.7%, 78.5%, 55.4%, and 26.2%, respectively. Repeated bronchial balloon dilatation (2–12 sessions; median, 4 sessions) was performed for 53 patients with recurrent bronchial stenoses. Secondary patency was achieved in 50 of the 65 bronchi (76.9%) after initial balloon dilatation (n = 12) and repeated balloon dilatation (n = 38). The 6-month, 1-year, 3-year, and 5-year secondary patency rates were 95.4%, 90.8%, 83.1%, and 78.5%, respectively. The log-rank test showed that the primary patency rates were significantly higher in the group without clinical symptoms than in the group with clinical symptoms (P = 0.013). The secondary patency rates were significantly greater in the group with prolonged balloon dilatation > 5 min (P = 0.010) and early-stage treatment (P = 0.048) than in the group with balloon dilatation ≤ 5 min and late-stage treatment, respectively (Fig. 3).

Of the lesions that were refractory to balloon dilatation (n = 15), six were managed with silicone stent placement. In four of them, the stents were removed at 13, 16, 21, and 22 months after placement. The patency of these four lesions was maintained during the follow-up period. The stents in the two remaining lesions could not be removed because the patient died due to recurrent pneumonia and sepsis. Bronchoscopic tissue removal was performed in one lesion because of marked granulation tissue within the bronchus. Information on the other eight lesions could not be obtained because the patients died (n = 5) or were lost to follow-up (n = 3).

Predictors of Outcomes

Table 2 shows the associations of selected clinical and technical parameters with bronchial patency after balloon dilatation. Univariable analysis showed that the presence of clinical symptoms was related to decreased primary patency (unadjusted HR, 0.422; 95% CI, 0.209–0.851; P = 0.013). Secondary patency was associated with prolonged balloon dilatation (unadjusted HR, 3.328; 95% CI, 1.050–10.546; P = 0.031) and early-stage treatment (unadjusted HR, 3.647; 95% CI, 1.117–11.908; P = 0.022). There was no significant association between the location of stenosis and

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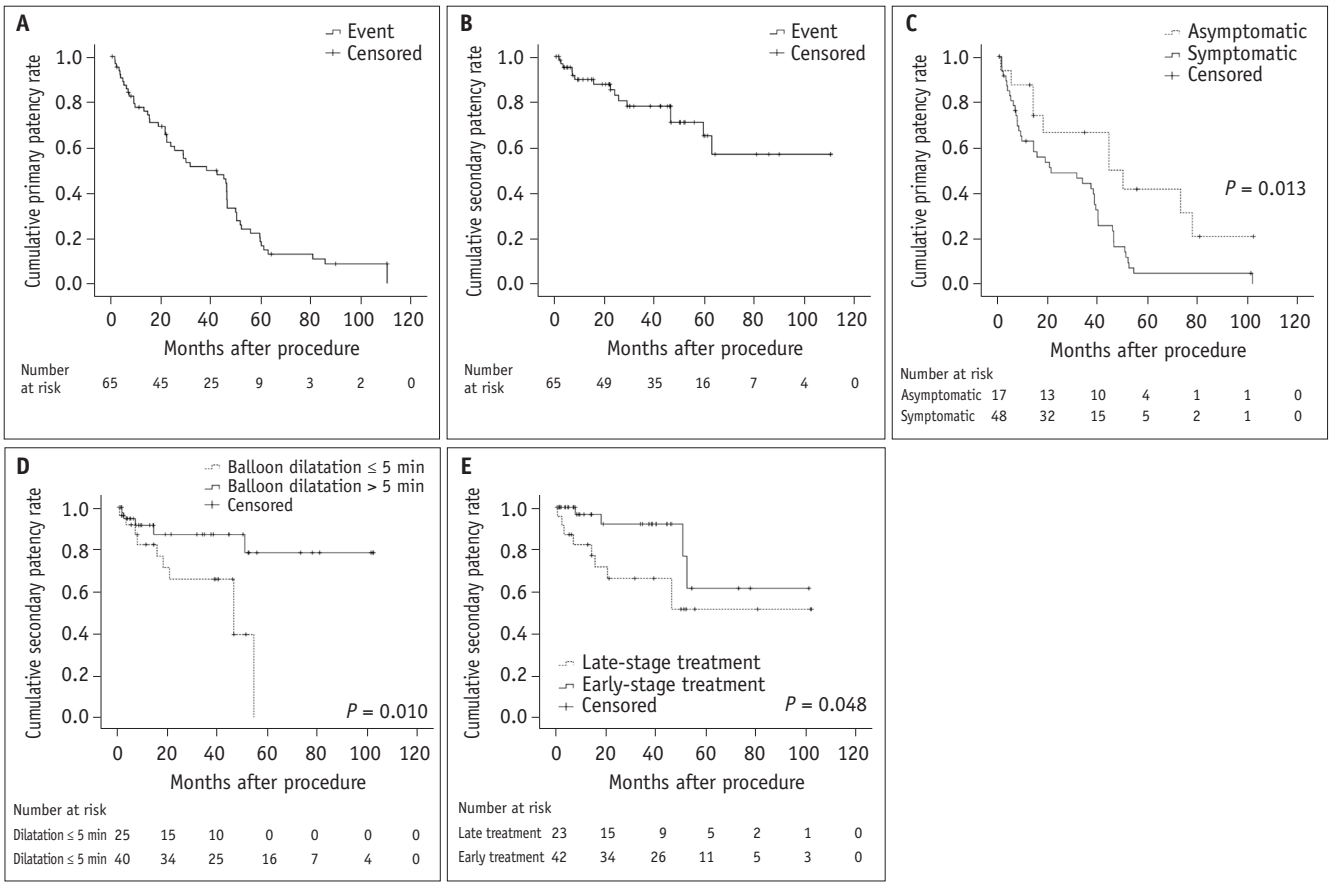

Fig. 3. Primary and secondary cumulative patency rates after bronchial balloon dilatation. **A:** The 6-month, 1-year, 3-year, and 5-year primary patency rates are 87.7%, 78.5%, 55.4%, and 26.2%, respectively. **B:** The 6-month, 1-year, 3-year, and 5-year secondary patency rates are 95.4%, 90.8%, 83.1%, and 78.5%, respectively. **C:** The primary patency rates are significantly greater in the group without clinical symptoms than in the group with clinical symptoms (P = 0.013). **D, E:** The secondary patency rates are significantly greater in the group with prolonged balloon dilatation > 5 min (P = 0.010) and early-stage treatment (P = 0.048) than in the group with balloon dilatation ≤ 5 min and late-stage treatment, respectively.

primary/secondary patency. Results from the multivariable analysis showed that the presence of clinical symptoms was negatively associated with primary patency (adjusted HR, 0.465; 95% CI, 0.220–0.987; P = 0.046). Early-stage treatment (adjusted HR, 3.588; 95% CI, 1.093–11.780; P = 0.035) and prolonged balloon dilatation (adjusted HR, 3.285; 95% CI, 1.018–10.598, P = 0.047) were associated with a higher secondary patency rate.

DISCUSSION

In the present study, 65 bronchi from 50 patients were used to describe the safety and efficacy of balloon dilatation for bronchial stenosis after LT and the predictors associated with bronchial patency. The technical success rate was 99.3% (275/277), and the primary and secondary patency rates were 18.5% (12/65) and 76.9% (50/65), respectively. No major procedure-related complications were noted.

Bronchial interventions can be performed under bronchoscopic or fluoroscopic guidance. However, bronchoscopy-guided procedures are not technically feasible when the bronchial stricture is too tight for the bronchoscope to pass through. Therefore, fluoroscopic guidance is worthwhile when the lumen is too narrow to pass through the stricture site using a bronchoscope. Furthermore, fluoroscopy can be used to measure the extent of the stricture site and properly position the balloon within the stricture site. However, if serious complications such as severe tissue laceration or bleeding occur during the fluoroscopy-guided procedure, immediate endoscopic hemostasis treatment may be required [11,12]. Therefore, a combined bronchoscopy and fluoroscopy approach for bronchial intervention was used in this study to demonstrate its viability and safety.

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Table 2. Univariable and Multivariable Analysis of Various Prognostic Factors for Primary and Secondary Patency after Procedure

Univariable analysis	Primary Patency				Secondary Patency			
	Patent	Stenosis	Unadjusted HR (95% CI)	*P*	Patent	Stenosis	Unadjusted HR (95% CI)	*P*
Sex								
Male	8	28	1.006 (0.585–1.730)	0.984	27	9	0.781 (0.254–2.400)	0.665
Female	4	25			23	6		
Level of stenosis								
Main bronchus†	8	28	0.671 (0.387–1.165)	0.154	26	10	1.041 (0.335–3.234)	0.945
Lobar or segmental bronchus	4	25			24	5		
Site of stenosis								
Anastomosis‡	2	8	1.246 (0.581–2.671)	0.571	7	3	1.112 (0.245–5.046)	0.890
Non-anastomosis	10	45			43	12		
Symptom								
Yes	5	43	0.422 (0.209–0.851)	0.013	35	13	0.367 (0.080–1.683)	0.180
No	7	10			15	2		
Stage*								
Early (≤ 6 mo)	5	37	0.555 (0.303–1.015)	0.053	36	6	3.647 (1.117–11.908)	0.022
Late (> 6 mo)	7	16			14	9		
Prolonged balloon (> 5 min)								
Yes	10	30	1.537 (0.869–2.716)	0.137	35	5	3.328 (1.050–10.546)	0.031
No	2	23			15	10		
Multivariable analysis			Adjusted HR (95% CI)	*P*			Adjusted HR (95% CI)	*P*
Level of stenosis (main)			0.687 (0.394–1.197)	0.185			-	-
Symptom (yes)			0.465 (0.220–0.987)	0.046			0.605 (0.112–3.282)	0.561
Early-stage treatment			0.589 (0.321–1.080)	0.087			3.588 (1.093–11.780)	0.035
Prolonged balloon			0.882 (0.468–1.617)	0.686			3.285 (1.018–10.598)	0.047

*Interval periods, from lung transplantation to initial bronchial balloon dilatation, †Right main bronchus, left main bronchus and right bronchus intermedius, ‡Bronchial anastomosis site during lung transplantation. HR = hazard ratio, CI = confidence interval

Meanwhile, unlike the results of previous studies, in which bronchial stenosis after LT occurred more frequently at the anastomotic site [1,8], more non-anastomotic stenosis (84.6% vs. 15.4%) was observed in this study. One reason for this result may be that end-to-end anastomosis was performed in most of our study patients (48 of 50 patients). Several surgical techniques are available, including telescoped anastomosis, wrapping of vascularized pedicles, and end-to-end anastomosis. While telescoped bronchial anastomosis is associated with a high rate of bronchial anastomotic stenosis, end-to-end anastomosis is associated with a low incidence of anastomotic stenosis [20]. Furthermore, in our study, stenosis occurred most frequently in the intermedius bronchus (40.0%), which is the most frequent site of non-anastomotic stenosis [1,8]. Severe symptomatic non-anastomotic narrowing of the bronchus intermedius and vanishing bronchus intermedius syndrome can occur, which ultimately results in intervention treatment. Therefore, we suspect that many patients were treated for non-anastomotic stenosis in this study.

The initial therapeutic efficacy of bronchial balloon dilatation was unsatisfactory because primary patency was achieved in 12 of 65 bronchi. However, bronchial stenosis was successfully treated using additional dilatation sessions in 50 of 65 bronchi, with 6-month, 1-year, 3-year, and 5-year secondary patency rates of 95.4%, 90.8%, 83.1%, and 78.5%, respectively. Previous studies reported that repeat balloon dilatation could be useful and safe for the management of nonmalignant airway strictures (for example, endobronchial tuberculosis, post-intubation status, post-LT, trauma), which is consistent with our findings [15,21,22].

Although balloon bronchoplasty has been widely used for the treatment of bronchial stenosis following LT, few studies have explored the factors associated with postprocedural bronchial patency. In this study, the presence of clinical symptoms was negatively associated with primary patency (HR, 0.465; $P = 0.046$). Previous studies reported that distal airway obstruction and extended lesions were associated with poor therapeutic and survival outcomes in patients with malignant airway obstruction [23,24]. Significantly

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obstructive and extensive bronchial lesions may cause more severe clinical symptoms such as cough, dyspnea, or obstructive pneumonia. Therefore, the results of our study showing a negative association between the presence of clinical symptoms and primary patency are consistent with those of previous studies [23,24].

In contrast, early-stage treatment (≤ 6 months) was associated with a significantly higher secondary patency rate than late-stage treatment (> 6 months) (HR, 3.588; P = 0.035). The relationship between early-stage treatment and bronchial patency may be attributed to the early diagnosis and treatment of bronchial stenosis, which can affect post-procedural outcomes and the patient life expectancy [25]. This is likely because acute fibroinflammatory bronchial lesions are histologically different from mature chronic fibrosis, which occurs as long-term sequelae. Previous research reported that the length of time until the stenotic scar had completely matured and formed fibrotic tissue was approximately 6 months [26]. Additionally, in our clinical experience, the re-intervention rate increases when balloon dilatation is performed 6 months after LT. Thus, early treatment of bronchial stenosis can prevent the development of irreversible fibrosis, which is more difficult to treat [27]. Furthermore, this result may explain why early-stage treatment is needed in patients with severe bronchial stenosis without clinical symptoms. However, further studies are needed to assess the efficacy of early-stage treatment for post-procedural bronchial patency.

In previous studies, bronchial balloon dilatation with a short duration (≤ 1 min) for nonmalignant lesions did not achieve satisfactory clinical outcomes, and the treatment effect was short [28,29]. In the present study, the mean balloon dilatation time in each procedure was 8.2 ± 2.8 min and showed satisfactory secondary clinical success without major complications. Furthermore, prolonged balloon dilatation was associated with a significantly higher secondary patency rate (HR, 3.285; P = 0.047). Few studies have assessed the influence of the balloon dilatation time on treatment outcomes. To the best of our knowledge, only one study on balloon dilatation for bronchial stenosis reported that a longer dilation time was effective in preventing re-stenosis of the bronchus [30]. Therefore, further research is required to evaluate the clinical importance of the balloon dilation time.

In LT recipients, balloon dilatation is considered the first-line treatment for airway strictures, although stent placement is also frequently used for recurrent strictures. Classically, two types of stents are used for airway intervention procedures: silicone and metallic. Silicone stents can be repositioned and removed as many times as is required. However, these are susceptible to dislodgement, and mucus retention often occurs because of their thick walls and narrow lumens, resulting in stent obstruction and infection. In contrast, metallic stents are less likely to dislodge and their walls are thinner, which improves secretion clearance. However, stent migration, fracture, and re-stenosis due to excessive granulation hyperplasia may occur during long-term implantation. Furthermore, serious complications such as mucosal tears with substantial bleeding can occur [31-33]. During the follow-up period of this study, the re-stenosis rate after repeat balloon dilatation was 23.1%, which is comparable to previous studies that reported a re-stenosis rate of 17%–52% after stent placement [3,33,34]. Furthermore, no major procedure-related complications were observed in the present study.

This study had some limitations. First, this study had a retrospective design. Second, this was a single-center study and the study population was small. Future studies with larger sample sizes may provide further insight into the usefulness of balloon dilatation for bronchial stenosis after LT. Third, the results of pre- and post-procedural pulmonary function tests were not assessed. Certain patients could not undergo the test because of unstable cardiovascular status, short periods since surgery, and inability to perform spirometry of acceptable quality. The decision to perform a pulmonary function test was left to the discretion of the referring physician. Further studies are required to assess the influence of repeated balloon dilatation on pulmonary function.

In conclusion, repeated balloon dilatation is a safe and effective treatment for bronchial stenosis following LT. Moreover, early-stage treatment and prolonged balloon dilatation could significantly promote long-term patency.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Joon Ho Kwon, Gyoung Min Kim. Data

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