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Right middle lobe syndrome after upper lobectomy: Role of the bronchial angle

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Abstract

Background: Right middle lobe syndrome is part of a spectrum of relatively rare but serious conditions that may occur following right upper lobectomy. We aimed to assess whether the preoperative middle lobe bronchial angle on CT predicted patients at risk of developing middle lobe syndrome.

Method: All patients who had a complete upper lobectomy over 4 years were retrospectively reviewed for clinical and imaging findings of middle lobe syndrome. Patients with previous lung surgery, preoperative chemo- or radiation therapy, or more extensive surgical resection were excluded. Patient demographics and symptoms, the surgical, pathologic and bronchoscopy reports, and pre- and post-operative chest imaging, to include 3D CT reconstructions and measurements of the middle lobe angles in a subset of patients, were retrospectively reviewed.

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Authors' note

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Supplemental material

Supplemental material for this article is available online.

Result: One hundred and twenty-eight patients met inclusion criteria. Ten (8%) had middle lobe syndrome based on symptoms and imaging features. Eight had severe middle lobe consolidation. Two had postoperative onset of wheezing, with middle lobe bronchial abnormality on CT. The pre- and postoperative middle lobe bronchial angles of 14 patients without middle lobe syndrome were compared to 10 patients with middle lobe syndrome. The middle lobe bronchus was completely obliterated postoperatively and could not be determined in 1 patient. There was no significant difference between the pre- and postoperative angles in patients with or without middle lobe syndrome.

Conclusion: Middle lobe syndrome occurred in 8% of patients with right upper lobectomy. The preoperative middle lobe bronchial angle did not predict patients at risk for developing middle lobe syndrome.

Introduction

Right middle lobe (RML) torsion and RML syndrome (RMLS) are not well understood and are likely multifactorial, underreported, and part of a spectrum of relatively rare and potentially rapidly fatal complications that may occur following right upper lobe (RUL) lobectomy.[1] Clinical features of torsion and RMLS are nonspecific, typically begin on postoperative day 1, and may include dyspnea, fever, chest pain, cough, hypoxia, tachypnea, and tachycardia.[2] However, patients may be asymptomatic.[1]

With RML torsion, the lobe twists around its bronchovascular pedicle, which may obstruct the airway and cause vascular compromise and ischemia. Imaging features may manifest as rapid consolidation of the lobe, “bulging” of the reoriented fissure, twisting of hilar structures, acute truncation of the pulmonary artery and diminished enhancement on contrast-enhanced computed tomography (CT).[3] Lobar torsion typically requires emergent reexploration, with derotation (detorsion) and pneumopexy when feasible,[4] or resection of nonviable lung.[2,5]

The pathophysiology of medical RML atelectasis was described by Graham et al. in 1948,[6] with enlarged lymph nodes extrinsically compressing the RML bronchus, in a patient with chronic cough, hemoptysis and recurrent infection. Based on a report by Ueda et al.,[7] the postsurgical name RMLS was adopted for a similar scenario that develops after RUL lobectomy (RULL) and consists of RML atelectasis and/or RML bronchial kinking, with or without respiratory symptoms. With RMLS, the RML bronchus, with its narrow diameter, may twist or kink as the RML ascends and rotates to fill the RULL space, without vascular compromise. Similarly, RMLS has been reported as a wedge-shaped consolidation along with the upper right aspect of the mediastinum, which may be sharply demarcated laterally by the reoriented minor fissure,[3] and as progressive RML consolidation. The RML bronchus may be kinked or obliterated on CT. Affected patients may need repeat bronchoscopic dilations, bronchial stent placement, or RML lobectomy.

Nonaka et al.[8] studied a rabbit model and found a significant change in the angle between the RML bronchus and bronchus intermedius after RULL, especially in the coronal plane. The authors also observed that deformation of the RML bronchial orifice correlated with decreased volume of the RML. Inners et al.[9] found that the RML inherently had decreased or ineffective collateral ventilation, which may predispose to atelectasis.

Considering that the orientation of the RML bronchus may affect the risk of RMLS, we hypothesized that an obtuse downward-sloping RML bronchial angle may predispose the bronchus to narrow or kink as the RML migrates to fill the lobectomy space. The altered 3-dimensional (3D) configuration of the airway and dynamic changes during the ventilatory phases may further facilitate atelectasis. We aimed to determine whether the preoperative RML bronchial angle measured on CT predicted patients at risk for RMLS following RULL.

Material/patients and methods

We retrospectively queried the electronic medical records and cancer tumor registry from our two teaching hospitals for patients who had undergone complete RULL via multi-port video-assisted thoracoscopic surgery (VATS) or thoracotomy from January 1, 2010, to December 31, 2013 (48 months), typically for early-stage lung cancer. The terms “right upper lobectomy” and “right upper lobe lobectomy” were queried. The study was approved by our institutional review board.

Patients who had partial RULL, more extensive surgical resection beyond RULL, sleeve RULL, previous lung resection, or preoperative chemotherapy or radiation therapy were excluded. Although the presence of complete fissures was not evaluated, patients with surgical sutures in the RML or right lower lobe (RLL) on postoperative CT, possibly from stapling of an incomplete fissure or more extensive lung surgery, were excluded. Patients were excluded when relevant pre- or postoperative imaging was not available.

Patient demographics and characteristics, to include clinical, surgical, and imaging features and outcomes, operative notes, reports of surgical pathology, tumor stage, and pulmonary function testing and all relevant pre- and post-operative chest radiographs and CTs and the reports were retrospectively reviewed. Patients were selected based on RML consolidation that persisted on radiograph beyond postoperative day 5 or day of discharge or manifested on CT as consolidation or bronchial kinking. The RML bronchial angles of patients with RMLS were compared to a random cohort without RMLS, selection of which was also based on the best quality of preoperative thin-section CTs and reconstructions. Measurements were not performed on all 128 patients due to the complexity of the measurements, the time commitment and less than optimal quality of some preoperative positron emission tomography CTs and CTs with 4–5 mm source images. Bronchoscopy reports from patients with suspected RMLS were reviewed. The time from RULL to the first postoperative CT and to the first postoperative bronchoscopy was recorded.

All imaging was independently interpreted by a chest radiologist with 25 years of experience. Although exact quantification was not possible, postoperative RML atelectasis or consolidation on chest radiograph and CT were visually scored to reflect the range of progressive RML involvement on the day of discharge or at the time of CT. Grade 0 reflected normal aeration of the reoriented RML, while grades 1–3 represented progressive atelectasis and/or consolidation, with grade 3 representing complete RML consolidation.

Postoperative narrowing, distortion, kinking or obliteration of the RML and/or segmental bronchi, the bronchus intermedius and/or RLL bronchus on CT was recorded.

On an independent Windows 7 CT workstation, using the Vitrea Enterprise Suite web-based application software, the axial, coronal, sagittal and 2-dimensional (2D) oblique CT and/or 3D reconstructions of the airways were analyzed synchronously to optimize measurement of the RML angle, as shown in Figures 1–3. Due to inherent anatomic variations, the RML bronchial angle frequently could not be measured in a single predictable projection. Manipulating a composite of 2D, and in some cases 3D CT projections when needed, a vector was placed in the near center of the lumens of the bronchus intermedius and the RML bronchus, and the RML bronchial angle was triangulated and measured (Figure 1), before and after RULL, in patients with RMLS and selected patients without RMLS. RMLS was defined as: 1) Moderate-to-severe persistent RML consolidation (grade 2–3), or 2) RML bronchial kinking or obliteration on CT, in conjunction with new postoperative wheezing on auscultation, intractable cough, recurrent pneumonia, fatigue, and/or dyspnea with progressive decline in pulmonary function. All CT reconstructions were performed by two CT technologists with expertise in chest CT. In addition, the postoperative change in RML angulation and the mean change in angulation between pre- and postoperative CTs were measured and calculated in a similar manner. All CT reconstructions and measurements were reviewed by the chest radiologist.

The RULL surgical approach consisted of division of the inferior pulmonary ligament and lymph node dissection of levels 9, 7, and 11, followed by anterior dissection with division of the upper pulmonary vein, while preserving the middle lobe vein, and dissection of additional lymph nodes, typically levels 10 and 12. The upper trunk of the pulmonary artery was identified, dissected, and divided, followed by dissection and division of the RUL bronchus, and if present, division of the ascending pulmonary artery branch. In most instances, dissection of the fissure was not needed, and RUL was removed after serial stapling of the parenchyma. Intraoperative bronchoscopy was performed in all cases. Instead of routine pneumopexy of the RML to the RLL, while the patient was on two-lung ventilation at normal tidal volume, we intraoperatively assessed the alignment of the RML to the RLL, and if there was evidence of tendency for the RML to twist, then pexy was performed. Our preferred method of fixation was a 2–3 cm long stapling between the RML and RLL, and in addition, RML bronchial patency was assessed via bronchoscopy. Pneumopexy performed on patients in the study group was recorded.

T-tests were conducted to determine whether preoperative RML, postoperative RML, or change in RML angles were associated with RMLS. Statistical significance was defined as p-value <0.05. Analyses were performed using SAS (version 9.4, Cary, NC).

Results

A total of 129 patients met the criteria for complete RULL, without more extensive surgery or preoperative chemo- or radiation therapy. Pulmonary function testing in all patients was satisfactory for lobectomy to be performed. The post-operative chest CT was not available for one patient, who did not develop RMLS. Pre- and postoperative chest radiographs and CTs were available for review in 128 patients. Ten (8%) of patients had RMLS based on moderate to severe persistent RML consolidation (grade 2–3) on chest radiograph that persisted longer than postoperative day 5 ($n = 8$) or new postoperative wheezing on auscultation with RML bronchial kinking on CT ($n = 2$), without atelectasis or consolidation. No patient had torsion or vascular compromise. Patient demographics and characteristics are depicted in Supplementary Table 1. Patient characteristics by right middle lobe syndrome (RMLS) status. Patients with RMLS ($n = 10$) had a mean age of 58.3 years, and four had pneumopexy (40%). The control group ($n = 14$) without RMLS had a mean age of 64.9 years, and two had pneumopexy (14.3%). Of the six patients with RMLS but no pneumopexy (60%), on intraoperative bronchoscopy, the RML bronchus was patent, and the lobes were well expanded, without findings to suggest the risk of RMLS.

On postoperative chest radiographs ($n = 128$), there was grade 0 or no RML consolidation ($n = 66$), grade 1–2 RML consolidation ($n = 54$) that typically resolved within five days, or grade 2–3 severe persistent RML consolidation associated with symptoms ($n = 8$), compatible with RMLS.

In patients with RMLS ($n = 10$), the interval from RULL to the first postoperative CT ranged from 2 to 264 days (Supplementary Table 1). In patients without RMLS ($n = 14$), the interval from RULL to the first postoperative CT ranged from 3 to 310 days. 2D and 3D CTs of the airways of patients with RMLS ($n = 10$) were compared with patients without RMLS ($n = 14$; Table 1). Statistical review (p-value <0.05) revealed no significant differences between the pre- and postoperative RML bronchial angles of patients with or without RMLS. The RML bronchus was obliterated in one case of RMLS and could not be measured.

Postoperative distortion of the airways of patients with RMLS included severe narrowing or obliteration of the RML bronchus ($n = 6$), severe narrowing or obliteration of the medial and/or lateral segments with a patent RML bronchus ($n = 3$), and severe narrowing of the RML and medial and lateral segmental bronchi ($n = 1$) as shown in Figures 1–3. Further, concurrent narrowing, distortion or kinking of the bronchus intermedius ($n = 3$), and/or the RLL bronchus ($n = 2$) were detected.

The interval from RULL to the first postoperative bronchoscopy ($n = 7$) in patients with RMLS ranged from 3 to 476 days. The bronchoscopy performed on day 476 was for routine surveillance at an outside facility. Three patients did not undergo bronchoscopy due to being transferred to another facility ($n = 1$), being lost to follow-up one month after surgery ($n = 1$), or the resolution of symptoms and imaging features of RMLS at five months ($n = 1$). Bronchoscopy revealed severe angulation and occlusion of the RML bronchus ($n = 2$), severe RML stricture and bronchomalacia ($n = 1$), kinking of the RML bronchus and bronchus intermedius ($n = 1$), thick secretions in the RML and RLL ($n = 1$), blood and mucous in the RML medial and lateral segments ($n = 1$), and normal right-sided bronchial anatomy ($n = 1$) on postoperative day 180 after RML consolidation had gradually decreased. Three patients with severe RML bronchial distortion and narrowing had a bronchial stent placed (Supplementary Figure 4). One patient with severe RML stricture, refractory to the placement of two stents, subsequently underwent RML lobectomy.

Discussion

RMLS occurred in 8% of patients in this retrospective cohort (*n* = 128) with RULL. The prevalence of RMLS was concordant with earlier reports. These data showed that the pre-operative RML bronchial angle does not predict patients at risk for developing RMLS after RULL. The pre- and post-operative RML bronchial angles were not significantly different for patients with or without RMLS.

This study represents a univariate analysis of a large cohort of all patients who underwent complete RULL over a 48-month period, with a similar surgical technique. Patients with surgical sutures in the RML or RLL on post-operative CT, possibly due to partial lobar section or stapling that could impair lung reexpansion, were excluded. Of patients with RMLS (*n* = 10), four had pneumopexy (40%) versus the control group without RMLS (*n* = 14), two had pneumopexy (14.3%).

Patients with imaging findings of significant RML atelectasis or consolidation in the postoperative period or those with clinical symptoms, such as wheezing, dyspnea, or recurrent pneumonia, underwent urgent chest CT. Many patients had subsequent chest CTs as part of routine oncologic and clinical surveillance, weeks to months later, at which time, RMLS/bronchial kinking was better depicted. All pre- and postoperative imaging were available, except for the pre-operative CT in one patient who did not develop RMLS. All postoperative imaging was performed within the same hospital system, and all imaging was retrospectively reviewed by an experienced chest radiologist

Progressive increasing volume of RML consolidation typically begins on postoperative day 1 following RULL and should raise the suspicion of RMLS or torsion. However, a significant minority of patients with uncomplicated RULL (*n* = 54, 42%) had mild postoperative RML atelectasis on chest radiographs following RULL that resolved within five days. Bronchial obliteration on CT is nonspecific since it may result from retained mucus or blood.[3] On bronchoscopy, the RML bronchial orifice may be occluded, narrowed, distorted, or tortuous or have a fish mouth configuration.[7,10]

In a retrospective review of 3D CT-bronchography performed on 50 patients following upper lobectomy, Ueda et al.[7] reported bronchial kinking in 42%. A bronchial kink was defined as a bronchial angulation causing obstruction or significant stenosis of the airway, measured as an 80% decrease in the airway diameter at the kink site, as compared to preoperative measurements. Of the 21 patients who met criteria for bronchial kinking, 16 developed symptoms, including shortness of breath (*n* = 16) and persistent cough (*n* = 4). Five patients who met criteria of bronchial kink were asymptomatic. Six patients without bronchial kink complained of similar symptoms. Functional lung volume and forced expiratory volume in the first second were significantly higher in the group with no bronchial kinking.

Different pexy fixation techniques have been described and include interlobar suturing, suturing of the lobe to chest wall structures, and the use of absorptive sheet and fibrin glue or collagen fleece coated with fibrin.[11–13] The risk of developing an air leak from suturing needs to be considered. Another innovative approach to limit displacement of the RML, and to potentially prevent bronchial kinking, consists of using the pericardial fat pad to create a pleural tent to partially fill and reduce the residual RULL space.[1,14] There is no evidence of how effective these methods are in preventing RMLS.

RMLS continues to be a challenging diagnosis. RMLS clinically represents a spectrum of acute severe respiratory distress with complete RML consolidation and bronchial obliteration to one with milder symptoms with almost no lung involvement. There may be a delay in obtaining CT or bronchoscopy relative to the time of onset of symptoms and imaging abnormalities. RML atelectasis or consolidation may not initially be recognized on chest radiograph, and some patients with RMLS, based on symptoms, other comorbidities, or surgeon's preference, may not urgently go to CT. The timing of CT and bronchoscopy and threshold for stent placement were tailored for each patient.

Many factors seem to be involved in postoperative RMLS and RML torsion, without a clearly established causative relationship. Anatomic factors include large complete fissures that prevent collateral air drift, the length or diameter of the RML bronchus, a long lobar vascular pedicle that is more prone to rotate, and a shorter distance from the carina to the RML orifice.[15,16] Surgical factors include the extent of lung and lymph node dissection, stapling of the fissure between the upper and middle lobes, and pexy of the RML to the RLL. It has been proposed that dividing the inferior pulmonary ligament may increase lung mobility and the risk of RMLS,[17] or alternatively and in contradistinction, it may decrease the risk of RMLS by freeing the RLL to move with the RML to fill the lobectomy space. VATS lobectomy has also been implicated due to repeated rotation and manipulation of the RML during dissection of hilar and mediastinal lymph nodes with this approach.[18] Chronic obstructive pulmonary disease[19] may also increase the risk of RML atelectasis after RUL resection.

The treatment of this condition is challenging. Conservative management, bronchoscopic dilation, and RML bronchial stenting have been employed with some success.[20,21] RML lobectomy is the most definitive and effective treatment. Pneumopexy of the RML to the RLL has been reported as a method to prevent torsion/kinking. Wong et al.[22] surveyed thoracic surgeons in the United Kingdom and reported that fixation of the RML to the RLL after RULL was a common practice. It is our practice to assess lung expansion intraoperatively after RUL resection and perform pneumopexy according to the degree of misalignment/torsion between RML and RLL.

Limitations include that this is a retrospective univariate study, and the sample size is limited by the single institution incidence of RMLS, which is low. The control group utilized for comparison was a convenient sample with a small number of patients. The RML bronchial angle may be difficult to measure for the following reasons: 1) Some preoperative chest CTs were reconstructed at 5 mm thickness, which limited the resolution of 2D and 3D reconstructions. 2) Following RULL, as the RML rotates superiorly, the reoriented RML and segmental bronchi may assume a parabolic shape, rather than a sharply demarcated measurable angle. 3) When the RML bronchus is obliterated by angulation or kinking, the angle cannot be accurately measured. 4) 2D and 3D reconstructions of the RML bronchus are tedious to perform, especially following RULL, and may require a significant learning curve. Finally, it may not be practical to measure the RML bronchial angle preoperatively, especially if it may not change the surgical approach for RULL.

Concerning future directions, questions remain as to whether this complication can be predicted preoperatively and prevented during RULL. It is necessary to define the clinical and imaging features and the nuances of the surgical techniques in all patients who develop RMLS following partial or complete RULL. Reporting conservative management, interventional therapies, and complications and the outcomes of patients with RMLS may in turn guide surgical treatment standardization. The use of pre- and postoperative 3D volume-rendered CT reconstructions may also facilitate surgical planning by precisely delineating volumes of the right upper, middle, and lower lobes, defining completeness of fissures, and depicting complex pulmonary vascular aborization and bronchial anatomy.[23,24] Finally, a multivariate analysis of multiple risk factors, to include right lobar volumes and ventilation/perfusion ratios, completeness of fissures, RML bronchial features, variations in body habitus and the chest wall, and surgical techniques, to include pneumopexy, is an important next step to help plan strategies to avoid this complication.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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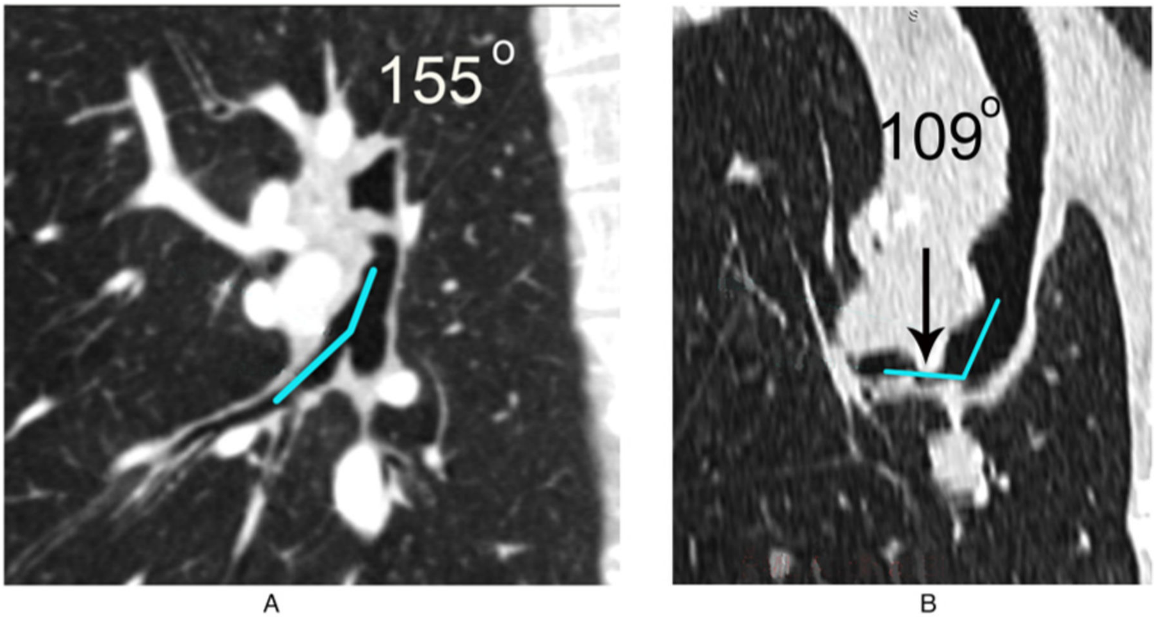

Figure 1.
A and B, A 57-year-old man was asymptomatic after RULL. No bronchoscopy was performed. 2D oblique CTs were performed. A) Preoperatively and B) 3 months after RULL. The RML bronchial angle (angled blue line) decreased from 155° to 109°, with a moderately severe short segment narrowing (arrow) of the RML bronchus. RULL = right upper lobe lobectomy; RML = right middle lobe.

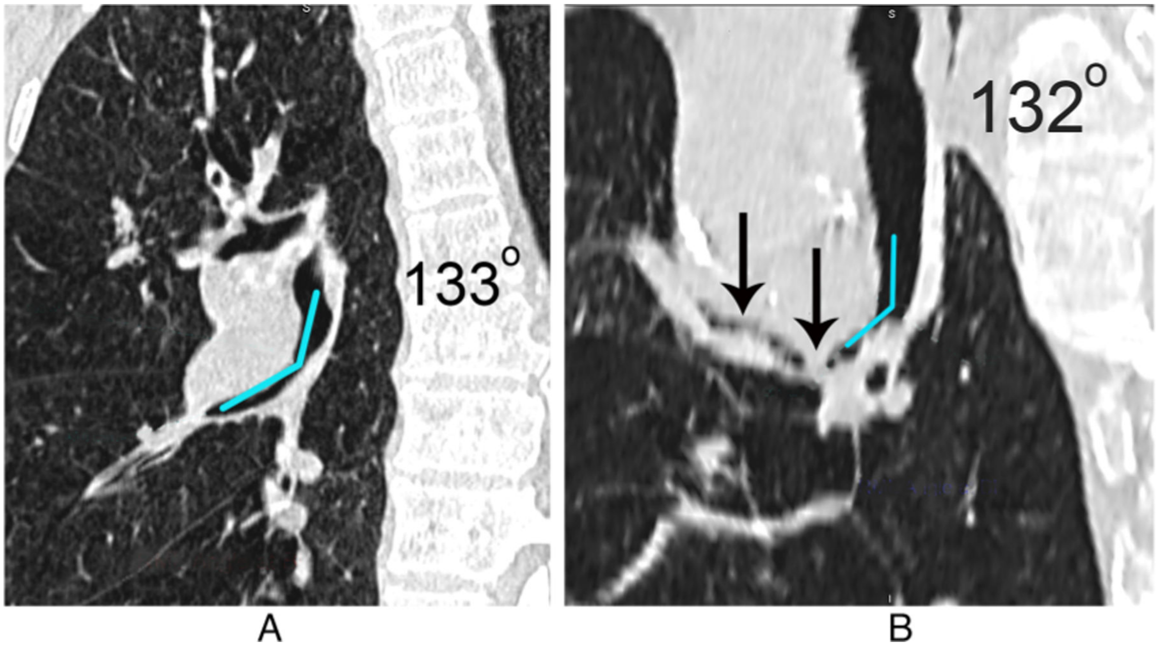

Figure 2.

A and B, A 61-year-old woman manifested with RML atelectasis on day 1 following RULL. Bronchoscopy performed 4 days later revealed copious RML secretions but no RML bronchial angulation. 2D oblique CTs were performed A) preoperatively and B) 9 months after RULL. The RML bronchial angle (angled blue line) was not significantly changed after RULL (133° vs. 132°) despite long segment multifocal narrowing and angulation of the RML and segmental bronchi (arrows), which resolved on chest CT 14 months after RULL. RML = right middle lobe; RULL = right upper lobe lobectomy.

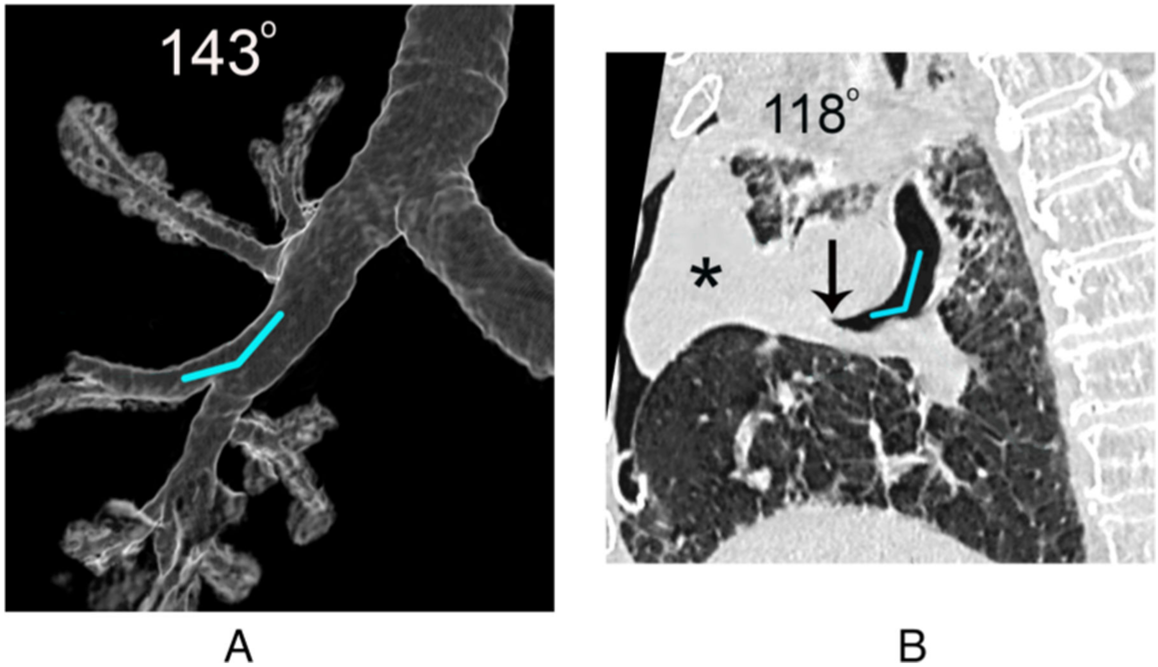

Figure 3.
A and B, A 59-year-old woman manifested with RML atelectasis on day 1 following RULL. No bronchoscopy was performed. A) Preoperative 3D volume rendered CT and B) 2D oblique CTon day 3 after RULL. The RML bronchial angle (angled blue line) decreased from 143° to 118°. Complete occlusion of the segmental and RML (arrow) bronchi and near complete RML consolidation (asterisk) resolved on CT performed 4.5 months later. RML = right middle lobe; RULL = right upper lobe lobectomy.

Table 1.

CT measurements of right middle lobe bronchial angles.

Measurement	Statistic	Total (n = 24)	Without RMLS (n = 14)	With RMLS (n = 10)	p-value*
Preoperative RML angle	Mean ± SD	132.4 ± 8.5	131.4 ± 8.4	133.9 ± 8.7	0.48
	Median (IQR)	131.0 (10.0)	130.0 (9.0)	133.5 (11.0)	
Postoperative RML Angle†	Mean ± SD	116.9 ± 12.5	113.9 ± 11.7	121.6 ± 12.8	0.15
	Median (IQR)	122.0 (18.0)	117.5 (17.0)	126.0 (10.0)	
Change in RML Angle†	Mean ± SD	−15.1 ± 15.1	−17.1 ± 16.6	−12.0 ± 12.8	0.44
	Median (IQR)	−9.0 (23.0)	−8.5 (28.0)	−13.0 (14.0)	

IQR: interquartile range; RML: right middle lobe; RMLS: right middle lobe syndrome; SD: standard deviation.

* p-value calculated using t-test.

† n = 1 excluded due to obliterated postoperative RML angle.

Plus-minus values are means ± SD. The 2-tailed t-test compares patients with RMLS to the control group. The control group represents patients who underwent right upper lobe lobectomy without postoperative RMLS.