



## Original Article

## Bleeding Complications After Endoscopic Lung Volume Reduction Coil Treatment: A Retrospective Observational Study<sup>☆</sup>



Marcel Simon,<sup>a</sup> Harald Ittrich,<sup>b</sup> Lars Harbaum,<sup>a</sup> Tim Oqueka,<sup>a</sup> Stefan Kluge,<sup>c</sup> Hans Klose<sup>a,\*</sup>

<sup>a</sup> Departamento de Medicina Respiratoria, University Medical Center Hamburg-Eppendorf, Hamburgo, Germany

<sup>b</sup> Departamento de Radiología Diagnóstica e Intervencionista, University Medical Center Hamburg-Eppendorf, Hamburgo, Germany

<sup>c</sup> Departamento de Medicina Intensiva, University Medical Center Hamburg-Eppendorf, Hamburgo, Germany

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## ABSTRACT

**Introduction:** Endoscopic lung volume reduction coil (LVRC) treatment is an option for selected patients with severe emphysema. This study was conducted to determine the incidence of bleeding complications after LVRC treatment, to identify risk factors and to discuss treatment options in cases of hemoptysis which does not resolve spontaneously.

**Methods:** Retrospective observational study conducted in the Department of Respiratory Medicine at the University Medical Center Hamburg-Eppendorf in all subjects in whom LVRC treatment was performed between April 1, 2012 and September 30, 2015.

**Results:** During the study period, 101 LVRC procedures were performed in 62 subjects. Early post-procedural bleeding was encountered in 65.3% of cases. Hemoptysis was significantly more likely to occur in patients receiving acetylsalicylic acid ( $P=0.005$ ). Hemoptysis resolved spontaneously in 98.5% of cases. In the one case (1.5%) with persistent hemoptysis, bronchial artery embolization was successful in terminating bleeding. Hospital stay was significantly prolonged in subjects with hemoptysis ( $P=0.01$ ). No significant differences were found between subjects with or without hemoptysis in terms of chronic obstructive pulmonary disease exacerbations within four weeks after LVRC treatment ( $P=0.18$ ). Late bleeding complications were observed in 3 subjects (3.0%). In 2 of these cases, bronchial artery embolization was performed successfully terminating the bleeding.

**Conclusions:** Self-limiting low volume bleeding is a common finding in the first days after LVRC treatment. However, persistent bleeding may occur in the early post-procedural phase and late after LVRC treatment. In these cases, bronchial artery embolization was a feasible and successful approach to terminating bleeding.

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## Complicaciones hemorrágicas tras el tratamiento endoscópico de reducción del volumen pulmonar con espiral: estudio observacional retrospectivo

## RESUMEN

**Introducción:** El tratamiento endoscópico de reducción del volumen pulmonar mediante espirales (RVPE) es una opción para determinados pacientes con enfisema grave. El estudio se llevó a cabo para determinar la incidencia de complicaciones hemorrágicas tras el tratamiento de RVPE, identificar los factores de riesgo y debatir las opciones terapéuticas en los casos sin resolución espontánea de la hemoptisis.

**Métodos:** Estudio observacional retrospectivo efectuado en el Departamento de Medicina Respiratoria del University Medical Center Hamburg-Eppendorf que incluyó a todos los pacientes sometidos a RVPE entre el 1 de abril del 2012 y el 30 de septiembre del 2015.

## Palabras clave:

Reducción endoscópica del volumen pulmonar  
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\* Corresponding author.

E-mail address: [klouse@uke.de](mailto:klouse@uke.de) (H. Klose).

**Resultados:** Durante el período de estudio se practicaron 101 procedimientos de RVPE en 62 pacientes. Después de la intervención, se observó hemorragia temprana en un 65,3% de los casos. La probabilidad de presentar hemoptisis fue significativamente mayor en los pacientes que recibían ácido acetilsalicílico ( $P=0.005$ ). La hemoptisis se resolvió espontáneamente en un 98,5% de los casos. En el caso de un paciente (1,5%) que presentó hemoptisis persistente, se logró el cese de la hemorragia embolizando la arteria bronquial. La estancia hospitalaria fue significativamente más prolongada en los pacientes que presentaron hemoptisis ( $P=0.01$ ). En cuanto a las exacerbaciones de la enfermedad pulmonar obstructiva crónica, en las 4 semanas siguientes al procedimiento de RVPE no se observaron diferencias significativas entre los pacientes con y sin hemoptisis ( $P=0.18$ ). Tres pacientes (3,0%) presentaron complicaciones hemorrágicas tardías. Dos de estos se sometieron a embolización de la arteria bronquial que puso fin a la hemorragia de manera satisfactoria.

**Conclusiones:** La hemorragia de poco volumen y autolimitada es un hallazgo frecuente en los primeros días después del tratamiento de RVPE. Sin embargo, tanto en los días siguientes a la intervención de RVPE como más adelante también puede aparecer una hemorragia persistente. En estos casos, la embolización de la arteria bronquial fue un abordaje viable y satisfactorio para lograr el cese del sangrado.

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## Introduction

Emphysema is a debilitating chronic pulmonary disease.<sup>1</sup> It is characterized by structural changes in lung parenchyma with consecutive reduction of gas exchange surface, loss of elastic recoil and dynamic hyperinflation leading to dyspnea, limited exercise capacity and reduced quality of life. The condition is incurable and therapeutic options are limited. In selected patients with severe emphysema, lung volume reduction may be considered.<sup>2</sup> However, lung volume reduction surgery, the original procedure, is associated with early morbidity and mortality.<sup>3,4</sup> Over the last decade, sophisticated interventional bronchoscopic procedures for lung volume reduction have been developed, including one-way valves,<sup>5</sup> airway bypass stents,<sup>6</sup> biological lung volume reduction,<sup>7</sup> bronchoscopic thermal vapor ablation,<sup>8</sup> and coils.<sup>9</sup>

Endoscopic lung volume reduction coil (LVRC) treatment was first introduced in 2010.<sup>9</sup> It is a treatment option not only for patients with heterogeneous but also for patients with homogeneous emphysema,<sup>10</sup> and is independent of the presence of collateral ventilation. Beneficial effects of LVRC treatment have been shown for pulmonary function, exercise capacity and quality of life.<sup>10–13</sup> LVRC treatment has also been shown to have a good safety profile.<sup>14,15</sup> Reported adverse events including chronic obstructive pulmonary disease (COPD) exacerbations, pneumonia and pneumothorax were all transient and resolved with routine medical care. Mild and spontaneously resolving hemoptysis was described to be commonly encountered during the first days after LVRC treatment and to occur in up to 75% of cases.<sup>11,15</sup> However, as long-term follow-up data begin to emerge, hemoptysis occurring late after LVRC treatment has also been reported.<sup>15</sup>

Three cases of hemoptysis not resolving spontaneously after LVRC treatment in our department have prompted us to perform this retrospective observational study to determine the incidence of bleeding complications, to identify possible risk factors, and to share our experience in the treatment of patients with hemoptysis which does not resolve spontaneously after LVRC treatment.

## Methods

### Study Design

The study was performed as a retrospective observational trial in the Department of Respiratory Medicine at the University Medical Center Hamburg-Eppendorf, Germany. The ethics committee of the Hamburg Chamber of Physicians waived the need to obtain consent for the collection, analysis, and publication of retrospectively obtained and anonymized data for this non-interventional study.

### Data Collection

All cases of LVRC treatment conducted between April 1, 2012 and September 30, 2015 were retrieved from the electronic endoscopic database (Endobase, version 12.0, Olympus, Tokyo, Japan). No cases were excluded from the study. The electronic patient database, including the electronic patient record (Soarian Clinicals, version 3.00 SP3, Cerner Health Services, USA), was subsequently used to retrieve patient characteristics, procedural details, data collected during initial assessment and follow-up visits including expected risk factors for bleeding complications and adverse events. An experienced radiologist (H.I.) re-evaluated all thoracic computed tomography scans for study purposes.

### Risk Factors for Bleeding Complications

Electronic patient records were systematically reviewed for factors expected to put the patient at an increased risk for bleeding complications. These included laboratory parameters (platelet count and international normalized ratio below the normal range), medication (anticoagulants and antiplatelet medication), and signs of right ventricular strain and pulmonary hypertension. Signs of right ventricular strain and pulmonary hypertension were defined as the presence of one or more of the following characteristics: mean pulmonary arterial pressure  $\geq 25$  mmHg measured by right heart catheterization, echocardiographic signs defining a high probability of pulmonary hypertension as defined by the guidelines for the diagnosis and management of pulmonary hypertension,<sup>16</sup> a pulmonary arterial diameter of more than 3 cm, a ratio of right to left atrial diameter of more than 1, a ratio of pulmonary artery to aortic diameter of more than 1, and reflux of intravenous contrast into the inferior vena cava seen on computed tomography and an elevated NT-proBNP level.

### Adverse Events

The electronic patient record was systematically reviewed for adverse events. As part of routine standard care, patients were questioned after LVRC treatment about changes in dyspnea and the occurrence of hemoptysis or chest pain on a daily basis during hospitalization and at each outpatient visit. Any complications encountered during the bronchoscopic procedure, pneumothorax, respiratory infections, COPD exacerbations within four weeks of the procedure, pleuritic pain associated with the position of coils and hemoptysis were considered adverse events. Hemoptysis was classified as mild if bleeding did not exceed 100 mL within 24 h, moderate if 3 or more bleeding episodes of more than

100 mL occurred within 24 h within 1 week, and severe if bleeding exceeded 300 mL within 24 h.

### Endoscopic Lung Volume Reduction Coil (LVRC) Treatment

In our department, all patients with severe emphysema are thoroughly evaluated, and the possibility of lung volume reduction surgery, different techniques of endoscopic lung volume reduction and lung transplantation are evaluated. Criteria indicating endoscopic lung volume reduction include emphysema, symptoms despite optimal medical therapy and pulmonary rehabilitation, severe or very severe airflow obstruction as defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD), hyperinflation with a residual volume of more than 175% predicted value and the absence of excessive sputum or active infection. To select the appropriate technique, the distribution of emphysema, the degree of tissue destruction and the evaluation of interlobar collateral ventilation are taken into account. Criteria favoring LVRC treatment include homogeneous emphysema, the presence of collateral ventilation in patients with heterogeneous emphysema, and tissue destruction of less than 75%.

LVRC treatment is performed according to a standardized protocol under general anesthesia using a flexible video bronchoscope (BF1TQ180, Olympus, Tokyo, Japan) passed through an 8.5 mm endotracheal tube or an 8.5 mm rigid bronchoscope. The target lobe is selected after evaluation of chest computed tomography images. The procedure is performed under fluoroscopic guidance. The flexible bronchoscope is advanced to visualize the subsegmental divisions of the bronchial tree of the targeted lobe. The guide wire is introduced through the working channel of the bronchoscope to the desired position and the delivery catheter is advanced over the wire. Appropriate coil size (100 mm, 125 mm or 150 mm) is determined by counting the number of radiopaque markers visible on the guide wire before its removal. The coil (PneumRx, Mountain View, CA, USA) is then loaded into the delivery system, advanced through the catheter by pushing the grasper and deployed by retracting the sheath. Finally, the grasper is opened and the coil released. The aim is to place 10 coils per treated lobe. All patients receive a 7-day course of 50 mg of prednisolone administered orally once a day starting 2 days before the bronchoscopic procedure.

### Data Analysis

Categorical variables are presented as absolute numbers and percentages. Continuous variables are presented as mean and standard deviation if normally distributed and as median and range if not normally distributed. Comparisons between subgroups were performed using the *t* test or the Mann–Whitney *U* test for metric data and the chi-square test for categorical data. A two-sided *P*-value below 0.05 was considered significant. The software used for statistical analyses was SPSS version 21.0 (SPSS Inc., Chicago, IL, USA).

## Results

### Case Selection

Between April 1, 2012 and September 30, 2015 a total of 101 LVRC procedures were performed in 62 patients. All of these cases were included in the study.

### Characteristics of Subjects

Of the 62 subjects included in the study, 45.2% were female and 54.8% were male. Mean age was 63±9 years. Emphysema was homogeneous in 61.3% and heterogeneous in 38.7% of cases. In total,

14.5% of subjects had severe airflow obstruction, and 85.5% of cases had very severe airflow obstruction, as defined by the GOLD criteria. All subjects were on optimal medical therapy for their pulmonary disease. Additionally, 46.8% of subjects were on long-term oxygen therapy due to chronic hypoxemia and 22.6% on intermittent non-invasive ventilation due to chronic ventilatory failure.

In total, 48.4% of subjects exhibited signs of right ventricular strain and pulmonary hypertension; 38.7% of subjects were receiving acetylsalicylic acid. Platelet counts and international normalized ratio were within normal limits in all cases. Patient characteristics are summarized in Table 1.

### Characteristics of the Endoscopic Lung Volume Reduction Coil (LVRC) Procedure

LVRC treatment was performed bilaterally in 39 subjects (62.9%) and unilaterally in 23 subjects (37.1%). Mean length of hospital stay after the procedure was 6.4±2.3 days. Characteristics of the endoscopic lung volume reduction procedure are shown in Table 2.

### Early Bleeding Complications

During hospitalization after the LVRC procedure, hemoptysis occurred in 65.3% of cases. Hemoptysis was classified as mild in all cases. Onset occurred after a median of 1 day (range 0–6 days) following the procedure and lasted for a median of 3 days (range 0–20 days). Hemoptysis was significantly more likely to occur in subjects receiving acetylsalicylic acid (*P*=0.005), and after treatment of the upper lobes compared to after treatment of the lower lobes (*P*=0.008). There was no significant correlation between the occurrence of hemoptysis and signs of right ventricular strain and pulmonary hypertension (*P*=0.89), the presence of bronchiectasis (*P*=0.71) or whether emphysema was heterogeneous or homogeneous (*P*=0.94).

In all cases bleeding was low volume and did not lead to detectable functional impairment. Hemoptysis resolved spontaneously in most cases (98.5%). The discontinuation of acetylsalicylic acid in 6.1% of cases with hemoptysis or the performance of bronchoscopy in 24.2% of these cases are not believed to have contributed to the cessation of bleeding. Bronchoscopy visualized old blood in the segmental bronchi of the lobe previously treated in all of these cases. The blood was removed. There was no sign of active bleeding during any of the bronchoscopic examinations. In one case (1.5%), hemoptysis persisted despite the discontinuation of acetylsalicylic acid and the bronchoscopic instillation of vasoconstrictive agents. After 13 days of persistent hemoptysis, permanent embolization of the bronchial artery was performed leading to the cessation of bleeding. Mean duration of hospitalization after the LVRC procedure was significantly longer in subjects with hemoptysis compared with subjects without hemoptysis (6.8±2.4 days vs 5.7±1.7 days, *P*=0.01). There was no correlation between the occurrence of hemoptysis and an exacerbation of COPD within four weeks of LVRC treatment (*P*=0.18).

### Late Bleeding Complications

Three subjects (3.0%) presented hemoptysis after the initial hospitalization for LVRC treatment, requiring re-admission to hospital. Bleeding commenced at 69, 139 and 195 days after LVRC treatment, respectively. In one subject, bleeding was associated with infection and resolved after antibiotic treatment. One of the other two subjects had been started on a vitamin K antagonist due to newly diagnosed atrial fibrillation. The third subject was receiving acetylsalicylic acid, but the actual cause of bleeding remained obscure. In the two latter subjects, bleeding did not cease after the discontinuation of anticoagulation or acetylsalicylic acid. Bronchial

**Table 1**  
Characteristics of Subjects.

Characteristic	Values
<b>Number of subjects [n]</b>	62
<b>Age [years]</b>	63±9
<b>Gender</b>	
Female	28 (45.2%)
Male	34 (54.8%)
<b>Emphysema [n]</b>	
Homogeneous emphysema	38 (61.3%)
Heterogeneous emphysema	24 (38.7%)
Alpha-1-antitrypsin deficiency	4 (6.5%)
<b>Treatment for lung disease [n]</b>	
Beta <sub>2</sub> -agonist	61 (98.4%)
Anticholinergic	61 (98.4%)
Inhaled corticosteroid	47 (75.8%)
Systemic corticosteroid	17 (27.4%)
Theophylline	15 (24.2%)
Roflumilast	15 (24.2%)
Acetylcysteine	6 (9.7%)
Ambroxol	2 (3.2%)
Long-term oxygen therapy	29 (46.8%)
Intermittent non-invasive ventilation	14 (22.6%)
<b>Listed for lung transplantation [n]</b>	16 (25.8%)
<b>Antiplatelet medication [n]</b>	
Acetylsalicylic acid	24 (38.7%)
<b>Laboratory parameters</b>	
Platelet count [ $\times 10^9/L$ ]	296±85
International normalized ratio (INR)	1.0±0.1
Activated partial thromboplastin time (aPTT) [s]	29±3
<b>Signs of right ventricular strain and pulmonary hypertension [n]</b>	30 (48.4%)
Right heart catheterization	
Mean pulmonary arterial pressure $\geq$ 25 mmHg	8 (12.9%)
Transthoracic echocardiography	
Peak tricuspid regurgitation velocity $>$ 3.4 m/s	2 (3.2%)
Peak tricuspid regurgitation velocity between 2.9 and 3.4 m/s and presence of additional signs suggesting pulmonary hypertension according to <sup>16</sup>	1 (1.6%)
Computed tomography	
Pulmonary arterial diameter $>$ 3 cm	9 (14.5%)
Ratio of right to left atrial diameter $>$ 1 <sup>a</sup>	7 (11.3%)
Ratio of pulmonary arterial to aortic diameter $>$ 1 <sup>a</sup>	8 (12.9%)
Reflux of intravenous contrast into the inferior vena cava <sup>a</sup>	1 (1.6%)
Elevated NT-proBNP level	8 (12.9%)
<b>Bronchiectasis detected on computed tomography [n]</b>	7 (11.3%)
<b>Blood gases</b>	
PaO <sub>2</sub> [mmHg]	67±10
PaCO <sub>2</sub> [mmHg]	42±7
pH	7.44±0.03
Hypoxemia (PaO <sub>2</sub> $<$ 60 mmHg)	34 (54.8%)
Hypercapnia (PaCO <sub>2</sub> $>$ 45 mmHg)	19 (30.6%)
<b>Pulmonary function tests before LVRC treatment</b>	
FEV <sub>1</sub> /VC [%]	33±7
FEV <sub>1</sub> [L]	0.6±0.2
Severe airflow limitation (30% $\leq$ FEV <sub>1</sub> $<$ 50% predicted)	9 (14.5%)
Very severe airflow limitation (FEV <sub>1</sub> $<$ 30% predicted)	53 (85.5%)
VC [L]	2.0±0.8
TLC [L]	7.8±1.1
RV [L]	5.7±1.0
RV/TLC [%]	74±8
Raw <sub>tot</sub> [kPa s/L]	1.3±0.5
sRaw <sub>tot</sub> [kPa s]	8.4±4.1
TLCO [mL/min/kPa]	2.8±1.8
<b>6-minute walk test [m]</b>	261±114

Values are given as mean and standard deviation or as absolute numbers and percentages.

<sup>a</sup> Analyzed only in the 21 computed tomography scans with intravenous contrast. Abbreviations: aPTT, activated partial thromboplastin time; LVRC, endoscopic lung volume reduction coil; FEV<sub>1</sub>, forced expired volume in one second; INR, international normalized ratio; PaO<sub>2</sub>, partial pressure of oxygen in arterial blood; PaCO<sub>2</sub>, partial pressure of carbon dioxide in arterial blood; Raw<sub>tot</sub>, total airway resistance; RV, residual volume; sRaw<sub>tot</sub>, specific total airway resistance; TLC, total lung capacity; TLCO, transfer factor of the lung for carbon monoxide; VC, vital capacity.

**Table 2**  
Characteristics of Endoscopic Lung Volume Reduction Procedure.

Characteristic	Values
<b>Number of procedures</b>	101
<b>Treated lobe</b>	
Right upper lobe	45 (44.6%)
Left upper lobe	36 (35.6%)
Right lower lobe	11 (10.9%)
Left lower lobe	9 (8.9%)
<b>Coils</b>	
Median total number of coils	10 (range 8–11)
Size 100 mm	6 (range 1–10)
Size 125 mm	4 (range 1–8)
Size 150 mm	2 (range 1–4)
<b>Adverse events</b>	
Hemoptysis	66 (65.3%)
Exacerbation of chronic obstructive pulmonary disease within 4 weeks of LVRC treatment	22 (21.8%)
Dental injury during bronchoscopy	1 (1.0%)
Pleuritic pain due to position of coil	1 (1.0%)

Values are given as mean and standard deviation if normally distributed, as median and range if not normally distributed or as absolute numbers and percentages.

artery embolization was performed in both subjects, successfully terminating the bleeding.

## Discussion

In this retrospective observational study, we analyzed bleeding complications after 101 endoscopic lung volume reduction coil treatment procedures. Hemoptysis occurring early after the LVRC procedure was observed in 65.3% of cases. Bleeding was low volume in all cases and resolved spontaneously within a few days in most cases (98.5%). However, 1 case of persistent hemoptysis occurred in the early phase and 3 cases of bleeding late after LVRC treatment. In all cases with hemoptysis that did not resolve spontaneously, bronchial artery embolization was successful in terminating the bleeding.

Mild hemoptysis has been reported as a common event after LVRC treatment. In all cases reported to date, hemoptysis was self-limiting. In a pilot study by Herth et al. including 11 subjects and 21 procedures, no bleeding complications were observed. However, patients on antiplatelet agents were excluded from participation in this study.<sup>9</sup> In a study by Slebos et al. including 16 subjects and 28 procedures, the most common adverse event was mild hemoptysis during the first days after the LVRC procedure occurring in 12 subjects and 21 procedures (75.0%) which resolved spontaneously in all cases. No bleeding episodes were observed later than one month after the procedure.<sup>11</sup> In a randomized controlled trial published by Shah et al. which included 23 subjects treated with LVRC, no hemoptysis was reported. However, in that study, hemoptysis was only recorded if it classified as a severe adverse event.<sup>12</sup> In a study by Deslee et al. including 60 subjects, hemoptysis within one month of the procedure was reported in 35 subjects (58%), within 1–6 months after the procedure in 3 subjects, and within 6–12 months after the procedure in 2 subjects, respectively. In one case (1.7%), hemoptysis was classified as a severe adverse event.<sup>13</sup> In a study by Klooster et al. including 10 subjects, slight hemoptysis was reported in 5 subjects (50%).<sup>10</sup> In a study by Kontogianni et al. including 26 subjects, light hemorrhage was seen in 6 subjects (23.1%).<sup>17</sup> In a study reported by Hartmann et al. in 38 subjects, 74% of subjects exhibited very mild hemoptysis just after the procedure. However, one case of more severe but spontaneously resolving hemoptysis was reported at the 3-year follow-up.<sup>15</sup> In the recently published REVOLENS trial, one case (2%) of hemoptysis within 30 days of the procedure was classified as a severe adverse event.

Mild self-resolving hemoptysis within 30 days of the procedure was the most frequent non-serious adverse event.<sup>18</sup> In our study, mild post-procedural hemoptysis was observed after 65.3% of LVRC procedures. Re-admission to hospital was required in 3 cases of hemoptysis occurring late after the LVRC procedure.

As with transbronchial biopsy,<sup>19</sup> the risk of bleeding after LVRC treatment may be increased in patients with pulmonary hypertension. In prospective studies on LVRC treatment, patients with known or suspected severe pulmonary hypertension were therefore excluded from participation.<sup>9–13</sup> In our study, there was no significant correlation between the occurrence of hemoptysis and the presence of signs of right ventricular strain and pulmonary hypertension. However, it has to be noted that none of the subjects showed any signs or suspicion of severely elevated pulmonary arterial pressure. Accordingly, a study by Diaz-Guzman et al. showed that in patients with mild to moderate pulmonary hypertension, transbronchial lung biopsy was not associated with an increased risk of hemorrhage.<sup>20</sup>

The fact that hemoptysis was significantly more likely to occur in subjects on acetylsalicylic acid in our study suggests that antiplatelet treatment should probably be discontinued prior to LVRC treatment if possible. This may help reduce the incidence of early hemoptysis and shorten the duration of hospital stay. However, it should be noted that in two cases of hemoptysis that did not spontaneously resolve, one occurring early and one late after LVRC treatment, discontinuing acetylsalicylic acid did not lead to the cessation of bleeding. This study was not designed to provide definitive answers as to whether antiplatelet treatment should be discontinued prior to LVRC treatment and if it plays a role in non-spontaneously resolving hemoptysis. Prospective studies including more subjects will be needed to address this issue.

While the site of bleeding in visible endoluminal lesions is accessible to bronchoscopic treatment, when bleeding occurs in peripheral areas of the lung, bronchoscopic options are limited to cold saline lavage, the topical application of vasoconstrictive agents or temporary isolation of the area containing the bleeding site by blockage of the respective bronchial lumen.<sup>21</sup> Stabilizing the patient in this way, allows for the treatment of the underlying pathology or as bridge to bronchial artery embolization or surgery. Bronchoscopy, which was performed in 24.2% of cases with hemoptysis in our study confirmed that bleeding after LVRC treatment originated as expected from the periphery of the previously treated lobe. Bronchoscopy was useful to clear bloody secretions from the bronchial tree, but was otherwise not helpful for the treatment of its underlying cause.

Bronchial artery embolization has been shown to be safe and effective in a variety of settings including acute major and chronic recurrent hemoptysis in patients with bronchiectasis, tuberculosis and lung cancer,<sup>22</sup> non-massive hemoptysis in cystic fibrosis,<sup>23</sup> mild, moderate and severe hemoptysis in acute infection, tuberculosis, bronchiectasis and tumors,<sup>24</sup> as well as moderate and massive hemoptysis in patients with tuberculosis and malignancy.<sup>25</sup> Three subjects in our study were treated with bronchial artery embolization for hemoptysis not resolving spontaneously after LVRC treatment. In all of these subjects, bronchial artery embolization successfully terminated the bleeding. Apart from severe bleeding requiring immediate intervention, the specific indications and the ideal timing of bronchial artery embolization in mild hemoptysis after LVRC treatment remain to be defined. Mild hemoptysis in the immediate post-procedure phase was seen to be usually self-limiting. Treatable underlying causes such as acute infection should also be ruled out. Bhalla et al. reported on the use of bronchial artery embolization in patients with mild hemoptysis that was recurrent, not controlled by medical therapy, or that limited quality of life.<sup>24</sup>

The study has some methodological limitations. The interpretation of the results is limited by potential biases introduced by the retrospective study design. Minor complications may have been missed due to incomplete documentation. However the follow-up of patients after LVRC treatment in our department is standardized, so we believe it unlikely that a relevant number of adverse events was missed. Because of their clinical relevance, we are especially confident that all severe incidents or persistent hemoptysis were fully documented at the time of their occurrence and were therefore not missed in the retrospective analysis. Furthermore, our results are only applicable to patients with similar characteristics, and it is therefore important to remember that 38.7% of subjects in this study were on antiplatelet medication.

## Conclusions

Mild hemoptysis was a common finding in the first days after endoscopic lung volume reduction coil treatment. Hemoptysis was significantly more likely to occur in subjects on acetylsalicylic acid. There was no correlation between the occurrence of hemoptysis and the presence of signs of non-severe pulmonary hypertension. Bleeding was low volume in all cases and self-limiting in most cases. However, persistent bleeding was observed in the early phase and late after endoscopic lung volume reduction coil treatment. In these cases, bronchial artery embolization was a feasible and successful approach to terminate the bleeding.

## Authors' Contributions

M.S., T.O. and H.K. made substantial contributions to the conception and design of the study, as well as to the acquisition, analysis and interpretation of data. H.I., L.H. and S.K. made substantial contributions to the analysis and interpretation of data. M.S., S.K. and H.K. drafted the submitted article. H.I., L.H. and T.O. revised it critically for important intellectual content. All authors read and approved the final manuscript.

## Conflict of Interests

M.S. and H.K. declare that they serve as advisors for PneumRx and have received honoraria for talks and workshops.

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