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CASE REPORT

Resection of mediastinal goiter extending to the carina with use of artificial pneumothorax, two-lung ventilation, and thoracoscopy, with the patient in a prone position

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Abstract
A 67-year-old woman was presented with a mediastinal tumor extending from the left lobe of the thyroid and passing through the posterior trachea, causing displacement of the esophagus to the left side of the patient and then descending into the right side of the mediastinum to below the carina. Surgery was performed under two-lung ventilation with the patient in a prone position; general anesthesia was performed with a single-lumen tube combined with artificial pneumothorax. In thoracoscopic surgery, we were able to confirm and preserve anatomical structures. After detachment of the tumor at the level of the left and right subclavian arteries, the patient was placed supine, a cervical incision was added, and the tumor was extracted. The tumor was diagnosed as a nonmalignant mediastinal goiter (MG). No such surgical report was found in the literature, and one would be useful for this new approach to MG removal.

Keywords Mediastinal goiter · Carina · Artificial pneumothorax · Prone position · Two-lung ventilation

Introduction

Many mediastinal goiters (MGs) can only be resected using a cervical approach. However, the presence of features such as extension of the MG below the aortic arch or into the posterior mediastinum, a dumbbell shape, or a thoracic component that is wider than the thoracic inlet may all require a thoracic approach such as median sternotomy or lateral thoracotomy. Although an MG is benign, a thoracic approach to resection is highly invasive. We experienced a case in which an MG extended below the carina, and surgery was safely performed through a cervical and thoracic approach using artificial pneumothorax and thoracoscopy and with the patient in a prone position. No such surgical report was found in the literature, and one would be useful for this new approach to MG removal.

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Case

A 67-year-old woman was found to have an abnormal shadow in the upper mediastinum. She had become aware of difficulty swallowing 7 years prior. Enhanced computed tomography (CT) showed a tumor extending from the left lobe of the thyroid and passing through the posterior trachea, causing displacement of the esophagus to the left side of the patient and then descending into the right side of the mediastinum to below the carina (Fig. 1 a–d). Nodular structures showing various CT values were observed inside the tumor. The tumor measured 138 × 41 × 43 mm and measured 97 mm from the thoracic inlet to the lower pole of the tumor. Three-dimensional enhanced CT showed that the tumor was located by the left subclavian artery, the left common carotid artery, the brachiocephalic artery, and the trachea, with the bronchial artery at the lower end of the tumor (Fig. 2). No mediastinal lymph-node enlargement or metastasis was observed. Aspiration cytology identified a benign tumor. We performed surgery, because the patient was experiencing symptoms caused by the esophageal displacement, such as difficulty swallowing. The operation was performed under two-lung ventilation with the patient in a prone position; general anesthesia was performed with a single-lumen tube (SLT) combined with artificial pneumothorax (6–8 mmHg CO_2 aeration). A 5-mm port was placed at the right 3rd intercostal space in the posterior axillary line, a second 5-mm port was placed at the right 7th intercostal space at the lateral scapular angle, and a 12-mm port was placed at the right 5th intercostal space in the posterior axillary line

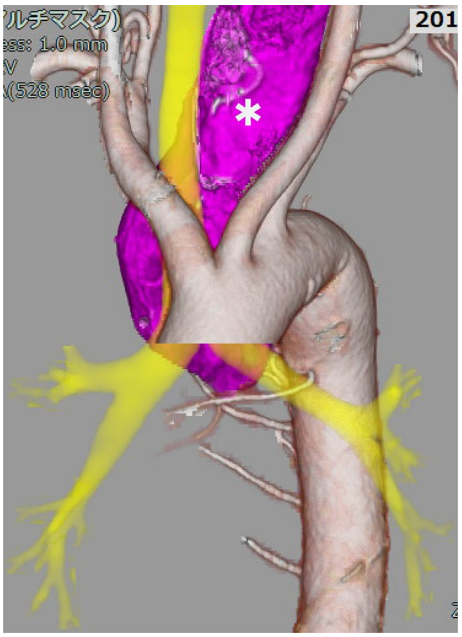

Fig. 2 Three-dimensional enhanced CT showed that the tumor was located by the left subclavian artery, the left common carotid artery, the brachiocephalic artery, and the trachea, with the bronchial artery at the lower end of the tumor. *Tumor

(Fig. 3). The tumor was clearly delineated and covered with mediastinal pleura (Fig. 4a). An incision was made in the pleura, and the tumor was dissected between the esophagus and trachea (Fig. 4b). As detachment progressed, the lungs, trachea, and esophagus fell ventrally with gravity, facilitating the procedure (Fig. 4c). We were able to confirm and preserve the vagus nerve, thoracic duct, and

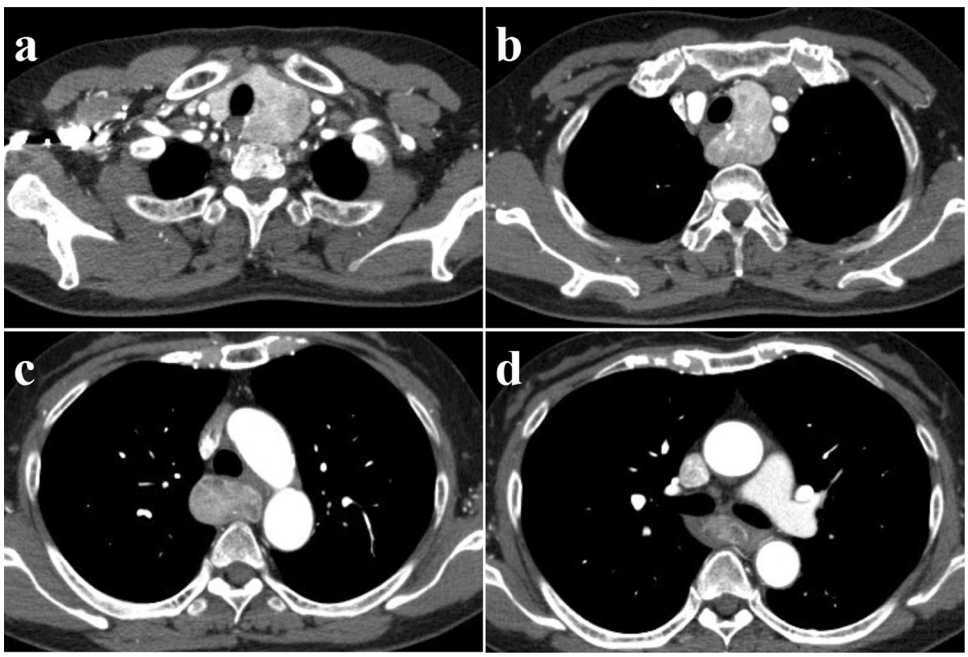

Fig. 1 Enhanced CT showed a tumor (138 × 41 × 43 mm and measured 97 mm from the thoracic inlet to the lower pole of the tumor) with smooth margin. The tumor extended from the left lobe of the thyroid (**a**) and passing through the posterior trachea (**b**). The tumor caused displacement of the esophagus to the left side of the patient and then descending into the right side of the mediastinum (**c**), and the lower pole of the tumor reached below the carina (**d**). Nodular structures showing various absorption values were observed inside the tumor

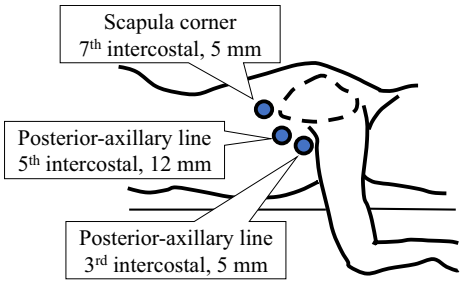

Fig. 3 Port sites and patient positioning

right recurrent nerve. After detachment of the tumor at the level of the left and right subclavian arteries, the patient was placed supine, a cervical incision was added, and the tumor was extracted (Fig. 4d). The left thyroid lobe was almost replaced by the tumor and was also excised. The operative times were 116 min for the thoracoscopic surgery, 105 min for the cervical manipulation, and 248 min for the entire procedure, including positional changes. The amount of bleeding was small. The macroscopic specimen was solid and dark red with a smooth margin. The mass measured $135 \times 50 \times 25$ mm, and it was pathologically diagnosed as a nonmalignant MG. There were no postoperative complications, and the patient was discharged on the 5th postoperative day.

Discussion

More than 90% of MGs can be excised through a cervical approach [1–3]. However, it has been reported [1] that excisions using this approach can only be performed down to the level of the aortic arch. The cervical approach is used to enable control of the blood flow to the MG from the inferior thyroid artery, and to limit damage to the recurrent nerve [2]. However, blind finger dissection can also lead injury to the recurrent nerve [1]. In addition, we think that it is difficult to operate with a cervical approach when a blind maneuver is performed in the thoracic cavity and major vessel damage occurs. To operate safely, it is necessary to confirm anatomical structures using a thoracic approach.

The following features have been described using thoracic approaches, such as median sternotomy and lateral thoracotomy, for resecting MGs: (1) extending to the caudal side of the aortic arch [4, 5], (2) reaching the carina [1, 4], (3) ectopic [4], (4) present in the posterior mediastinum [5], (5) dumbbell-shaped [5], (6) a thoracic component wider than the thoracic inlet [5, 6], and (7) blood flow supply from the chest cavity [6]. One study used CT to measure the MG length using the cranial view, as well as the thyroid volume in the mediastinum. It reported a tumor length $\geq$ 166 mm and volume $\geq$ 162 cm^3, requiring an approach other than through the neck [7]. Based on these reports, it seemed reasonable to use a combined thoracic approach in this case.

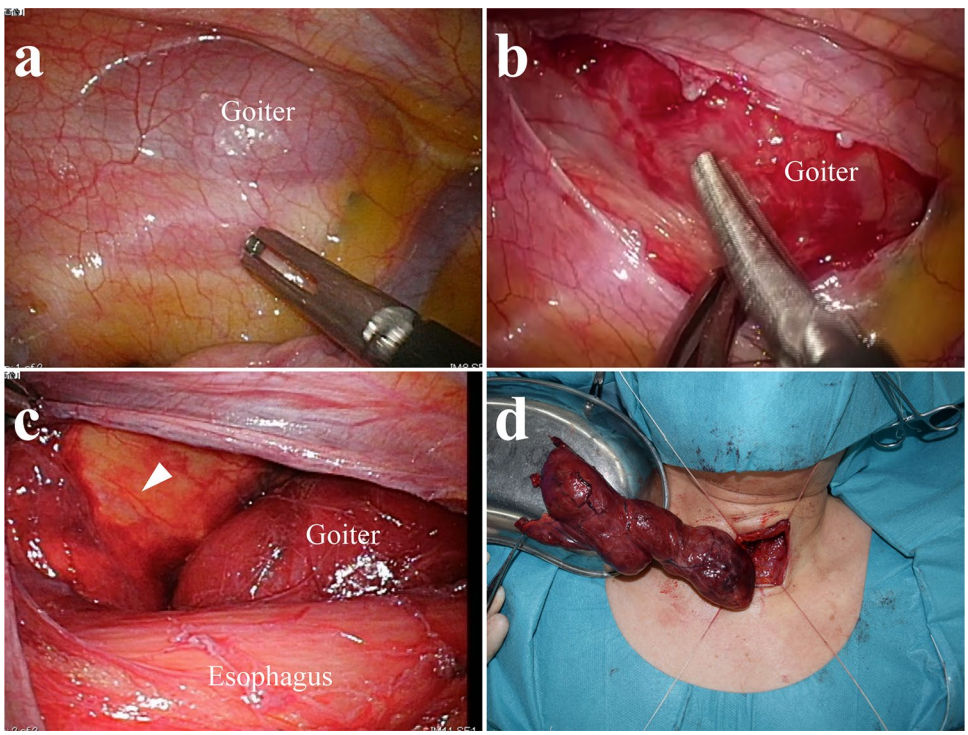

Fig. 4 Surgical findings (**a**–**c** during thoracoscopic surgery; **d** though the cervical incision). **a** Tumor was clearly delineated and covered with mediastinal pleura. **b** Incision was made in the pleura, and the tumor was dissected between the esophagus and trachea. **c** As detachment progressed, the lungs, trachea, and esophagus fell ventrally with gravity, facilitating the procedure. Allow head: thoracic duct. **d** Patient was placed supine, a cervical incision was added, and the tumor was extracted

The features of our surgical approach include (1) a prone position, (2) artificial pneumothorax, (3) intubation with an SLT, (4) thoracoscopy, (5) preceding intrathoracic surgery, and (6) tumor withdrawal through a cervical incision.

Surgery in a prone position is widely used for thoracoscopic esophagectomy in Japan, but a few reports have described its use for mediastinal tumors. A lateral or supine position is often selected for mediastinal surgery. However, if a patient is in a lateral or supine position for surgery on a posterior mediastinal tumor, the lung falls into the mediastinum or in a dorsal direction due to gravity and the operative field becomes poor, requiring counter-traction by the assistant. Although repositioning is somewhat difficult, with the patient in a prone position, it is possible to improve the operative field when performing unassisted surgery by utilizing gravity [8]. In terms of exposure of the operative field, artificial pneumothorax further simplifies the operation. As traction is applied by pressure induced by the pneumothorax, tissue dissection is easy, and light bleeding can be avoided. Furthermore, by performing surgery under SLT intubation rather than with separated lung ventilation using a double-lumen tube (DLT), rapid anesthesia induction is possible, tracheal mobility is ensured, and handling of the trachea and posterior mediastinum is efficient. Anesthesia using SLT intubation and an airway blocker remains unstable, requiring caution in anesthesia management.

With the patient in a prone position, the combination of artificial pneumothorax and two-lung ventilation with SLT has added advantages compared with separated lung ventilation and DLT intubation. Pressure from the airway and artificial pneumothorax compresses the alveolar venular bed, shunting and decreasing blood flow on the operative side. In surgery using artificial pneumothorax, the mediastinal pleura is opened, and bilateral artificial pneumothorax often develops. Particularly, in separated lung ventilation cases, the shunted blood flow rate may increase compared to what is typical in two-lung ventilation due to the low airway pressure in the nonventilated surgical side [8].

For a thoracic approach, median sternotomy and lateral thoracotomy are often performed, but the former creates a large wound, and the operative field cannot be secured for a tumor extending to the posterior mediastinum. In the latter method, surgery under direct vision is also difficult. To perform minimally invasive and safe thoracic surgery, the concurrent use of thoracoscopy is considered indispensable. However, there are a few reports of thoracoscopy use for an MG resection. Brichkov and colleagues [9] reported 7 cases of MG (3 cases involving the azygos vein, 2 involving the carina, and 2 involving the aortic arch) that were addressed surgically using artificial pneumothorax, thoracoscopy, and a cervical approach. However, their cases involved surgery with the patient in a supine position, with no change in posture. In addition, the neck and thoracic surgeries were concurrent, and separated lung ventilation with DLT intubation which was used. The case details are unknown, but the operative data were unsatisfactory: the average MG tumor size was 8.3 cm, the average bleeding volume was 215 ml, and the average operative time was 180 min. When the tumor is posterior to the trachea or esophagus in the supine position, the trachea and esophagus can fall to the dorsal side when the tumor is detached, and the operation becomes somewhat difficult, leading to increased bleeding and prolongation of the operative time.

The disadvantage of surgery in a prone position is that an additional thoracotomy in a case of emergency is difficult compared to a lateral or supine position. Therefore, it is important to evaluate the tumor invasion, especially vascular invasion in detail before surgery. Mediastinal tumors without invasion to the surrounding tissue are considered to be good indication for our surgical approach. However, if surgery cannot be performed safely because of malignant or vascular invasion, we should immediately convert from thoracoscopic surgery to thoracotomy in an appropriate position. In case of emergent hemorrhage in the contralateral thoracic cavity, we recommend thoracoscopic surgery or thoracotomy under separated lung ventilation using SLT intubation and an airway blocker.

Surgery is often required for MGs when symptoms caused by the displacement of surrounding organs are observed. In this case, the patient's difficulty swallowing was improved by surgery. Although it is difficult to justify surgery when such symptoms are not present, papillary cancer of the thyroid is seen in 19% of MGs, and 72% of these cancers are reportedly found in the thoracic cavity [10]. Therefore, when symptoms are present or when an MG is observed on imaging, surgery should be performed because of the possibility of cancer.

Conclusion

We experienced a case of an MG that extended below the carina for which thoracoscopic surgery was performed using two-lung ventilation and artificial pneumothorax with the patient in a prone position. There were no such surgical reports in the literature prior to this, and this method could be useful as a new approach to the resection of MGs.

Compliance with ethical standards

Conflict of interest The authors have no conflicts of interest.

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