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APPLICATION OF COMBINED ENDOSCOPIC TREATMENT OF PATIENTS WITH BRONCHIAL STENOSIS AFTER LUNG TRANSPLANTATION USING THULIUM LASER, BALLOON DILATION, CRYOABLATION, AND AIRWAY STENTING

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Bronchial stenosis (BS) is a persistent, breathing-independent narrowing of the bronchial lumen, primarily brought on by scar and/or granulation tissue. BS occurring after lung transplantation tend to be recurrent, resulting in a higher frequency of hospitalizations compared to the group of patients without this complication. Minimally invasive endoscopic repair of the bronchial lumen is a generally recognized treatment for BS. This article demonstrates the experience of using a combined technique for restoring the lumen and preventing recurrent stenosis using thulium laser, balloon dilation, cryoablation, and stenting (hereinafter referred to as the combined technique).

Keywords: lung transplantation, airway complications, bronchial stenosis, thulium laser, endoscopic balloon dilation, cryoablation, airway stenting.

INTRODUCTION

Bronchial stenosis (BS) is one of the most common airway complications that occur after a lung transplant (LT) [1–3]. According to medical literature, it typically occurs between 3–6 months after an LT [4]. Balloon dilation, bronchial bougienage, argon plasma coagulation (APC), laser use, cryoablation, and stenting are all endoscopic techniques used to restore bronchial lumen and prevent a recurrence [5–6]. Among these, balloon dilation, bougienage, APC, and laser therapy provide immediate effects, while cryoablation has a delayed therapeutic impact [7–8]. Airway stenting is a method used to prevent recurrent bronchial stenosis. Despite the availability of various endoscopic techniques for bronchial lumen restoration and the use of stenting to maintain bronchial patency, BS remains a frequently recurring complication. This, in turn, leads to increased hospitalizations and a reduced quality of life for lung transplant recipients. This article presents the experience of using a combined approach – incorporating thulium laser, balloon dilation, cryoablation, and stenting – to restore bronchial lumen and prevent recurrent stenosis in lung transplant recipients at the Shumakov National Medical Research Center of Transplantology and Artificial Organs ("Shumakov Transplant Center").

Table 1

ISHLT classification of bronchial stenoses

Stenoses	Location	a – anastomotic site
		b – anastomotic and lobar/segmental site
		c – lobar/segmental site only
	Extent	1 – 0% to 25% reduction in cross-sectional area
		2 – >25% to 50% reduction in cross-sectional area
		3 – >50% but <100% reduction in cross-sectional area
		4 – 100% obstruction

MATERIALS AND METHODS

Between September 2014 and November 2024, a total of 119 lung transplants were performed at the Shumakov Transplant Center. The primary diagnostic methods for detecting BS post-transplant included bronchoscopy and chest computed tomography, while spirometry was used at later stages to identify suspected cases. To classify and assess the severity of BS, we applied the bronchial complication classification proposed by the International Society for Heart and Lung Transplantation (ISHLT) (Table 1) [9].

The primary treatment methods for BS in lung transplant recipients at the Shumakov Transplant Center include mechanical bougienage, balloon dilation, APC, and stenting. However, in most cases, these approaches provided only short-term relief, necessitating repeated interventions.

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Since 2020, cryoablation has been introduced as an independent treatment for BS. This technique has proven effective, particularly in managing BS caused by granulation tissue overgrowth [8].

Since 2021, the thulium laser has been used for scar tissue dissection. When used for recanalizing scar stenoses, it demonstrated a reduced carbonization effect and greater precision compared to APC.

The primary criterion for selecting patients for endoscopic bronchial lumen restoration using a combined approach was the presence of grade 2–4 BS, as well as recurrent BS despite previous airway recanalization attempts.

Endoscopic procedures employing the combined technique were performed in an operating room under general anesthesia, with a preference for rigid intubation and high-frequency mechanical ventilation. Following tracheal intubation, the tracheobronchial tree was thoroughly examined.

The first stage of the procedure involved the dissection of scar tissue using a thulium laser. The pulse energy was initially set at a minimum of 0.025 J with a frequency of 240 Hz. When an increased intensity was required, priority was given to adjusting the radiation frequency rather than the energy level. To minimize tissue carbonization, continuous irrigation and aspiration of a 0.9% sodium chloride solution were performed using a catheter (Fig. 1).

Following scar dissection, the next stage involved balloon dilatation using three-step balloons with incremental diameter increases of 1 mm (6–7–8 mm, 8–9–10 mm, 10–11–12 mm, 12–13.5–15 mm). The required pressure inside the balloon was generated using a specialized blower (Fig. 2).

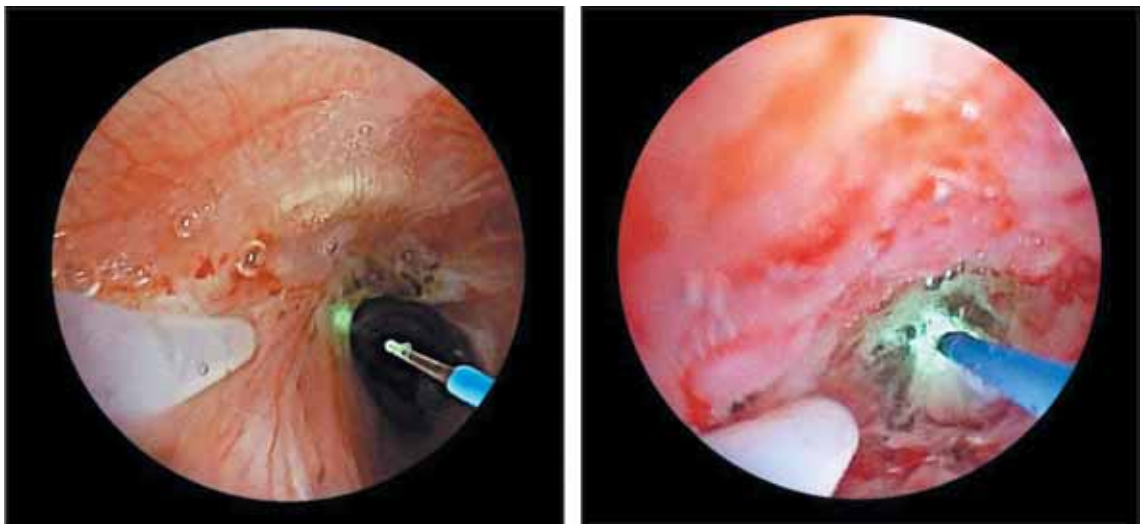

Fig. 1. Stage of vaporization with irrigation with sodium chloride 0.9%

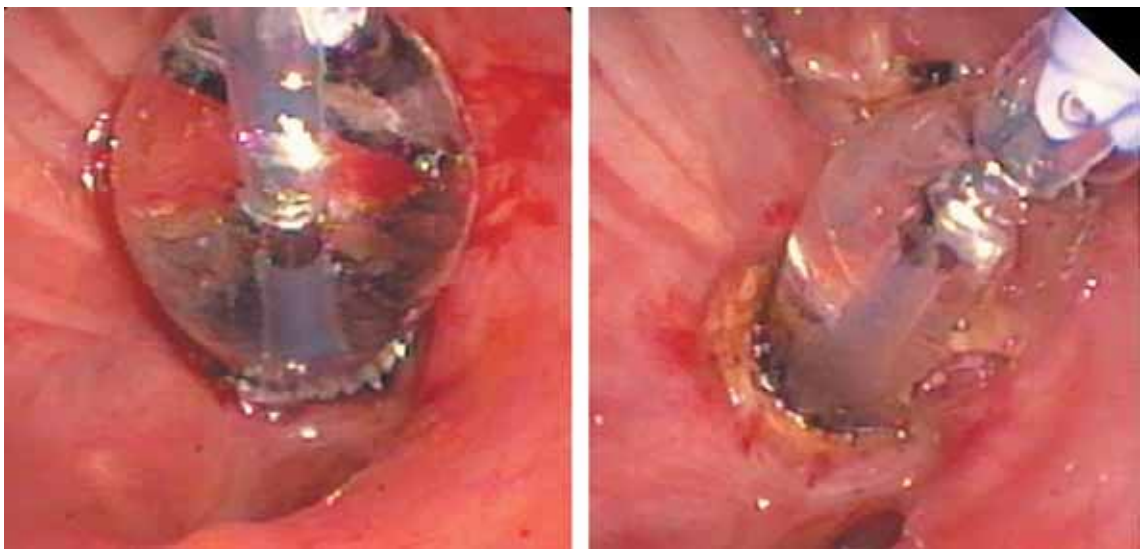

Fig. 2. Balloon bronchoplasty stage

To prevent recurrence, cryotherapy was applied to the stenotic area. The cryoprobe was placed in direct contact with the bronchial mucosa at the site of stenosis, followed by freeze-thaw cycles lasting 30–45 seconds each. Tissue thawing was allowed to complete before the cryoprobe was detached from the mucosa. A total of three freeze-thaw cycles were performed in each treatment zone. The cryoprobe was then repositioned 5–6 mm from the previous site, and the cryotherapy sessions were repeated until the entire stenotic area was treated (Fig. 3).

In cases of impaired bronchial framework function, stenting was performed using a self-expanding nitinol stent (Fig. 4).

RESULTS

The combined technique for bronchial lumen restoration was applied to seven lung transplant recipients with BS. Among them, two patients (28.58%) were diagnosed with intermediate BS, while five (71.42%) had multifocal stenosis. Prior to undergoing the combined technique, the patients had an average of 5.8 ± 1.5 endoscopic recanalization attempts.

A total of 19 surgical interventions were performed using the combined technique for 34 cases of stenosis, averaging 2.71 procedures per patient. The key characteristics of BS in this patient group are summarized in Table 2 and illustrated in Figs. 5–7.

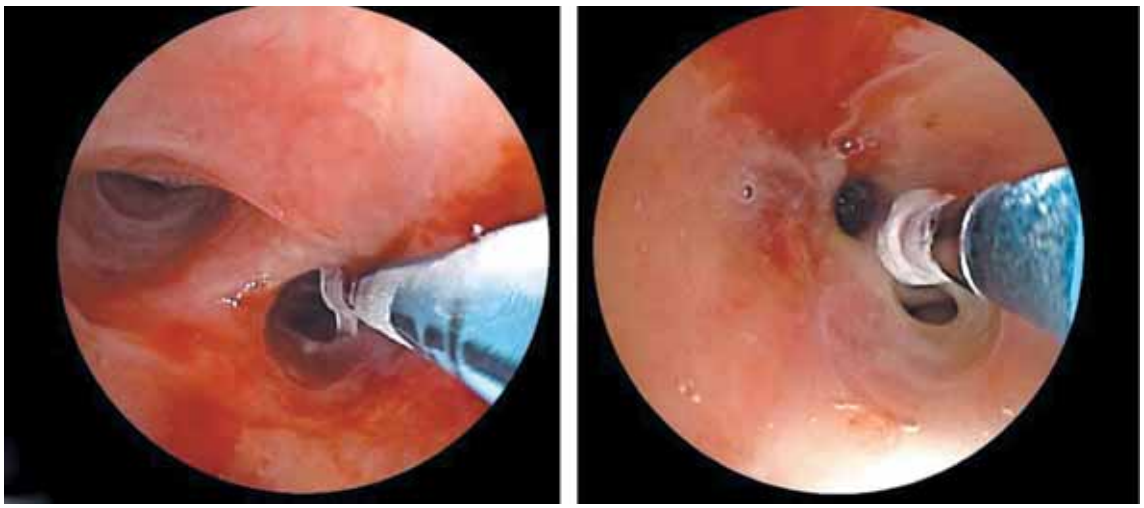

Fig. 3. Cryotherapy stage

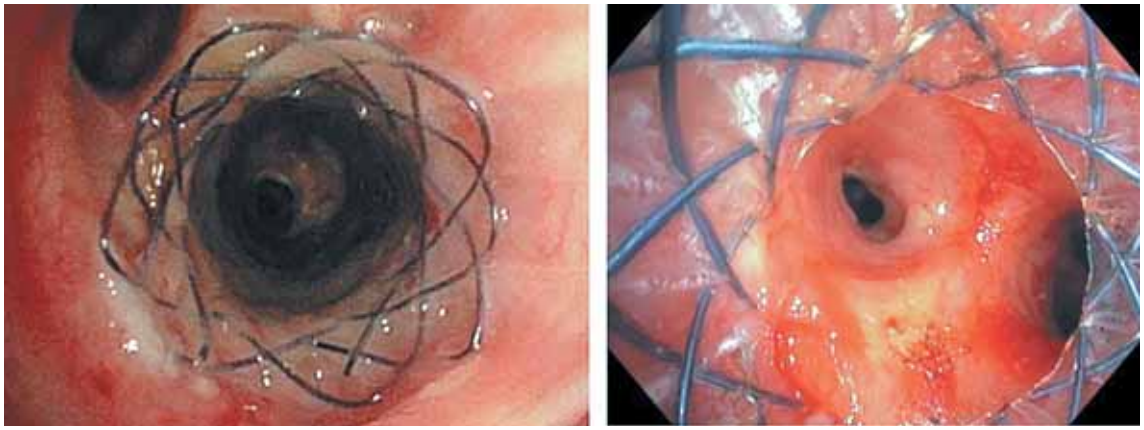

Fig. 4. Bronchial stenting stage

Table 2

Number of surgical interventions according to ISHLT stenosis classification

Types of stenosis	Number of operations
Central airway stenosis	7
Distal airway stenosis	11
Combined airway stenosis	1

Repeated surgical interventions in lung transplant recipients with BS who underwent endoscopic recanalization using the combined technique were associated with the following complications: recurrent narrowing of the lumen at the proximal or distal edge of the nitinol stent (5 cases, 14.7%) and stent migration during diagnostic

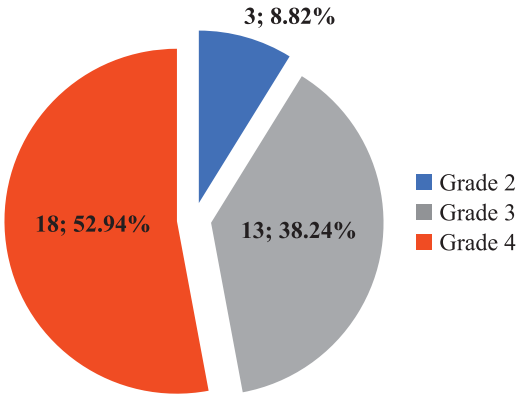

Fig. 5. Extent of bronchial stenosis according to ISHLT classification

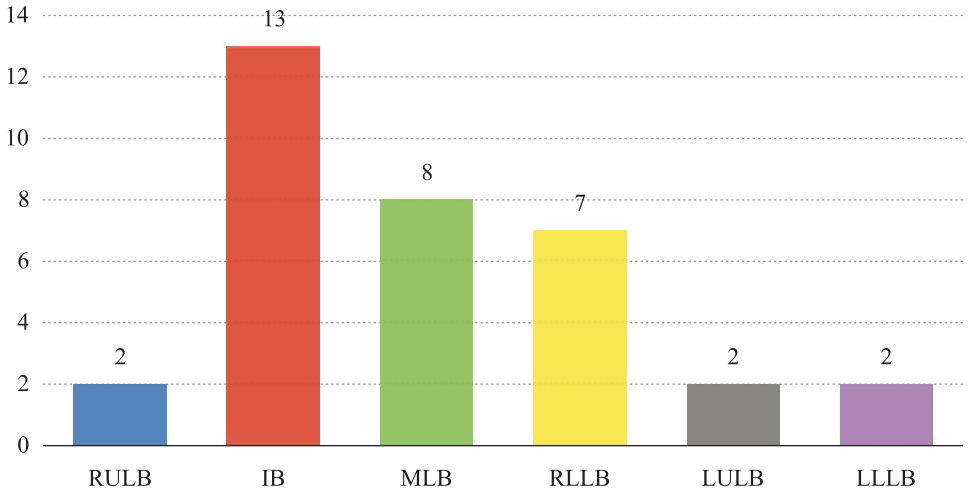

Fig. 6. Location of bronchial stenosis for which recanalization was performed using a combined technique. RULB, right upper lobe bronchus; IB, intermediate bronchus; MLB, middle lobe bronchus; RLLB, right lower lobe bronchus; LULB, left upper lobe bronchus; LLLB, left lower lobe bronchus)

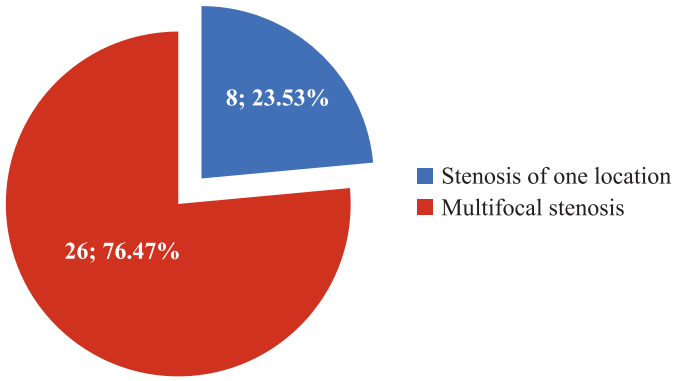

Fig. 7. Prevalence of bronchial stenosis

bronchoscopy (1 patient, 2.9%). There were no cases of bleeding and bronchial wall rupture in the study group.

The stent was removed in cases where no recurrent BS was detected for at least one year post-stenting. A persistent remission, with a recurrence-free period exceeding one year, was achieved in six lung recipients (85.71%).

CONCLUSION

Despite advancements in surgical techniques for lung transplantation, improved postoperative management, and minimally invasive endoscopic interventions, the incidence of recurrent BS in lung recipients remains high. This highlights the need for developing new approaches to endoscopic treatment for this patient cohort.

The use of a combined technique – incorporating thulium laser, balloon dilation, cryoablation, and stenting – for bronchial lumen restoration and recurrent stenosis prevention in lung recipients has proved to be effective in lung transplant recipients. Notably, no significant complications, such as bleeding or bronchial wall rupture, were observed, further supporting the safety and efficacy of this approach.

Recurrent BS when using the combined technique was primarily attributed to lumen narrowing at the proximal and distal edges of the nitinol stent. In cases of recurrence, repeat surgical intervention involving thulium laser, balloon dilation, and cryoablation was performed.

According to several studies, the recurrence rate during stenting may be reduced by using Dumont silicone stents [10–12]. However, the structural characteristics of silicone stents – such as an average wall thickness of 1 mm and the presence of outer protrusions that prevent migration – can narrow the bronchial lumen, making them unsuitable for stenting in lobar and segmental bronchi.

The development of alternative stent materials, including biodegradable options, integration of 3D printing technology, and the use of drug-eluting stents, may offer promising solutions for reducing recurrence rates in BS treatment [13–15].

The authors declare no conflict of interest.

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