Preoperative Small Pulmonary Nodule Localisation Using Hookwires or Coils: Strategy Selection in Adverse Events

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Abstract

Objective

We conducted a retrospective study of adverse events associated with the preoperative procedure of computed tomography (CT)−guided hookwire or coil localisation. We analysed the experience of and process flaws in resecting ground-glass nodules (GGNs) using video-assisted thoracoscopic surgery (VATS) and determined the remedial strategy.

Methods

Adverse events were evaluated in 20 patients with 25 GGNs who underwent CT-guided hookwire or coil localisation before VATS. For lesions not successfully marked or detected, palpation, resection of the highly suspected area, segmentectomy or lobectomy was performed.

Results

Among all adverse events, 10 were dislodgement of the marking materials, 2 were breakaway of the marking materials, 4 were >2-cm distance between the lesions and the tip, one was marking material across the two adjacent lobes, 10 were pneumothorax and two were certain parts of marking materials stuck into the walls. All GGNs were resected successfully. Fifteen lesions were detected by palpation. Three GGNs were discovered after the resection of highly suspected areas. The GGNs were removed by lobectomy. Segmentectomies and lobectomies were performed directly on two and four GGNs, respectively.

Conclusions

When adverse events occur, a second localisation, intraoperative localisation, resection of a highly suspected area, or a segmentectomy or lobectomy can be successfully attempted using VATS for resection of GGNs.

Introduction

In recent years, low-dose computed tomography (CT) has played an important role in the identification of pulmonary nodules (GGNs) with ground-glass nodules (GGNs).[1] Individuals with a GGN <3 cm in diameter have better outcomes, with 5-year survival rates as high as 60−80%.[2] To obtain a definite diagnosis of a GGN with high clinical suspicion of lung cancer on chest CT, proof must be established by either needle biopsy or nodule resection. Video-assisted thoracoscopic surgery (VATS), a less-invasive type of thoracic surgery, can provide better evidence for the diagnosis of GGNs, while at the same time, active radical treatment should also be taken.[2] However, if the GGN is ≤10 mm in diameter, has a low density, or is >5 mm away from the pleural surface, it is especially challenging for surgeons to palpate these lesions.[4]

A number of small-nodule localisation techniques have been devised to detect lesions and reduce the unnecessary loss of lung tissue during the surgical process. Metallic hookwire or microcoil localisation under CT guidance is the most widely used localisation technique worldwide.[5] It is also a safe, effective technique for preoperative localisation and increases the success rate of VATS.[6−8] However, adverse events, including puncture-related complications, complications of localisation and unsuccessful excision, do occur. We collected these adverse events with the aim of determining appropriate remedial measures.

Patients And Methods

The institutional review board of our hospital approved the present retrospective study. Patient consent forms were obtained from all patients after discussing all related risks and benefits as well as all treatment alternatives.

Definition of adverse events

Adverse events were defined as follows:

1. Puncture-related complications: pneumothorax, haemorrhage, air embolism, acute pain and so forth
2. Complications of localisation: unhooking or dislodgement
3. Unsuccessful excision: No lesion detected in the excision of lung tissue

Patients

A total of 240 patients undergoing the preoperative procedure of CT-guided hookwire and/or coil localisation were evaluated in this study between 1 January 2020 and 1 October 2020. Selection criteria were based on at least one of the following CT findings: lesion diameter ≤10 mm, no pleural indentation and pure GGN or a lesion mostly composed of GGNs. For patients with multiple GGNs, only those who underwent the adverse preoperative procedure of CT-guided hookwire or coil localisation were recorded in this study.

Radiologic localisation procedure

All CT-guided localisations were performed on the day of VATS surgery. The hookwire set (275S090102; Pajunk GmbH Medizintechnologie, Geisingen, Germany) was composed of a calibrated cannula (21-gauge, 100-mm long) and a calibrated wire (20-cm long) with a thorn. The size, location, shape, number and surrounding tissue of the lesion were analysed before surgery based on the preprocedural CT images. A thin-layer CT scan was conducted in the area where the GGN was most likely located. A puncture site was forecasted, and an optimal trajectory was designed between the skin and the edge of the lesion. After the skin disinfection, administration of local anaesthesia and calibration of the cannula needle, the hookwire with the cannula needle was inserted through the skin and pulmonary parenchyma to reach the edge of the lesion. The thorn of the hookwire was then released, and the cannula needle was pulled out. A CT scan was repeated to ensure that the thorn was around the GGN and that the invasive manipulation did not lead to complications. The trailing end of the hookwire was covered by sterile gauze.

The coil localisation equipment included an embolisation coil (MWCE-35-5-4, Cook Inc., Bloomington, IN, USA), Chiba biopsy needle with 10-mm graduations on the needle shaft (DCHN-18-15.0, Cook) and Radifocus guide wire (RF*GA35153M, Terumo Corp, Shibuya, Tokyo, Japan). The procedure process was similar to that given above.

Surgical procedures

Patients received general anaesthesia with single-lumen endotracheal intubation and were placed in the lateral position. Povidone–iodine was applied to the patient, who was wrapped in a sterile drape. The procedure of VATS resection required one (or two) 40-mm thoracic port(s) for the thoracoscope as well as the endoscopic medical apparatus and instruments. The trailing end of the hookwire was pulled into the chest and then folded, so as to avoid stabbing the organs. The edge of the wire or coil was touched to detect the lesion, which contains a lesion with sponge forceps during the procedure. The lung tissue was clamped, and the lesion was sequentially resected by cut staplers. The resected hookwire or coil and lung tissue were packed into sterile gloves to prevent metastatic implantation of malignant disease and were withdrawn from the chest via an intercostal incision. The lung tissue on oblect stand was cut open to examine the integrity of the wire or coil as well as the lesion. When the lesion was not successfully localised, palpation with thoracoscopic instruments was first performed to localise it. When the palpation failed, resection was attempted on the highly suspected area or a segmentectomy or lobectomy was performed. All resected lung specimens were immediately sent for frozen section examination. If the pathological result was benign or indicated primary lung cancer, a chest tube was inserted and VATS was conducted after bleeding and air leak were excluded. If the diagnosis was infiltrating carcinoma, a segmentectomy or lobectomy and a lymphadenectomy or systematic lymph nodal sampling were carried out and if necessary, another thoracic incision was made to facilitate the subsequent thoracoscopic resection. Otherwise, if the result suggested a metastatic tumour following wedge resection, the procedure was terminated until a multidisciplinary treatment scheme was set up.

Pathological diagnosis

Pathological diagnosis was classified according to the International Association for the Study of Lung Cancer/American Thoracic Society/European Respiratory Society International Multidisciplinary Classification of Lung Adenocarcinoma.[9]

Data analysis

We performed the statistical analysis using commercially available statistical software, IBM SPSS Statistics software version 20.0 (IBM Corp., Armonk, NY, USA).

Results

GGNs were detected on lung cancer screening CT in 13 patients (14 lesions); 7 patients (11 lesions) were incidentally detected on CT due to symptoms of cough or sputum. This study included nine men and 11 women, with a mean age of 48 years (range, 28–72 years). Six patients were former smokers and two were current smokers. The mean number of pack-years was 20.7 (range, 10–35). Of the 20 patients, 2 had a history of cancer, three had a history of hypertension, three had diabetes and two had tuberculosis (Table I).

Among the 20 patients, 1 had two lesions to localise and one had five lesions to localise, which were situated in various segments of the left lung. The GGNs were located in the right upper lobe (n = 6), right middle lobe (n = 2), right lower lobe (n = 3), left upper lobe (n = 7) and left lower lobe (n = 5; Table II). The diameter of the lesions ranged from 4.0 to 12 mm (mean, 8.5 mm). The distance of the lesion from the pleural surface (including the interlobular pleura and mediastinal pleura) ranged from 1.5 to 55 mm (mean, 15.6 mm).

A total of 14 (56%) and 11 (44%) lesions were marked by hookwires and coils, respectively. As for the types of all unsuccessful localisation, 10 were dislodgements of marking materials (Figure 1), 2 were breakaway of marking materials (Figure 2), 4 had a distance of >2 cm between the lesion and the tip of wires or coils (Figure 3), 1 was marking material in different lung lobes adjacent to the GGN (Figure 4), 6 were pneumothorax and two were certain parts of marking materials stuck into the walls (Figure 5). No severe complications occurred after this procedure, but several grade 1 adverse events were observed. None of the cases with pneumothorax required a particular intervention, such as manual aspiration of air or chest tube placement.

All GGNs were successfully resected. Fifteen lesions were detected by palpation. Three GGNs were discovered after the highly suspected areas of lung were resected. When the GGN could not be detected after a highly suspected area of lung, a lobectomy or segmentectomy was carried out. Lobectomies were performed directly on three and four GGNs, respectively.

Frozen section histopathology provided adequate information for appropriate intraoperative management, as confirmed by subsequent permanent section analysis in all cases. Of 25 lesions, 2 were interstitial fibrous tissue proliferation, seven were atypical adenomatous hyperplasia, nine were adenocarcinoma in situ, five were minimally invasive adenocarcinoma and four were invasive adenocarcinoma.

Discussion

Pulmonary wedge resection using VATS is the most commonly used method available for the surgical treatment of GGNs <1 cm in diameter. However, the probability of palpation failure in localising lesions can be as high as 63%.[10] Thus, accurately localising the lesions is crucial.

We can classify the localisation of lesions into three types,traditionally.[11,12] The first type is localisation with imaging modalities during thoracoscopy. This includes intraoperative ultrasonography[13] and CT fluoroscopy[14]. The second type is preoperative localisation with an injection of dyes[15], contrast media[16], radionuclides[17] or coloured adhesive agents[18]. The third type is preoperative localisation with hook wire or coil placement[19,20]. The most popular localisation technique is CT-guided hookwire or microcoil localisation. Most studies published in recent years have reported high success rates of localisation with coils or hookwires, with rates ranging from 0.4–42%.[8,10,20,21].New methods, sunch as injecting indocyanine green (ICG) under the guidance of electromagnetic navigation bronchoscope,may cost more money and requires more equipment.[22]

Common adverse events of localisation and their cause

Complications of coil and hookwire are similar.[23,24] Dislodgement is the most common cause for operation failure. Iwasaki reported that wire dislodgement occurred in up to 20% of cases.[25] Among our occurrences of placement failure, 10 (40%) were dislodgement of marking materials, of which 7 and 3 were marked by hookwires and coils, respectively. According to Mullan et al.[26], a wire is generally dislodged at one of three times: during transportation of the patient to the surgical suite, during surgical deflation of the lung, or during resection, when the surgeon often applies gentle retraction to the wire. Coil dislodgement occurs less than wire dislodgement does, because its rough fibre coating induces coagulation and increases adhesion to the lung tissue, and its tension fixes it on lung tissue cracks. Nonetheless, a wide needle passage or tiny pulmonary elastic resistance still causes dislodgement. The coil is soft and pliable and causes less damage to lung tissue than the wire does when dislodged. Gagliano et al. [27] reported a case in which a displaced coil was uncoiled, causing less tissue damage when compared with hookwire for localisation in ex vivo goat lungs. Breakaway is a special type of dislodgement. The breakaway of marking materials was observed in 2 (8%) of GGNs. The most serious breakaway we encountered occurred when the wire tip was embedded in the chest wall. According to Seo et al[21], the distance between the wire tip and pleural surface can be regarded as the only independent factor for successful localisation. When the distance is <1 cm between the marking materials and pleural surface, the marking materials can break away from the lung due to the cutting force of the wire or the tension of the coil.

A distance of >2 cm from the GGN to the tip of the wire or coil also means a failure of localisation, which occurred in four cases (16%) in this study. During the operation, the location of the GGN and safe resection margin cannot always be predicted. An unskilled operator or uncooperative patient urges to this kind of failure. In our cases, shaking and shortness of breath caused by hypertension of the patient aroused this failure. In addition, deep lesions might suffer from this failure more often.

If the tip of the wire or coil is located in different lobes of the lung adjacent to the GGN or across two adjacent lobes, difficulties will be encountered during the operation, and even normal lung tissue will be removed. A distance of <1 cm between the marking materials and adjacent pulmonary fissure is an important risk factor for this kind of failure.

In contrast to dislodgement or breakaway, the entire or a portion of a hookwire or coil sometimes gets stuck in the chest walls when the GGN is in the vicinity of the pleural surface, and meanwhile, marking materials are released into the pleural cavity.

Another important reason for unsuccessful localisation is the occurrence of complications. Common complications include pneumothorax, haemorrhage, air embolism, acute pain and so forth. The incidence rate of pneumothorax may account for nearly half of all complications of this procedure.[8,10] Repeated puncture, thick puncture needle and large-diameter coil are the main reasons for pneumothorax. Generally, haemorrhage can be divided into two categories: pulmonary haemorrhage (Figure 7) and haemothorax. Intervention strategies for patients with haemorrhage are not always necessary, while minimal pneumothorax and asymptomatic haemorrhage often occur during the localisation procedure. Embolisation often occurs in wires; however, the coiled configuration and fibre coating virtually eliminate the risk of embolisation.

How to avoid failure of localisation

First, we need to determine the indications for CT-guided hookwire or coil localisation. In their study designed to establish the utility of preoperative CT-guided hookwire localisation of GGNs, Ciriaco et al. [4] concluded that it may be beneficial when the GGN size is <10 mm and/or the distance from the pleural surface is >15 mm and may be advisable when the GGN size is >10 mm and/or the distance from the pleural surface is between 15 and 25 mm. A discriminant function analysis performed by Saito et al. [28] indicated that a linear function (i.e. depth = 0.836 × size − 2.811) could be used to differentiate between undetectable and detectable small peripheral GGNs and that preoperative hookwire marking for small peripheral GGNs should be considered for nodules in regions above those. Actually, we believe that CT-guided hookwire and coil localisation, and especially the latter, have wider indications. As long as the needle reaches the lesions, there will be some promise for success in localisation.

For lesions with a distance of <10 mm from the pleural surface, the tip of the wire or coil should be extended about 10 mm beyond the edge of the lesion. If delocalisation of the chest wall or adjacent lung lobe occurs, it is widely recommended that the pleural end of the coil or wire be removed from the chest wall via thoracoscopy. The tail end of the hookwire ought not to be fixed when CT-guided hookwire localisation is completed, to avoid pulling to deflation of the lung. The coil should not have a thick diameter to avoid a wide needle insertion route. These measures can contribute to reducing the incidence of dislodgement or breakaway.

When a GGN hides in the inner side of the shoulder blades and blocks the route through which the needle goes, it is advisable to place a hookwire after the upper body posture is adjusted. However, shoulder blades change their positions in the lateral position, and pulling the wire during coil localisation can avoid this failure.

The patient must be induced to remain static and relaxed. Because lesions in the lower lung are easily influenced by respiration, respiratory coordination in patients with such lesions is thus of great significance. Avoiding repeated punctures and paying more attention to pulmonary vessels and airways will assist in preventing complications.

What to do after an unsuccessful localisation

Under certain circumstances, despite an unsuccessful preoperative CT-guided hookwire localisation, relocalisation will be attempted. Two types of localisations can be tried simultaneously.[29] Though multiple percutaneous puncture produced a significantly higher incidence of pneumothorax and hemorrhage,the localizations were clinically feasible and safe.[30,31]

Lung nodules can be localised during surgery after every effort is exerted before operation. Palpation is the easiest way to detect GGNs during VATS. Suzuki et al. [11] demonstrated that in cases of lesions of ≤10 mm in size, if the distance to the pleural surface is >5 mm, the probability of failure to detect the lesions is >50%; when the distance is >10 mm, the failure probability is 100%. However, we detected 16 (64%) lesions by palpation. Finger palpation is the simplest method. Radiographic findings on preoperative CT images puncture site and the position of the unsuccessful localisation materials in the lung all help to detect small pulmonary lesions during thoracoscopic exploration. The success rate of palpation by which lesions were detected can be verified. Based on the radiographic findings on preoperative CT images, puncture site and the position of unsuccessful marking materials in the lung, detecting the highly suspected area of lesion in lung tissue is feasible. A point we raise with regard to the detection of lesions by palpation is to clamp this area with sponge forceps and run a finger over this area along a straight line. In this way, even a slight difference in the sense of touch can be felt. However, this technique does not usually work if the lesion is located deep in the lung parenchyma.

In cases in which palpation failed to localise the nodule, Suzuki et al. [18] chose to convert to thoracotomy. Resection of the highly suspected area of lesion in the lung tissue is also commonly used. Some newly designed methods or tools for the detection of pulmonary lesions have been considered effective during thoracoscopy. Ohtaka et al. [32] described that O-arm is an intraoperative imaging device that can provide CT images and that the positional relationship between the lesion and needle marking will be determined based on these O-arm CT images. Barmin et al.[33] designed a new tactile mechanoreceptor, with the help of which the surgeon can see the border between normal and high-density tissue in the inspected area. Okusanya et al.[34] intravenously injected indocyanine green 24 hours before surgery and claimed that, during lung resections, intraoperative near-infrared imaging can be used to detect GGNs that are poorly visualised on CT and difficult to discriminate on finger palpation. All of these new methods are considered to be additional tools for facilitating intraoperative localisation and surgical resection of nonpalpable lung lesions. Segmentectomy or lobectomy should also be considered during surgery after every traditional effort has been exerted preoperatively.Wu et al.[35] reported that three-dimensional navigation combined with anatomic segmental pulmonary resection avoids the adverse factors of puncture, and can replace puncture localization for GGN located in the central region of segmental or subsegmental lung or adjacent intersegmental veins.

We acknowledge some limitations of this retrospective study. First, most of the lesions in the cases we included were subcentimetre nodules. The smaller the lesions we needed to locate, the more difficult it was to do so. In addition, our study was not designed to compare the failure rate, cause of localisation failure and the method of amending after unsuccessful localisation and so forth between the two marking materials. Moreover, we have become aware of some potential technical biases in our study. Despite these limitations, the results of this study contribute to additional significant experience on localisation failure, and we conclude that, after an unsuccessfully preoperative procedure of CT-guided hookwire or coil localisation, a second localisation, intraoperative localisation, resection of the highly suspected area, or a segmentectomy or lobectomy can be successfully attempted using VATS for resection of GGNs.

Abbreviations

CT:computed tomography

ICG:indocyanine green

GGN:ground-glass nodule

VATS:video-assisted thoracoscopic surgery

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki.Ethics approval was obtained from ethics committee of Tianjin Medical University Cancer Institute and Hospital, and written informed consent for participation was obtained from the patient. A copy of the written consent is available for review by the Editor of this journal.

Consent for publication

Written informed consent was obtained from the patient for publication of this study and any accompanying images. A copy of the written consent is available for review by the Editor of this journal.

Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

All authors declare that they have no competing interests.

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Authors' contributions

TZ and ZG designed and carried out experiments, BW analyzed sequencing data and developed analysis tools. contributed significantly to analysis and manuscript preparation.TZ wrote the manuscript. BC helped perform the analysis with constructive discussions. ZZ contributed to the conception of the study.

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Tables

Table 1 Characteristics of 20 patients who underwent an unsuccessful preoperative procedure of CT-guided hookwire or coil localization and VATS.

Characteristic	No. of patients
Age(years)	48(range,28-72)
Gender	
Man	9
Female	11
First symptoms	
Founding by physical examinations	13
Cough or sputum	7
Cancer history	
Yes	2
No	18

Table II. Characteristics of 25 GGNs from 20 patients who underwent an unsuccessful preoperative procedure of CT-guided hookwire or coil localization and VATS.

Characteristic	No. of lesions
Marking material	
Hookwire	14
Coil	11
The types of unsuccessful localization	
Dislodgement	10
Breakaway	2
The distancemore more than 2 cm between the lesion and the tip of wires or coils	4
Marking material in different lung lobes adjacent to GGN	1
Pneumothorax	6
Marking materials stuck into walls	2
Remedies	
palpation	15
Resecting the highly suspected areas	3
Segmentectomies	2
Lobectomy	4
Histological diagnosis	
Interstitial fibrous tissue proliferation	2
Atypical adenomatoid hyperplasia	7
Adenocarcinoma in situ	9
Minimally invasive adenocarcinoma	5
Invasive adenocarcinoma.	4

Figures

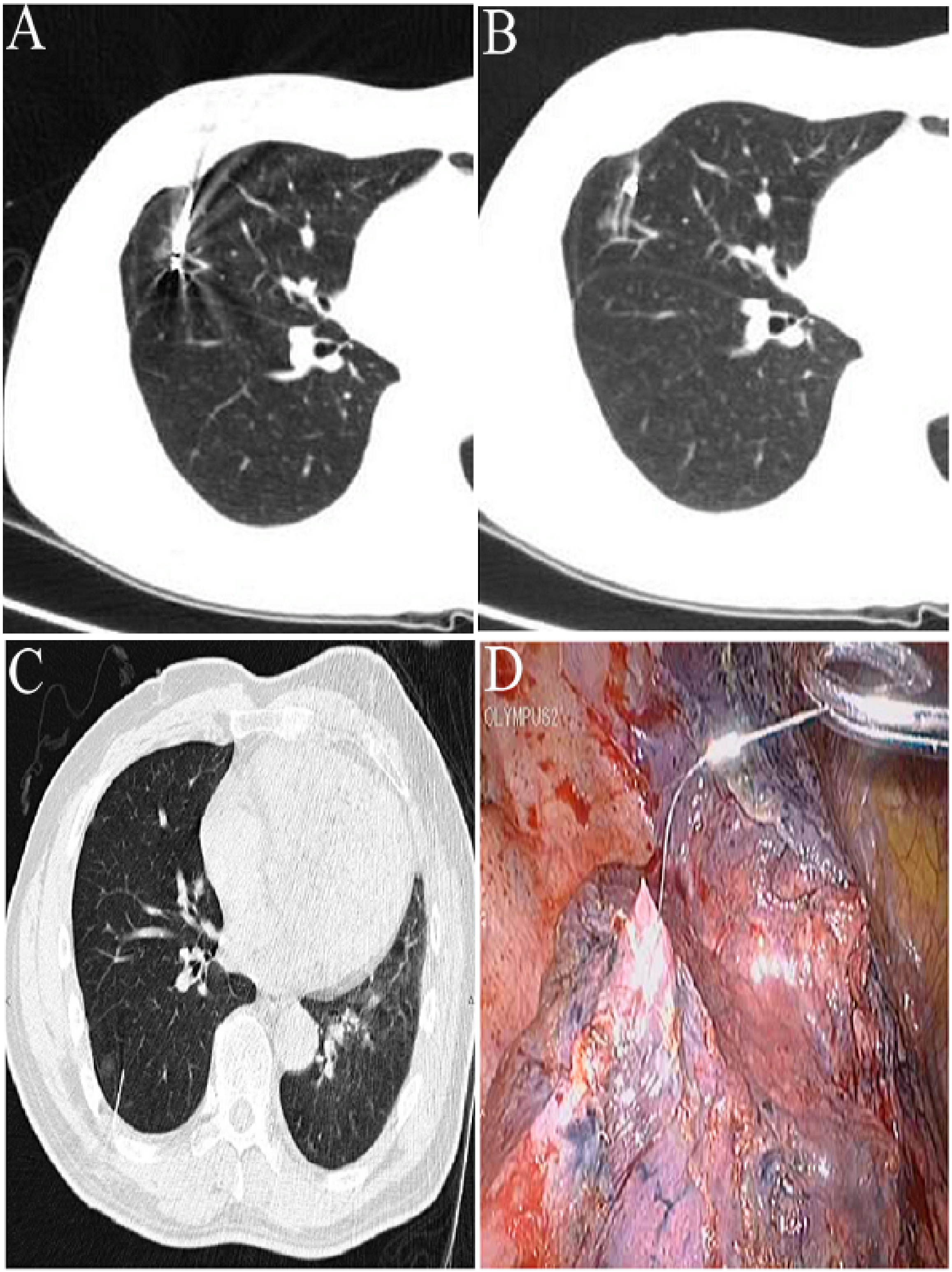

Figure 1

Images of lung computed tomography (CT) scan and surgical field for dislodgement of marking materials. (A) The coil was adjacent to a GGN after it was released. (B) Coil dislodgement occurred through the needle passage. (C) The tip of the hookwire was extended more than 3 cm into the lung tissue before the operation. (D) The tip of the hookwire was extended less than 1 cm into the lung tissue during an operation.

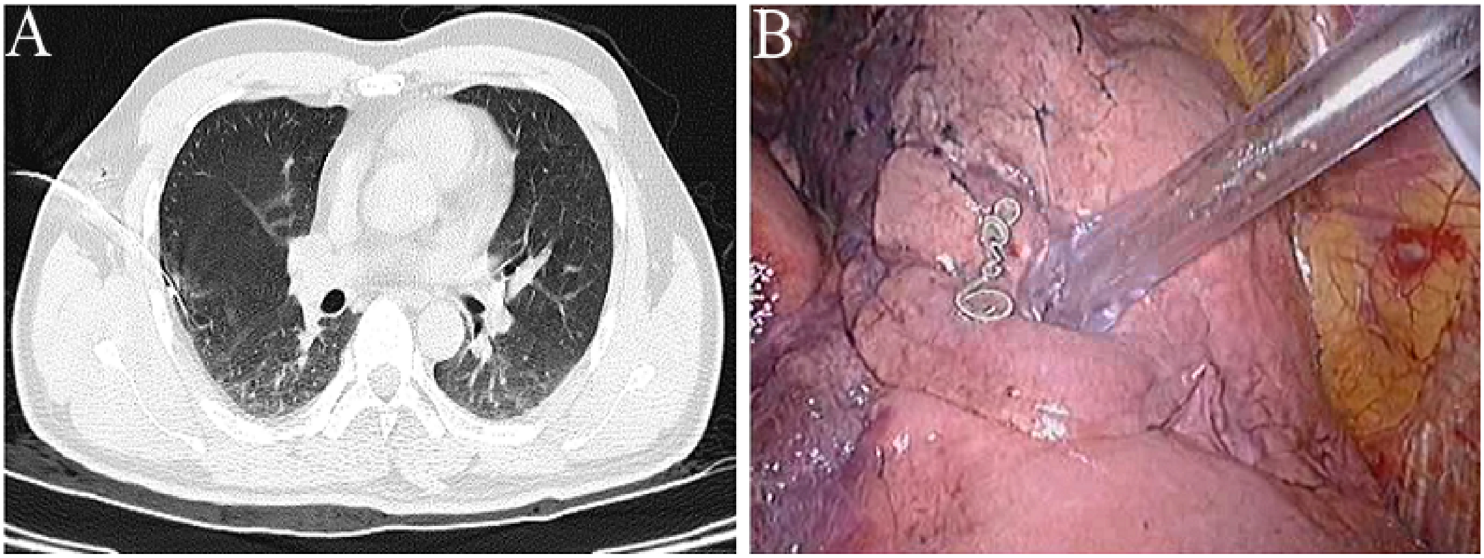

Figure 2

Images of lung CT scan and surgical field for the breakaway of marking materials. (A) A breakaway of the coil was observed after the trocar needle was withdrawn. (B) A breakaway coil was found in the pleural cavity during VATS.

Figure 3

Images of lung CT scan for the distance between the lesion and the wire tip. As shown in the image, there was a distance of more than 2 cm between the lesion and the tip of the wire.

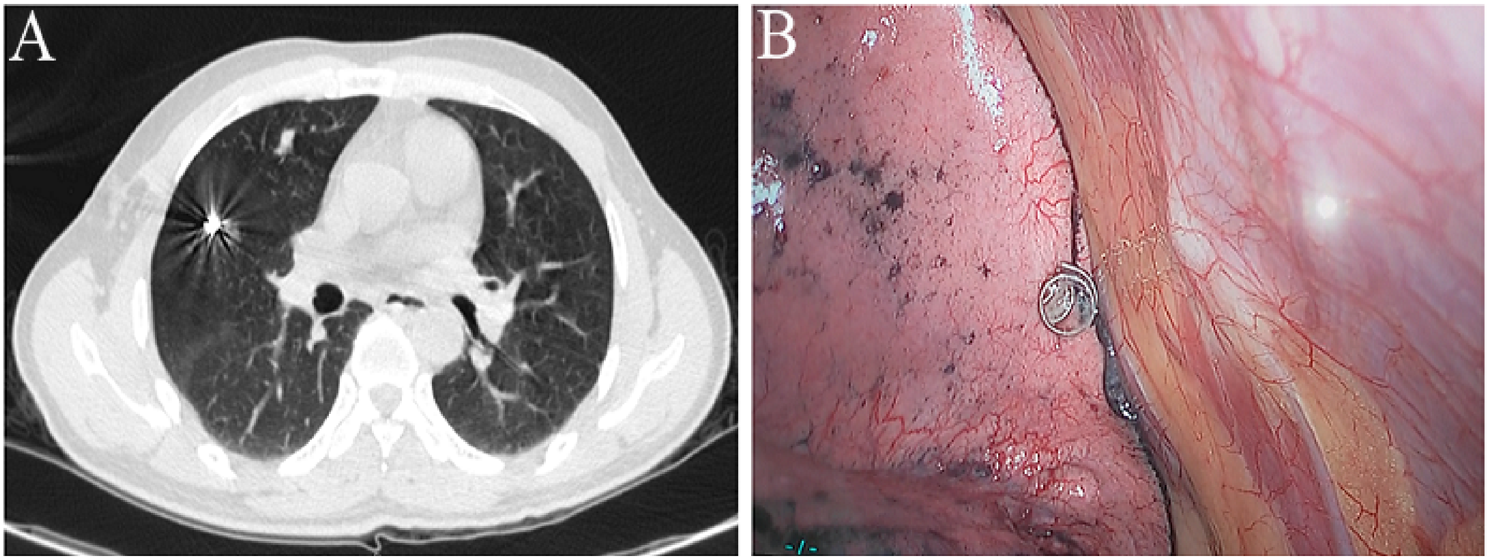

Figure 4

Images of lung CT scan and surgical field for coil localisation. (A) A GGN in the right middle lobe was localised with the coil. (B) The coil for lesion localisation was found in the upper lobe.

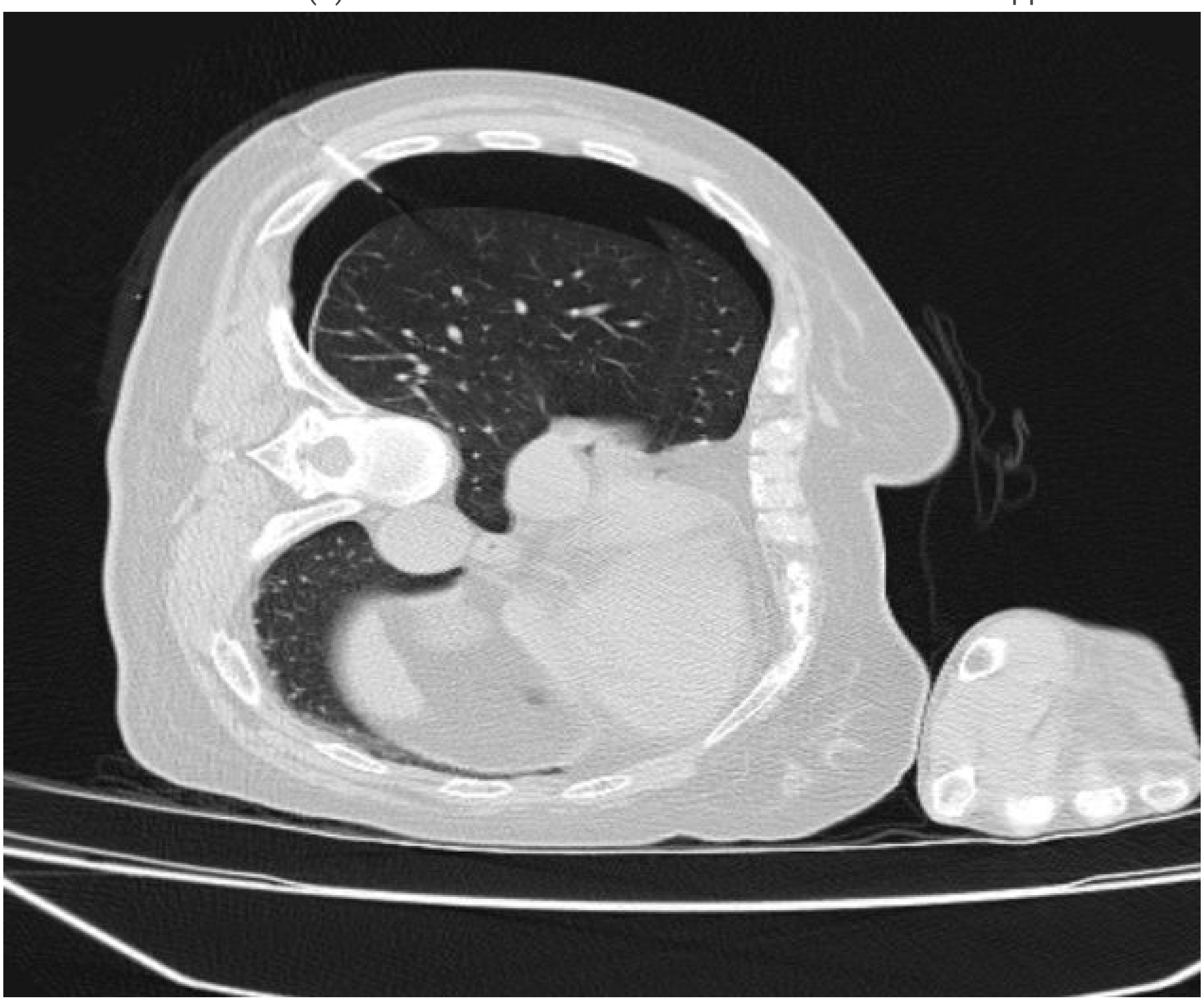

Figure 5

Images of lung CT scan for the development of pneumothorax. A mild-sized right pneumothorax, characterised by a subpleural bulla, compression of the lung parenchyma and deviation of the mediastinum toward the contralateral hemithorax, was demonstrated.

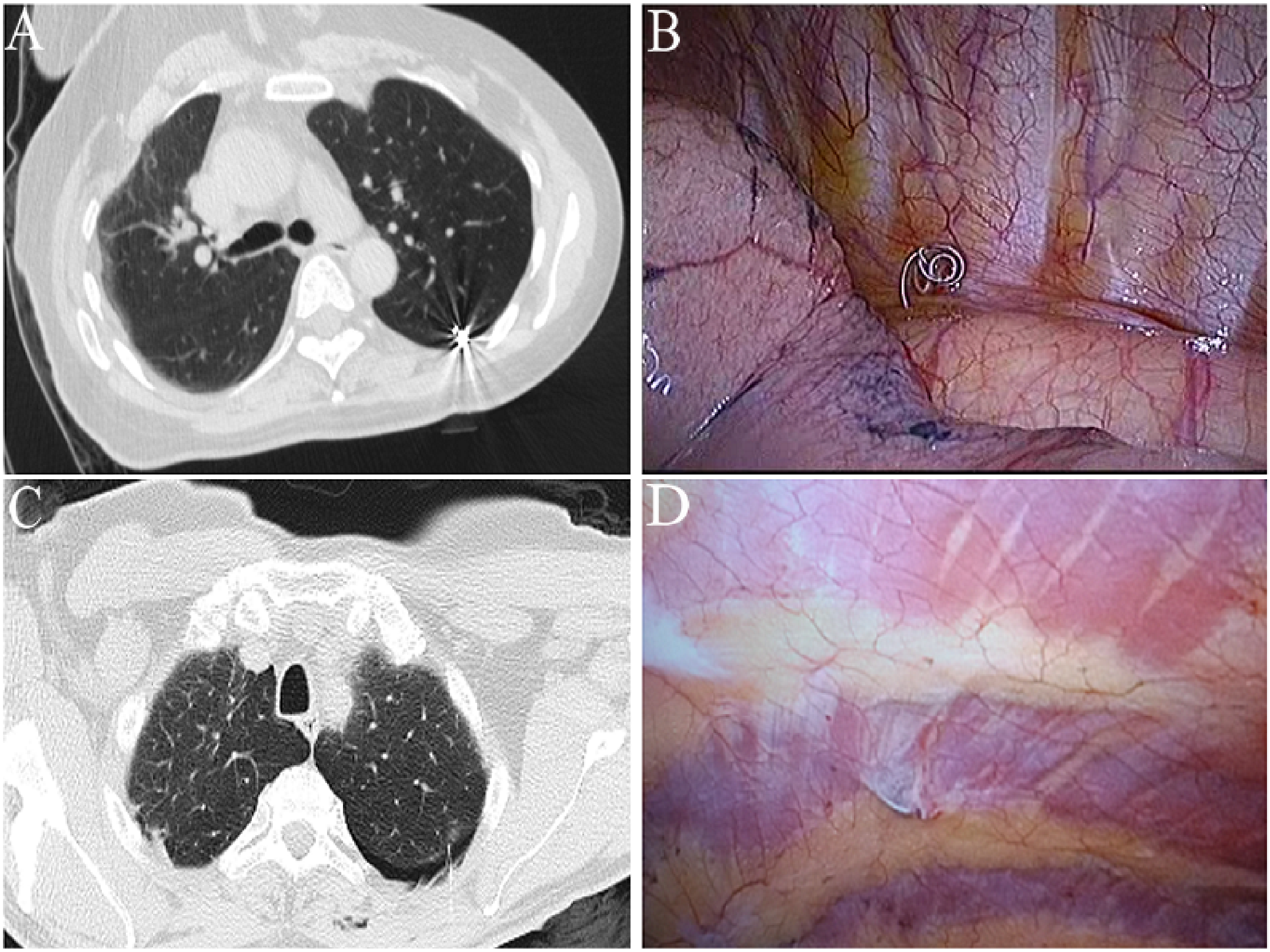

Figure 6

Images of lung CT scan and surgical field for placement and fixation of marking materials. (A) The coil was placed into a GGN adjacent to the pleura. (B) The coil was fixed to the chest wall. (C) The tip of the hookwire was placed into a GGN at the left lung. (D) The hookwire was fixed to the chest wall.

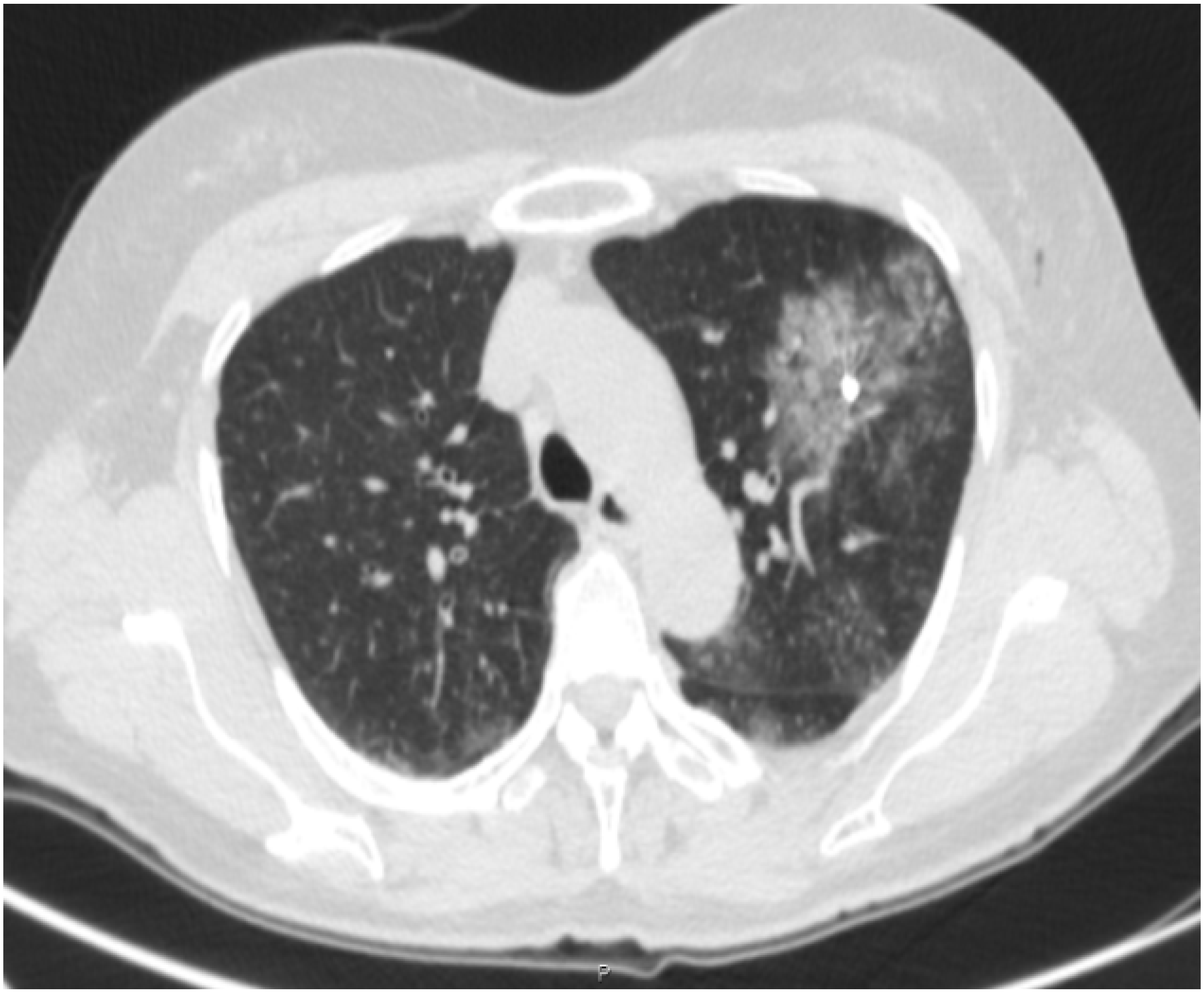

Figure 7

Images of lung CT scan for the development of pulmonary haemorrhage.