Int J Clin Exp Med 2020;13(5):3393-3401
www.ijcem.com /ISSN:1940-5901/IJCEM0109269

Original Article

Bronchoscopic argon plasma coagulation, high-frequency radio-wave electrosurgery, and cryotherapy for tracheal stenosis

Peng Wei[1,2], Zhenjie Huang[1], Luoman Gan[3], Yu Li[2], Caicheng Qin[1], Guangnan Liu[1,2]

[1]*Guangxi Medical University, Nanning, Guangxi Zhuang Autonomous Region, China;* [2]*Department of Respiratory Medicine, The Second Affiliated Hospital of Guangxi Medical University, Nanning, Guangxi Zhuang Autonomous Region, China;* [3]*Department of Stomatology, Medical College of Qinghai University, Xining, Qinghai Province, China*

Received February 15, 2020; Accepted March 18, 2020; Epub May 15, 2020; Published May 30, 2020

Abstract: Objective: The aim of the current study was to investigate therapeutic effects of the triple combination of argon plasma coagulation (APC), high-frequency radio-wave electrosurgery, and cryotherapy for treatment of patients with tracheal stenosis. Methods: Eighty patients with tracheal stenosis were recruited for this study and randomly assigned to the observation group (n=40) and control group (n=40), in accordance with a random digital table. Patients in the observation group underwent APC, high-frequency radio-wave electrosurgery, and cryotherapy, while those in the control group received high-frequency radio-wave electrosurgery alone. Patients in both groups were observed regarding therapeutic effects, blood gas measures (before and after treatment), dyspnea severity, and tracheal stenosis grading (before and after treatment), as well as postoperative complications. Results: After treatment, analysis of the therapeutic effects of patients with tracheal stenosis demonstrated that the total effective rate of the observation group was higher than that of the control group (P<0.05). Greater increases in values for PO_2 and SaO_2 (P<0.05, P<0.001), along with greater decreases in the values for PCO_2 (P<0.05), were observed in the observation group, compared to the control group. Differences were statistically significant. After treatment, there were statistically significant differences in dyspnea classification and tracheal stenosis grading between the observation group and control group (all P<0.05). Analysis of postoperative complications indicated that the rate of postoperative complications was lower in the observation group than in the control group, with no statistical differences (P>0.05). Conclusion: This triple combination of APC, high-frequency radio-wave electrosurgery, and cryotherapy effectively resolved tracheal stenosis and improved pulmonary function. Moreover, it did not increase postoperative complications in patients with tracheal stenosis. Therefore, this triple therapy method is worthy of wide clinical application.

Keywords: Tracheal stenosis, bronchoscopy, argon plasma coagulation, high-frequency radio-wave electrosurgery, cryotherapy, therapeutic effect

Introduction

Management of tracheal stenosis has always been a challenge in clinical practice. With the development of interventional technology and clinical application of new techniques and equipment, treatment of tracheal stenosis has become increasingly safer [1]. Interventional techniques include mechanical dilation, bronchoscopy, balloon dilation, stent placement, argon plasma coagulation (APC), high-frequency radio-wave electrosurgery, cryotherapy, and endobronchial laser photo-resections [2-7]. Patients with tracheal stenosis frequently suffer from compression by hyperplastic tissue at the stenotic site. Therefore, surgical procedures are recommended to remove the lesions, resolve compression, and reduce relapse in patients with tracheal stenosis. High-frequency radio-wave electrosurgery is the best choice to remove lesions in clinical practice and it is recommended in the guidance of interventional therapy. However, it carries the risk of inducing severe hemorrhaging [8-10]. APC, also known as argon scalpel, can cleanse superficial lesions and has a good effect of hemostasis. However, its thermal effects may bring damage to the mucosa surrounding the lesions, resulting in granuloma formation. Cryotherapy, with its ultra-low temperature effects, can facilitate surgical resections of the lesions and reduce granuloma formation, resulting from the thermal effects [11]. Hence, a combination of APC and cryotherapy may be clinically applied to remove tumor lesions, making full use of its advantages of minimal invasion, simplicity, effectiveness, and safety [12]. The triple combination of APC, high-frequency radio-wave electrosurgery, and cryotherapy is advantageous in treating patients with tracheal stenosis. Lesions can be rapidly removed by means of APC and high-frequency radio-wave electrosurgery, then the necrotic tissues are frozen by cryotherapy after thermal ablation. This is followed by resection of the frozen tissues by APC, preventing bleeding. Frozen tissues are prone to bleeding [13, 14]. However, studies investigating the clinical triple combination of APC, high-frequency radio-wave electrosurgery, and cryotherapy for treatment of tracheal stenosis have been quite rare. Therefore, the present study was designed to explore the clinical efficacy of the triple surgery of APC, high-frequency radio-wave electrosurgery, and cryotherapy using a bronchoscope, compared with high-frequency radio-wave electrosurgery alone, for treatment of patients with tracheal stenosis.

Materials and methods

General data

A total of 80 patients with tracheal stenosis, admitted to the Department of Intervention in The Second Affiliated Hospital of Guangxi Medical University, from January 2016 to June 2019, were recruited for the current study. Of the enrolled patients, 50 were male and 30 were female. They ranged in age from 18 to 72 years, with a mean age of 46.7±13.5 years. The 80 patients were randomly assigned to the observation group (n=40) or control group (n=40), according to a random number table. Patients in the observation group underwent APC, in combination with high-frequency radio-wave electrosurgery and cryotherapy (triple surgery). Of these, 27 were male and 13 were female (mean, 46.2±13.0 years). Patients in the control group (23 males and 17 females, with a mean age of 47.2±14.2 years) received high-frequency radio-wave electrosurgery alone. The present study was approved by the Hospital Ethics Committee and all patients provided written informed consent.

Inclusion and exclusion criteria

Inclusion criteria: Patients were eligible for enrollment in the study if they had tracheal stenosis, as diagnosed by the criteria for tracheal stenosis released by the American Thoracic Society (ATS) and the European Respiratory Society (ERS) in 2002; If they were unable to undergo surgical resection, missed the opportunity for surgical treatment, or were unwilling to receive surgical treatment due to benign or malignant tracheal stenosis, for which the common etiological factors were tracheotomy, tracheal intubation, bronchial tuberculosis and tumors; Patients had dyspnea induced by benign or malignant lesions in the trachea, main bronchi, lobe or segmental bronchi, but the distal trachea was unobstructed and the distal lung tissue had normal function, indicating endoscopic interventional therapy; Patients had expected good therapeutic effects using endoscopic therapy or if they had complete clinical data and cooperated in follow-up of the study [15]. Exclusion criteria: Patients were ineligible for enrollment if they were intolerant to the relevant surgical operations due to extremely poor general conditions; Patients with severe disease in the heart and lungs; Patients with abnormal coagulation with a significant tendency to hemorrhaging; Patients with concurrent distal obstructive pulmonary dysfunction and were unable to participate in follow-ups.

Methods

Patients in the control group received the monotherapy of high-frequency radio-wave electrosurgery. Protocol for surgery included the following steps. Combined anesthesia was induced in each patient by intravenous midazolam injections at a dose of 0.05 to 0.10 mg per kilogram of body weight (Jiangsu Nhwa Pharmaceutical Co., Ltd., China) and sufentanil citrate injection at a dose of 0.2 to 0.3 μg per kilogram of body weight (Yichang Humanwell Pharmaceutical Co., Ltd., China). This was followed by local anesthesia with 20 mL of lidocaine hydrochloride (Tianjin KingYork Pharmaceutical Co., Ltd., China), administered by combining aerosolized inhalation and infusion by bronchoscopic lung biopsies via a fiberoptic bronchoscope (Olympus BF-1T260, Japan). Under anesthesia, the patient was placed in the supine position. Electrodes were pasted on the right leg of the patient. The electrodes were then confirmed if they were in good contact with the skin of the body. They were connected to a radiofrequency therapy device (Jiangxi Liwei Medicine, TKR-300B) and a fiberoptic bronchoscope was introduced and advanced into the lesion site, aiming to remove surrounding secretions. When removal of the secretions was completed, the performance was conducted gently to avoid lesion bleeding. The electrodes for treatment were selected according to the shape of the lesions and the surrounding tissues. Subsequently, the electrodes were inserted into the endobronchial lumen through the biopsy port of the fiberoptic bronchoscope and the columnar electrode was protruded approximately 1-2 cm away from the front end of the bronchoscope and pushed to the surface of the lesion. The mode of electrotomy (output mode: 30-35 w) was adopted for common lesion tissues. The mixed mode of electrotomy and electrocoagulation (output mode: 35-45 w) was used for cleansing the lesion tissues with richer blood supply. The mode of electrocoagulation was utilized for lesion tissues with significant bleeding. After completion of electrocoagulation and electrotomy, the presence or absence of active bleeding was confirmed. If bleeding symptoms occurred, 1U of hemocoagulase agkistrodon (Beijing Konruns Pharmaceutical Co., Ltd., China) was locally and extensively applied to stop bleeding. If stenosis was still present after high-frequency radio-wave electrosurgery, balloon dilation (Boston Scientific, USA) was performed. The necrotic tissue was cleansed using a fiberoptic bronchoscope three to five days after surgery.

In contrast, patients in the observation group were treated with APC in combination with high-frequency radio-wave electrosurgery and cryotherapy. The protocol for the triple surgery covered the following steps. Anesthesia was induced in the same manner as described above for patients in the control group. Under anesthesia, a patient was placed in the supine position and electrodes were pasted on the right leg of the patient. Next, the electrodes were confirmed if they were in good contact with the skin of the body. APC and radiofrequency therapy devices (ERBE Elektromedizin GmbH, Germany) were connected. An APC nozzle (ERBE Elektromedizin GmbH, Germany, ERBE VIO200S) was inserted into the endobronchial lumen through the biopsy port of the fiberoptic bronchoscope. The nozzle was protruded approximately 1 to 2 cm away from the front end of the bronchoscope and pushed to 0.5 cm away from the lesion surface. APC (output power of 30-50 w and argon flow at 0.8-1.6 l/min) was performed to manage the lesions for approximately 1 to 2 seconds once, until the color of the surface lesions turned white to yellowish or burnt black. If there were bleeding symptoms, extensive application of hemocoagulase agkistrodon (1U) was locally used for hemostasis. The lesion was removed using the radiofrequency therapy device and electrotomy and electrocoagulation were performed in the same manner as for the patients in the control group. Subsequently, cryotherapy was conducted. A cryoprobe (ERBE ERBOKRYO CA, Germany) was introduced through the biopsy port of the fiberoptic bronchoscope and inserted in the center of the tumor where freezing points were set. More than one freezing point could be set if the tumor was quite large. The freezing temperature was set at -50 to -70°C and the freezing duration 30 to 120 seconds. The tumor mass was removed by high-frequency radio-wave electrosurgery and APC before the tissue was completely cleansed after freezing. If there was still stenosis, dilation balloon was performed. At 3 to 5 days after the operation, clearance of the necrotic tissue was conducted via the fiberoptic bronchoscope.

Outcome measures

At 1 month after treatment, patients in both groups were assessed for therapeutic effects of stenosis with the use of bronchoscopy [16]. A patient was cured if the lesion was generally cleansed and the trachea showed normal function after treatment. Treatment was significantly effective if more than 50% of tracheal stenosis was opened and the trachea showed largely normal function after treatment. Treatment was effective if less than 50% of tracheal stenosis was opened and the trachea kept largely

Table 1. Comparison of general data between the two groups

Item	Observation group (n=40)	Control group (n=40)	χ^2/t	P
Age (years)	46.2±13.0	47.2±14.2	0.329	0.743
Sex (male/female)	27/13	23/17	0.853	0.365
Disease location			0.223	0.894
Weasand	5 (12.50%)	6 (15.00%)		
Left principal bronchus	13 (32.50%)	14 (35.00%)		
Right principal bronchus	22 (55.00%)	20 (50.00%)		
Pathogenesis			0.221	0.921
Trachea cannula	6 (15.00%)	7 (17.50%)		
Tracheotomy	10 (25.00%)	9 (22.50%)		
Endobronchial tuberculosis	16 (40.00%)	15 (37.50%)		
Malignant tumor	8 (20.00%)	9 (22.50%)		
BMI (kg/m^2)	24.71±3.76	24.59±4.28	0.110	0.913
Complicating disease				
Hyperlipidemia (yes/no)	16/24	18/22	0.205	0.651
Hypertension (yes/no)	21/19	19/21	0.200	0.655
Coronary heart disease (yes/no)	8/32	7/33	0.082	0.775
Obesity (yes/no)	11/29	12/28	0.061	0.805
Type 2 diabetes mellitus (yes/no)	15/25	17/23	0.208	0.648

Note: BMI, Body mass index.

normal function after treatment. Treatment was ineffective if the lesion was not cleansed and tracheal stenosis was not improved. The total effective rate was calculated as follows: Total effective rate = Number of cases of (Cured + Significantly effective + effective)/Number of total cases * 100%.

Arterial blood gas measures, including arterial partial pressure of oxygen (PO_2), arterial partial pressure of CO_2 (PCO_2), and arterial oxygen saturation (SaO_2), were analyzed in the patients before treatment and 1 month after treatment. Gas analysis was performed using an i-stat 300 portable blood gas-analyzer (Abbott Laboratories, USA).

Dyspnea classification and airway obstruction grading of patients were carried out before treatment and 1 month after treatment [17]. Severity of dyspnea was classified by Levels 0 to 4: Level 0, a patient breathed normally; Level 1, the patient showed tachypnea when walking fast; Level 2, the patient had tachypnea when walking at a normal speed; Level 3, the patient stopped walking due to presence of dyspnea at a normal walking speed; and Level 4, the patient showed tachypnea when doing light physical activity. Severity of tracheal stenosis was described by Grades I to V: Grade I (tracheal stenosis ≤ 25%); Grade II (tracheal stenosis of 26-50%); Grade III (tracheal stenosis of 51-75%); Grade IV (tracheal stenosis of 76-90%); and Grade V (tracheal stenosis of 91-100%), with higher grades indicating more severe dyspnea and tracheal stenosis.

Patients in both groups were observed for postoperative complications at 1 month after treatment. Postoperative complications included irritant dry cough, hemoptysis, sputum retention, infections, restenosis, and fistula formation.

Statistical analysis

Data analysis was performed using SPSS statistical software, version 17.0.

Continuous variables are represented by standard deviation ($\bar{x}$ ± sd). Continuous variables with normal distribution and homogeneity of variance were measured with the use of t-tests. Intragroup comparisons were made using paired samples t-tests before and after treatment. Moreover, intergroup comparisons were conducted using independent sample t-tests, expressed as t. Continuous variables that showed no normal distribution nor homogeneity of variance were assessed using rank sum tests, expressed by Z. Count data were detected with the use of Pearson's Chi-square tests. *P*-values <0.05 indicate statistical significance.

Results

Comparison of general data between the observation and control group

There were no significant differences in age, sex, disease site, etiology, body mass index (BMI), and complications between the observation group and control group (all P>0.05, **Table 1**).

Table 2. Comparison of therapeutic effects of patients with tracheal stenosis between the two groups

Group	Cured	Significantly effective	Effective	Ineffective	Total effective rate (%)
Observation group (n=40)	8 (20.00)	16 (40.00)	13 (32.50)	3 (7.50)	92.50
Control group (n=40)	3 (7.50)	6 (15.00)	21 (52.50)	10 (25.00)	75.00
χ^2		12.470			4.501
P		0.006			0.034

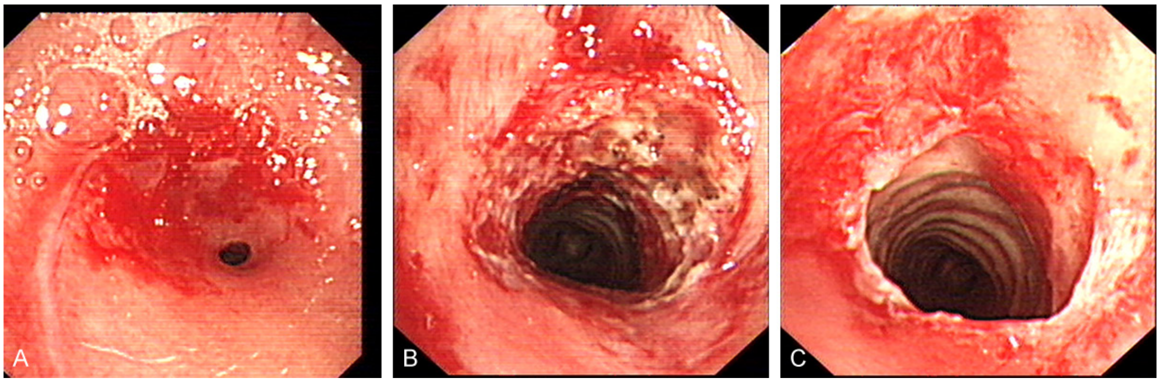

Figure 1. A 64-year-old male patient admitted to the ICU for endotracheal intubation due to respiratory failure. The patient developed tracheal stenosis after extubation. He underwent APC in combination with high-frequency radio-wave electrosurgery and cryotherapy using a bronchoscope. A. The condition of the patient with endoscopy before treatment; B. The condition of the patient with endoscopy after the triple surgery; C. Reexamination with endoscopy 1 month after treatment. APC, argon plasma coagulation; ICU, intensive care units.

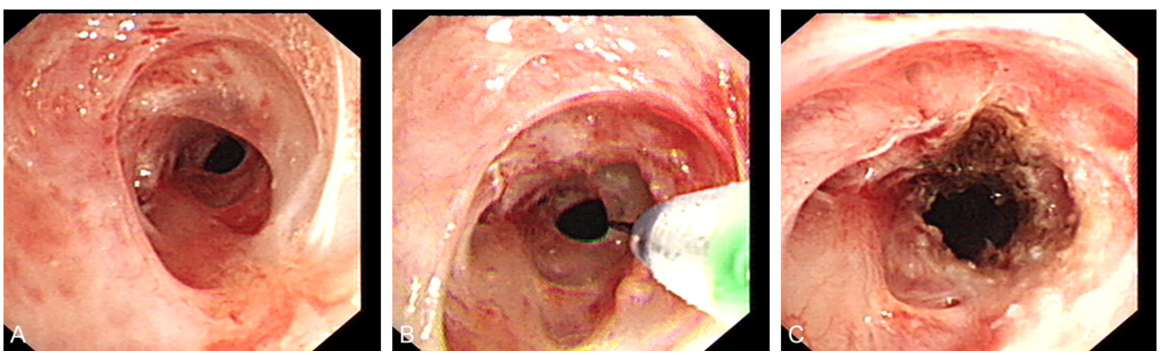

Figure 2. A 49-year-old male patient that developed tracheal stenosis due to bronchial tuberculosis. The patient received the triple treatment of APC, high-frequency radio-wave electrosurgery and cryotherapy using a bronchoscope. A. The condition of the patient with endoscopy before treatment; B. The condition of the patient with bronchoscopy during the triple surgery; C. The condition of the patient with endoscopy after treatment. APC, argon plasma coagulation.

Comparison of therapeutic effects of patients with tracheal stenosis between the observation and control group

A comparison between the two groups showed that the observation group was superior to the control group in the efficacy of tracheal stenosis (P<0.01), with a significant higher total effective rate in the observation group (P<0.05, **Table 2**). Graphs describing the therapeutic effects of tracheal stenosis in the observation group are shown in **Figures 1** and **2**.

Comparison of blood gas values for patients between the two groups (before and after treatment)

Before treatment, values for PO_2, PCO_2, and SaO_2 in patients were insignificantly different between the two groups (all P>0.05). More sig-

Table 3. Comparison of blood gas values for patients between the two groups before and after treatment

Item	PO_2 (mmHg)	PCO_2 (mmHg)	SaO_2 (%)
Before treatment			
Observation group	54.26±10.04	43.23±7.77	85.03±7.51
Control group	53.16±10.24	44.78±8.20	84.32±7.55
t	0.485	0.868	0.416
P	0.629	0.388	0.679
After treatment			
Observation group	80.30±7.61^a	37.88±4.33^a	95.58±2.34^a
Control group	75.90±8.69^a	40.45±6.14^a	92.08±2.20^a
t	2.409	2.167	6.89
P	0.018	0.033	<0.001

Note: PO_2, arterial partial pressure of oxygen; PCO_2, arterial partial pressure of CO_2; SaO_2, arterial oxygen saturation, compared with before treatment, $^a P<0.05$.

nificant improvements in PO_2, PCO_2, and SaO_2 were observed after treatment than before treatment (all $P<0.05$), with greater increases in PO_2 and SaO_2 ($P<0.05$, $P<0.001$). There were greater decreases in PCO_2 in the observation group than in the control group ($P<0.05$). Differences were statistically significant ($P<0.05$, **Table 3**).

Dyspnea classification and airway obstruction grading, before and after treatment, in the two groups

There were no differences between the observation group and control group in dyspnea classification and airway obstruction grading before treatment (both $P>0.05$). After treatment, however, dyspnea classification and airway obstruction grading scores were significantly different between the two groups (both $P<0.05$, **Table 4**).

Comparison of postoperative complications between the two groups

Analysis of postoperative complications between the two groups indicated that the rate of postoperative complications was lower in the observation group than in the control group, without statistical differences ($P>0.05$, **Table 5**).

Discussion

The etiology of tracheal stenosis is complicated. Tracheal stenosis is divided into benign and malignant stenosis. Most cases of tracheal stenosis are attributed to intratracheal masses, tracheal external pressure, airway wall lesions, and invasive procedures of clinical endotracheal intubation or tracheotomies. After development of tracheal stenosis, patients may clinically manifest impaired respiratory function, such as dyspnea and tachypnea. Further aggravation of the disease may induce respiratory failure or even death [18, 19]. With the development of interventional technology, high-frequency radio-wave electrosurgery using a bronchoscope can cleanse airway obstruction rapidly and effectively. The cost of the surgery is relatively low. As a result, the surgical technique has become the first-line treatment for tracheal stenosis [20]. With further investigation, high-frequency radio-wave electrosurgery has been found to cause great damage and is prone to severe hemorrhaging [10]. In recent years, the combination of APC and cryotherapy has been characteristic of minimal invasion and effectiveness for tumor resections [12]. However, the combined surgery can only cleanse small lesions. Therefore, attempts have been made to add high-frequency radio-wave electrosurgery to APC and cryotherapy for treatment of tracheal stenosis. In the current study, improvements were found in patients with tracheal stenosis undergoing high-frequency radio-wave electrosurgery alone in the control group and in those with the triple combination of APC, high-frequency radio-wave electrosurgery, and cryotherapy in the observation group. However, overall therapeutic effects were better in the observation group.

The working principles for APC are as follows. An Argon ion beam is generated under the action of the current from the high frequency electrotome. The resultant thermal effect is used to coagulate the affected tissues. Moreover, high-frequency current can resect the lesions from the lateral, axial, and radial directions. With these thermal effects, APC can promote lesion drying, cell deactivation, and coagulation. It also provides hemostatic effects in addition to tumor resections [21]. With APC, compared with the conventional electrotome, the affected tissues are not directly contacted

Table 4. Dyspnea classification and airway obstruction grading before and after treatment in the two groups

Item	Before treatment				After treatment			
	Observation group (n=40)	Control group (n=40)	χ^2	P	Observation group (n=40)	Control group (n=40)	χ^2	P
Dyspnea classification			0.217	0.995			10.362	0.035
Level 0	1 (2.50)	1 (2.50)			16 (40.00)	5 (12.50)		
Level 1	7 (17.50)	6 (15.00)			12 (30.00)	12 (30.00)		
Level 2	9 (22.50)	10 (25.00)			10 (25.00)	15 (37.50)		
Level 3	10 (25.00)	11 (27.50)			1 (2.50)	4 (10.00)		
Level 4	13 (32.50)	12 (30.00)			1 (2.50)	4 (10.00)		
Airway obstruction grading			0.498	0.974			11.926	0.018
Grade I	2 (5.00)	1 (2.50)			17 (42.50)	4 (10.00)		
Grade II	6 (15.00)	7 (17.50)			11 (27.50)	14 (35.00)		
Grade III	12 (30.00)	13 (32.50)			10 (25.00)	16 (40.00)		
Grade IV	11 (27.50)	10 (25.00)			1 (2.50)	4 (10.00)		
Grade V	9 (22.50)	9 (22.50)			1 (2.50)	2 (5.00)		

Table 5. Comparison of postoperative complications between the two groups

Postoperative complications	Observation group (n=40)	Control group (n=40)	χ^2	P
Irritating dry cough	1 (2.50%)	2 (5.00%)	0.346	0.556
Hemoptysis	1 (2.50%)	2 (5.00%)	0.346	0.556
Phlegm retention	3 (7.50%)	3 (7.50%)	0.000	1.000
Infection	1 (2.50%)	1 (2.50%)	0.000	1.000
Restenosis	1 (2.50%)	1 (2.50%)	0.000	1.000
Hemorrhage	0 (0.00%)	1 (2.50%)	0.001	0.972
Total case	7 (17.50%)	10 (25.0%)	0.672	0.412

and it acts on the superficial lesions. This avoids tissue adhesion and perforation after surgery. However, due to its superficial effects, APC has been deemed to be ineffective at cleansing deeper lesions [22]. Cryotherapy is performed using ultra-low temperature technology to manage lesions. The use of cryotherapy has shown to reduce leukocyte infiltration and inflammation of lesions [23]. The combination of APC and cryotherapy is synergistic in enhancing therapeutic effects. This is mainly because it is prone to bleeding when the probe is removed during cryotherapy. APC is effective in hemostasis. Moreover, the combination of APC and cryotherapy has shown better therapeutic effects [24]. Additionally, APC can act on only the superficial lesions and is ineffective in cleansing deeper lesions, while high-frequency radio-wave electrosurgery can overcome the defects of APC. Thus, it is more effective in cleansing deeper lesions [25]. Using the triple therapy of APC, high-frequency radio-wave electrosurgery, and cryotherapy, affected lesions are first coagulated and cut by the mixed mode of coagulation and cutting. Next, the necrotic tissues in the local lesion are cleansed by repeated freeze-thaw. Low temperatures reduce the necrotic tissue and granuloma formation after thermal treatment. Therefore, this triple surgery method is beneficial in improving hypoxia and pulmonary function, providing an unobstructed respiratory tract for a longer time. Restenosis also occurs rarely in the patients [26]. In the present study, the triple combination of APC, high-frequency radio-wave electrosurgery, and cryotherapy, compared with monotherapy high-frequency radio-wave electrosurgery, was performed to treat patients with tracheal stenosis. Present results suggest that triple therapy had better therapeutic effects. Greater increases in the values for PO_2 and SaO_2, along with greater decreases in the values for PCO_2, were seen in the observation group, compared to the control group. Differences were statistically significant. Patients in the observation group and control group differed significantly in dyspnea severity and airway obstruction grades. This may be related to the fact that the triple combination of APC, high-frequency radio-wave electrosurgery, and cryotherapy complemented the advantages of each.

The triple combination of APC, high-frequency radio-wave electrosurgery, and cryotherapy has the following advantages [24]. First, APC and high-frequency radio-wave electrosurgery result in quick resections of the affected tissues. Cryotherapy is more effective in freezing and cleansing the necrotic tissues after thermal ablation. Second, it is prone to bleeding when the affected tissues are cut using cryotherapy. However, the use of APC plus high-frequency radio-wave electrosurgery can stop bleeding rapidly, as APC has a better effect of hemostasis. Third, for some polypoid lesions, after resection of the lesions with the use of high-frequency electric snares, the lesion base is managed by cryotherapy, resulting in inhibited proliferation of the lesions and extended time to restenosis. Therefore, in the current study, incidence of complications was lower in the observation group than in the control group. This may be related to effective hemostasis with APC and reduced lesion infections and granuloma formation with cryotherapy.

However, there were some limitations to the current study. The sample size was small. More samples are necessary in future studies. Moreover, the follow-ups were quite short. Extended follow-up periods are necessary, aiming to explore differences between the two groups.

In conclusion, the triple combination of APC, high-frequency radio-wave electrosurgery, and cryotherapy, along with the use of bronchoscopes associated with effective clearance of tracheal stenosis, improved pulmonary function. Moreover, this method reduced postoperative complications. Therefore, the present triple therapy method is worthy of generalization in clinical practice.

Acknowledgements

The present work was supported by the National Natural Science Foundation of China for Study on the Role and Regulation of Histone Deacetylase 2 in Tracheal Stenosis after Tracheal Injury (No. 81760001).

Disclosure of conflict of interest

None.

Address correspondence to: Guangnan Liu, Department of Respiratory Medicine, The Second Affiliated Hospital of Guangxi Medical University, No. 166 Daxuedong Road, Nanning 530007, Guangxi Zhuang Autonomous Region, China. Tel: +86-15994316399; E-mail: liuguangnan93j8@163.com

References

[1] Mondoni M, Radovanovic D, Sotgiu G, Di Marco F, Carlucci P, Centanni S and Santus P. Interventional pulmonology techniques in elderly patients with comorbidities. Eur J Intern Med 2019; 59: 14-20.

[2] Shah PL and Herth FJF. Progress in interventional pulmonology. Respiration 2018; 95: 287-288.

[3] Mudambi L, Miller R and Eapen GA. Malignant central airway obstruction. J Thorac Dis 2017; 9 Suppl 10: S1087-S1110.

[4] Sarmand N and Gompelmann D. Interventional bronchoscopy: what is possible and what makes sense? Dtsch Med Wochenschr 2018; 143: 1097-1102.

[5] Sabath BF and Ost DE. Update on airway stents. Curr Opin Pulm Med 2018; 24: 343-349.

[6] Lee BR, Oh IJ, Lee HS, Ban HJ, Kim KS, Kim YI, Lim SC, Kim YC, Park YW and Kwon YS. Usefulness of rigid bronchoscopic intervention using argon plasma coagulation for central airway tumors. Clin Exp Otorhinolaryngol 2015; 8: 396-401.

[7] Özdemir M and Balevi A. Successful treatment of classic kaposi sarcoma with long-pulse neodymium-doped yttrium aluminum garnet laser: a preliminary study. Dermatol Surg 2017; 43: 366-370.

[8] Chinese Thoracic Society. Expert consensus on interventional diagnosis and treatment of benign central airway stenosis by bronchoscopy. Chin J Tuber Respir Dis 2017; 40: 408-418.

[9] Jia LI, Zhang HG and Zhu XH. Clinical study of high-frequency electric knife through fiberoptic bronchoscopy in the treatment of central airway tumor. Chinese Journal of Mod Drug Appl 2017; 11: 16-17.

[10] Dai Y, Tian Q, Yang Z, Zhao W, Wang H, Shaohui HU, Fei QI, Lina LI and Chen L. Argon plasma coagulation in treatment of patients with central airway obstruction under bronchoscope: an analysis of 72 cases. Acad J Chin Pla Medical School 2015.

[11] Hohenforst-Schmidt W, Zarogoulidis P, Steinheimer M, Schneider T, Benhassen N, Rupprecht H and Freitag L. A retrograde y-stenting of the trachea for treatment of mediastinal fistula in an unusual situation. Ther Clin Risk Manag 2017; 13: 655-661.

[12] Tsuboi R, Oki M, Saka H, Kogure Y, Oka S, Nakahata M, Hori K, Murakami Y, Ise Y, Moursi Ahmed SN, Tao M and Kitagawa C. Rigid bronchoscopic intervention for endobronchial metastasis of renal cell carcinoma. Respir Investig 2016; 54: 250-254.
[13] Wang H, Shu S, Li J and Jiang H. Management of liver cancer argon-helium knife therapy with functional computer tomography perfusion imaging. Technol Cancer Res Treat 2016; 15: 29-35.
[14] Biswas A, Mehta HJ and Sriram PS. Diagnostic yield of the virtual bronchoscopic navigation system guided sampling of peripheral lung lesions using ultrathin bronchoscope and protected bronchial brush. Turk Thorac J 2019; 20: 6-11.
[15] Bolliger CT, Mathur PN, Beamis JF, Becker HD, Cavaliere S, Colt H, Diaz-Jimenez JP, Dumon JF, Edell E, Kovitz KL, Macha HN, Mehta AC, Marel M, Noppen M, Strausz J and Sutedja TG; European Respiratory Society/American Thoracic S. ERS/ATS statement on interventional pulmonology. European respiratory society/American thoracic society. Eur Respir J 2002; 19: 356-373.
[16] Bergler W, Hönig M, Götte K, Petroianu G and Hörmann K. Treatment of recurrent respiratory papillomatosis with argon plasma coagulation. J Laryngol Otol 1997; 111: 381-384.
[17] FRY J. A textbook of medicine in general practice. I. Diseases of the respiratory system. Med World 1963; 99: 99.
[18] Bibas BJ, Cardoso PFG, Salati M, Minamoto H, Luiz Tamagno MF, Terra RM and Pêgo-Fernandes PM. Health-related quality of life evaluation in patients with non-surgical benign tracheal stenosis. J Thorac Dis 2018; 10: 4782-4788.
[19] Shin B, Kim K, Jeong BH, Eom JS, Song WJ, Kang HK and Kim H. Clinical significance of differentiating post-intubation and post-tracheostomy tracheal stenosis. Respirology 2017; 22: 513-520.
[20] Zhang Y, Xin J, Ma Y, Li Q and Liu B. Use of univent tube for intermittent lung isolation during thoracoscopic mediastinal tracheal resection and reconstruction: a case report. Medicine 2017; 96: e8945-e8945.
[21] Ofstead CL, Quick MR, Wetzler HP, Eiland JE, Heymann OL, Sonetti DA and Ferguson JS. Effectiveness of reprocessing for flexible bronchoscopes and endobronchial ultrasound bronchoscopes. Chest 2018; 154: 1024-1034.
[22] Shu L, Hu Y and Wei R. Argon plasma coagulation combined with a flexible electronic bronchoscope for treating foreign body granulation tissues in children’s deep bronchi: nine case reports. J Laparoendosc Adv Surg Tech A 2016; 26: 1039-1040.
[23] Janke KJ, Abbas AE, Ambur V and Yu D. The application of liquid nitrogen spray cryotherapy in treatment of bronchial stenosis. Innovations (Phila) 2016; 11: 349-354.
[24] Chen L, Zhang YY and Yu CX. Argon plasma coagulation combined with CO(2) cryotherapy under bronchoscope for treatment of 40 patients with pulmoconiosis complicated by lung cancer in central airway. Chin J Ind Hyg Occup Dis 2017; 35: 375-377.
[25] Singh A, Pattabhiraman VR, Srinivasan A and Mahadevan S. Dumbbell posterior mediastinal schwannoma invading trachea: multidisciplinary management - weight off the chest. Lung India 2018; 35: 269-272.
[26] Oswald N, Halle-Smith J, Kerr A, Webb J, Agostini P, Bishay E, Kalkat M, Steyn R and Naidu B. Perioperative immune function and pain control may underlie early hospital readmission and 90 day mortality following lung cancer resection: a prospective cohort study of 932 patients. Eur J Surg Oncol 2019; 45: 863-869.