Bronchial Deformation Associated with Lobectomy

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Bronchial stenosis or obstruction (BSO) can arise as a congenital disorder with other associated abnormalities, but it may also occur as an acquired lesion secondary to other conditions.1–4) BSO after chest surgery is a relatively rare condition. BSO after upper lobectomy probably occurs due to upward movement of the remaining lobe(s) with torsion or deformation of the bronchus. The diagnosis of BSO can be confirmed at the time of bronchofiberscopy (BF) or computed tomography (CT) scan by the findings of a kinked lobar bronchus. Bronchofiberscopic findings will show partial or complete obstruction of the bronchus to the affected lobe, which is caused by edema or distortion. In addition, there are some radiological findings of lung lobar torsion: (1) a collapsed or consolidated lobe that occupies an unusual position on chest roentgenography or CT scan; (2) hilar displacement in a direction inappropriate for the lobe that appears to be atelectasis; (3) alteration in the normal position and sweep of the pulmonary vasculature—if central vascular markings extend laterally from the hilus and then sweep superiorly instead of inferiorly, lobar torsion can be postulated; (4) rapid opacification of an ipsilateral lobe following chest surgery—the thorax may be completely opaque, especially if an entire lung has undergone torsion; (5) a change in position of an opacified lobe on sequentially obtained chest roentgenography; (6) bronchial distortion, demonstrated occasionally on chest roentgenography, but better seen on CT scans; (7) lobar air trapping; and (8) signs of lobar collapse.5)

Among the various reasons for bronchial deformation, lung torsion is fatal. Brooks6) described that lung lobar torsion of the right middle lobe after upper lobectomy is the most common, but it can occur in all lobes. Arai et al.7) reported bronchial deformation of the left lower lobe bronchus after left upper lobectomy. Wong et al.8) reported 28 cases of lobar torsion after lung resection; 16 (57%) of these 28 cases involved middle lobe torsion after right upper lobectomy. The others involved left upper lobe torsion after left lower lobectomy, and right lower lobe torsion after right upper lobectomy. There are published articles on left lower lobe torsion after left upper lobectomy, as well as right lower lobe torsion after right upper lobectomy.9)

Brooks6) asserted that the fissure must be completely isolated between the remaining lobes. Furthermore, torsion of the lower lobe cannot occur if the inferior pulmonary ligament is not divided. He recommended that care be taken to prevent torsion of the remaining lobes, which may become fixed together by suturing, and complete re-expansion of the lung during chest closure is essential to prevent lung lobar torsion. Wong et al.8) recommended that, after lobectomy, the remaining lobe(s) be anchored with sutures to minimize the likelihood of pulmonary torsion.

Khanbhai et al.10) reported that the division of the pulmonary ligament reduces the free space in the upper thorax and may lead to BSO. Preservation of the ligament may prevent the condition by prohibiting the movement of the residual lobe(s) to the upper part of thorax. However, there is no convincing evidence that the preservation of the pulmonary ligament in an upper lobectomy reduces these complications. Matsuoka et al.11) conducted a randomized controlled trial of 35 consecutive patients undergoing
upper lobectomy for lung cancer. They sometimes had experienced the deformation of the residual bronchus after left upper lobectomy with ligament division.

Felson\(^5\) described that lung lobar torsion occurs under three different situations: (I) spontaneously, but in association with some other pulmonary abnormality; (II) following traumatic pneumothorax; and (III) as a complication of thoracic surgery such as lobectomy. Furthermore, he asserted that the mechanisms of development of lung lobar torsion include the following: (A) an airless lobe commonly being present, but not always; (B) a long, free, lobar pedicle; (C) absence of a parenchymal bridge between contiguous lobes; (D) pneumothorax or pleural effusion; and (E) division of the inferior pulmonary ligament. He reported that the pulmonary rotation is often stated to be clockwise in direction and occasionally stated to be counter-clockwise after upper lobectomy.

Pinstein et al.\(^7\) reported that torsion of the right middle lobe may occur following right upper lobectomy when the middle lobe twists on its narrow pedicle in a clockwise rotation. If the radiologist is not aware of an upper lobectomy, the episode of middle lobe torsion may be misinterpreted as atelectasis of the right upper lobe. However, since the horizontal fissure lay at the level of the hilus, they considered an oblique fissure line extending below the level of the right hilus to be inconsistent with the diagnosis of atelectasis of the right upper lobe. In the postoperative state, other possible radiographic misinterpretations include atelectasis of the superior segment of the right lower lobe or simple atelectasis of the right middle lobe.

The remaining bronchus may produce deformation even if lung lobar torsion does not occur. Arai et al.\(^7\) described endoscopic and pathological study on deformation of the remaining bronchus after left upper lobectomy in 1986. They asserted that deformation of the remaining bronchus after upper lobectomy was observed most predominantly in cases of left upper lobectomy. The cause of the deformation of the remaining bronchus was investigated pathologically, comparing with BF findings in one patient whose remaining left lung had been removed because of metachronous primary lung cancer five years after the left upper lobectomy.

Bronchial stenosis of the remaining lobe after upper lobectomy for reasons other than lung torsion after upper lobectomy is an uncommon condition. We experienced a case of postoperative severe bronchial stenosis without lung lobar torsion caused by bending at the orifice of the right middle lobe bronchus occurring 5 months after right upper lobectomy.\(^12\) At the time of the right upper lobectomy, the suturing line by using absorbable surgical sutures for bronchial stump of the upper lobe was placed across the longitudinal axis of the remaining bronchus, which is called Overholt’s method. We had not performed suturing for fixing to another of the remaining lobes after right upper lobectomy.

After right upper lobectomy, the orifice of the middle lobe bronchus is round in some cases, but is deformed in others. To investigate the cause of the deformation, we examined the conjugate and transverse axis and areas of the orifice of the right middle lobe bronchus by using flexible BF measurement.\(^13\) The orifice of the right middle lobe bronchus was classified into four different groups: (a) the orifice was round before and after right upper lobectomy; (b) the orifice was round before upper lobectomy but was deformed afterwards; (c) the orifice was semicircular before and after upper lobectomy; and (d) the orifice was semicircular before surgery but was deformed after upper lobectomy. When the orifice was semicircular before right upper lobectomy, deformation of the orifice of the right middle lobe bronchus was common after right upper lobectomy.

Generally, the pleural space of the apex will be refilled by four mechanisms after upper lobectomy: (i) expansion of the remaining lobe; (ii) shifting of the mediastinum toward the ipsilateral side; (iii) narrowing of the intercostal space on the ipsilateral side; and (iv) elevation of the ipsilateral diaphragm. Wong et al.\(^8\) reported that some rotation/kinking of the right middle lobe bronchus with atelectasis of the middle lobe is a common postoperative condition after right upper lobectomy. They insisted that the right middle lobe relocated into the upper thorax anterior to the superior segment of the lower lobe and adjacent to the superior vena cava. When the middle lobe was very mobile or if had been divided free at operation, it twisted on its narrow pedicle.

To explore the anatomical repositioning of the middle lobe after right upper lobectomy, we measured the lobar volumes of the lung and the branching angles of the airway, and defined their changes after right upper lobectomy in a rabbit model.\(^14\) In this study, the bronchial deformation after upper lobectomy was caused passively by displacement and volume change of the remaining lobes. The volume of the right middle lobe and left lung increased and the right middle lobe bronchus diverged more laterally after right upper lobectomy. It was shown that the angle between the truncus intermedius and the right middle lobe bronchus diminished. It was suggested that the volume changes of the small lobe will affect the postoperative...
bronchial deformation. Furthermore, the presence of a pre-operative flattened orifice of the right middle lobe bronchus may also play a role in the occurrence of atelectasis.

We considered it necessary to examine in humans how different right lung lobar volume ratios contribute to deformation of the orifice of the right middle lobe bronchus after right upper lobectomy. Therefore, we examined the relationship between the postoperative deformation of the orifice of the right middle lobe bronchus and the preoperative and postoperative right lung lobar volume ratio. This was calculated by using a chest CT scan, and the form of the orifice of the right middle lobe bronchus was determined by BF. A chest CT scan and BF were experienced in 19 patients before and after right upper lobectomy for peripheral primary lung cancer, of which the average diameter of the tumor was 23 mm, and these had no bronchial deformation before right upper lobectomy. The volume ratio of the right middle lobe to the volume of the right middle and lower lobes was compared before and after right upper lobectomy. The orifice of the right middle lobe bronchus was deformed when the volume ratio of the right middle lobe to that of the right middle and lower lobes was less than 60%, regardless of the preoperative form of the orifice, but when the ratio was greater than 60%, the orifice was not deformed. In this study, postoperative deformation of the preoperatively semicircular orifice of the right middle lobe bronchus was observed when the postoperative volume ratio of the right middle lobe to the right middle and lower lobes was under 30%. On the other hand, postoperative deformation of the preoperative round orifice of the middle lobe bronchus was not observed even though the postoperative volume ratio of the right middle lobe to the right middle and lower lobes was extremely low. These results suggest that the postoperative volume ratio of the right middle lobe to the right middle and lower lobes is a good predictor of deformation of the orifice of the right middle lobe bronchus in cases with a preoperative semicircular orifice of the right middle lobe bronchus.

Headly et al. reported five cases of lung collapse associated with giant omphalocele. Narrowing of the bronchus was confirmed by tracheobronchography, and vascular compression was excluded by magnetic resonance imaging. Until recently, tracheobronchography was relied on as an accurate diagnostic method for tracheobronchial stenosis. However, the radiocontrast agents had not been used for the definitive diagnosis of airway stenosis because of other diagnostic procedures beginning to be used in place of tracheobronchography.

Leuven et al. reported two cases of BSO after left upper lobectomy or right upper and middle bilobectomy for primary lung cancer. They treated these cases of BSO associated with kinking of the lower lobe bronchus by using endobronchial stenting. Not only does the torsion result in bronchial obstruction and atelectasis, but it may produce pulmonary infarction by losing blood flow, which is a life-threatening condition. The urgent operation for the infarcted tissue is necessary about these states. Treatment for the lobe which caused twisting is usually a lobectomy, and should be performed as soon as the definitive diagnosis is confirmed.

On the occasion of the onset of BSO, BF and chest CT scan are effective for the definitive diagnosis and are valuable tools for ruling out conditions such as atelectasis or pneumonia. Chest CT scan is the best imaging technology to evaluate an airway lesion. Respiratory tracts are visualized because air contained within the tracheobronchial tree has lower attenuation than surrounding pulmonary parenchyma. Introduction of the multidetector CT (MDCT) technique improved the ability to assess the state of proximal airways in three dimensions (3D). Virtual bronchoscopy provides an internal analysis of the tracheobronchial walls and lumens that simulates a BF view of the respiratory tract.

Chest surgeons should be aware of BSO of the remaining lobes after lobectomy for chest diseases, and should prevent this condition and its inherent or other associated complications.

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**References**

