CT Guided Placement of the End of the Microcoil in the Pleural Cavity: A More Helpful Method for Video-Assisted Thoracic Surgery (VATS) Resection of Ground Glass Opacity (GGO)

Jianli An  
Qinhuangdao Municipal No.1 Hospital

Yanchao Dong  (✉️ dyc_hometown@aliyun.com)  
Qinhuangdao Municipal No.1 Hospital

Yanguo Li  
Qinhuangdao Municipal No.1 Hospital

Xiaoyu Han  
Qinhuangdao Municipal No.1 Hospital

Hongtao Niu  
Qinhuangdao Municipal No.1 Hospital

Zibo Zou  
Qinhuangdao Municipal No.1 Hospital

Jingpeng Wu  
Qinhuangdao Municipal No.1 Hospital

Ye Tian  
Qinhuangdao Municipal No.1 Hospital

Zhuo Chen  
Qinhuangdao Municipal No.1 Hospital

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Abstract

**Objective** To investigate and summarize the effectiveness and safety of CT guided microcoil localization before video-assisted thoracic surgery (VATS) for the removal of ground glass opacity (GGO).

**Method** 147 patients with GGO who were treated in our hospital from January 2019 to February 2021 were retrospectively analyzed. They were divided into two groups according to the final position of the end of the microcoil, intracavity group (n=78) and extracavity group (n=69). Comparison of the two groups of patients with puncture complications, and the influence of the end position of the coil for VATS.

**Results** The proportion of supine and prone position in the intracavity group was significantly higher than that in the extracavity group (82.1% vs. 66.7%, P<0.05). The incidence of intrapulmonary hemorrhage, chest pain and coil displacement in the intracavitary group was significantly lower than that in the extracavitary group (28.2% vs. 46.4%; 19.2% vs. 39.1%;1.3% vs. 11.6%, P<0.05), and the incidence of pneumothorax had no significant difference(P>0.05). The time of VATS and the rate of conversion to thoracotomy in the intracavity group were significantly lower than those in the extracavity group (103.4±21.0min vs. 112.2±17.3min, 0% vs. 5.8%, P<0.05).

**Conclusion** CT-guided placement of the microcoil was a very practical, simple and convenient localization method before VATS with high success rate and few complications, further more, it was a better method to place the end of the coil in the pleural cavity because of the lower complication rate, shorter VATS time and lower rate of thoracotomy conversion.

Introduction

At present, lung cancer was one of the most dangerous malignant tumors, with a high morbidity and mortality, especially in the elderly[1]. Related studies showed that the 5-year survival rate of patients with advanced lung cancer was less than 2%[2, 3]. While the 5-year survival rate of early lung cancer with ground-glass opacity (GGO) was even as high as 100%[4, 5]. Therefore, early diagnosis and treatment of lung cancer were particularly important.

With the development of medical imaging technology, high-resolution computed tomography (HRCT) was gradually popularized, and small pulmonary nodules were found more and more, which attracted people's attention[6]. However, because GGO was relatively small and the solid component was relatively less, needle biopsy was difficult, and there were few tissues available, so it was difficult to make accurate pathological diagnosis, which made the early diagnosis of GGO more difficult. For all small pulmonary nodules, if the possibility of early lung cancer was highly suspected, surgical resection should be the first choice, which can not only clearly diagnose but also achieve the purpose of treatment[7]. However, traditional thoracotomy was highly traumatic and prone to complications such as pneumothorax after operation. Video-assisted thoracic surgery (VATS) had gradually replaced traditional thoracotomy because of its advantages of integrated diagnosis and treatment, minimally invasive and less complications[8]. Unfortunately, it was one of the difficult problems that puzzles thoracic surgeons to
locate pulmonary nodules quickly and accurately during operation, especially for ground glass nodules with small size, deep position and few solid components[9]. Studies had shown that more than half of the nodules were difficult to accurately locate in VATS, finally, thoracotomy was needed[10].

Therefore, the key to complete the operation was to locate GGO effectively before VATS. As early as the 1990s, Asamura et al. first used platinum microcoils applied to vascular embolization to locate GGO, and achieved good results[11]; After that, Powell et al. invented a better positioning method, which placed the end of microcoils in the pleural cavity, so that the position of microcoils could be visually observed during VATS operation, and GGO resection was easier and more convenient[12]. We use this microcoil positioning method from the Powell, the head of coil was placed around the GGO and the end of coil was placed in the pleural cavity, so as to locate the GGO during the VATS for accurate resection. However, in fact, the end of coil cannot be accurately positioned in the pleural cavity, and sometimes the end may be located in the soft tissue of the chest wall outside the pleura. There was no previous research on the influence of the tail position of microcoil on preoperative positioning. So the purpose of this study was to discuss and review the CT-guided positioning of microcoils for GGO before VATS, and the influence of the different position of the end of microcoils on puncture complications and VATS.

**Materials And Methods**

**Study subjects**

The clinical data of GGO patients in our hospital from January 2019 to February 2021 were analyzed retrospectively. The inclusion criteria were as follows: (1) all patients were diagnosed as solitary GGO by chest CT (lung window setting), and after more than 6 months of follow-up, the diameter of GGO increased or the solid components increased, and more than 2 radiologists with more than 10 years of experience suspected malignant nodules; (2) nodule diameter ≤ 15mm (the whole tumor diameter); (3) according to the shape and position of CT, it was considered that it was unlikely to be touched during operation. Exclusion criteria: (1) serious cardiopulmonary dysfunction; (2) abnormal coagulation function; (3) contraindication of VATS; (4) there was a large vascular structure around the GGO, and the risk of puncture was extremely high; (5) the patient was restless or unable to coordinate with puncture location due to severe cough. This study was approved by the Medical Ethics Committee of the Qinhuangdao Municipal No.1 Hospital, because it was a retrospective study without signing an informed consent form.

Grouping: 147 patients who received CT-guided micro-coil positioning GGO before VAST were selected and divided into two groups according to the position of coil end: 78 cases in intracavity group (coil end was located in pleural cavity, see Figure 1) and 69 cases in the extracavity group (coil end was located outside pleural cavity and in soft tissue of chest wall, see Figure 2).

**CT-guided microcoil localization**
CT-guided microcoils were positioned within 12 hours before VATS. CT-guided positioning method of microcoils: according to preoperative CT, discuss the positioning scheme and body position with thoracic surgeons; CT scan (interval 1.25 mm) was performed after placement of locator before puncture, and the position of puncture point, depth and angle of needle insertion were determined, avoiding intercostal nerves, blood vessels, large blood vessels and bronchus in lung. Routine disinfection and towel laying, local infiltration anesthesia with 2% lidocaine, instructing the patient to hold his breath and insert a 21 G Chiba needle into the lung pleura, reexamining CT quickly, instructing the patient to hold his breath again and adjust the needle tip position, inserting the needle into the normal lung tissue around the lesion (the distance from the GGO was<5mm), reexamining CT again to determine the position, then pulling out the needle core and connecting the microcoil (COOK). We selected the microcoil with appropriate length according to the pleural distance of nodules. Generally, it was at least 2cm larger than the distance from nodule to pleura. Push the coil around the nodule to anchor, repeat CT plain scan, and then gradually withdraw the needle according to the measured distance between the needle tip and the lung pleura, and release the end of the microcoil to form a ring outside the viscera pleura. After observing for about 10min minutes, re-check CT to determine the position of the coil, and check whether the patient has any complications such as intrapulmonary hemorrhage and pneumothorax. And then the patient was sent back to the ward by wheelchair without chest tightness, shortness of breath and bleeding at the puncture point.

**VATS Resection**

In all cases, thoracoscopic resection was performed within 12 hours after placement of microcoils. All patients were transported by bed to a preoperative holding area before being transferred to the operating room. Instruct patients to avoid strenuous activities, panting and coughing as much as possible.

Intravenous general anesthesia was performed with double-lumen endotracheal intubation, the healthy side was placed in 90 lateral position, and the towel was disinfected routinely. The 7th/8th intercostal space of the affected side was selected as observation hole, and the 3rd/4th intercostal space was selected as operation hole. After the lung collapsed, the coil located on the surface of the lung was clearly observed. After touching the coil located next to the lesion, the wedge-shaped lobectomy was performed with Echelon endoscope linear cutting stapler (Johnson & Johnson, 60mm). The lung tissue was resected, and the lesions were found along the microcoil. The lesions were resected and pathological examination was performed by rapid frozen section. According to the results of pathological examination, decide whether to perform lobectomy plus lymph node dissection.

**Data collection**

CT-guided puncture positioning related indicators: patient's puncture position, puncture times, positioning time, distance between the head of coil and the nodule, and positioning success rate. Incidence of puncture complications: pneumothorax (mild pneumothorax: the distance between the widest part of the gas density shadow between the affected chest wall and the lung edge was less than 2cm; severe pneumothorax: the distance between the widest part of the gas density shadow between the affected
chest wall and the lung edge was more than 2cm), Intrapulmonary hemorrhage (mild hemorrhage: a new patchy ground glass density shadow in the lung, see Figure 3; severe hemorrhage: new patchy ground glass density shadow in the lung, and inability to show the original pulmonary nodules, see Figure 4), pain [pain score by visual analogue scale (VAS), 0 was painless, 1-3 was mild pain, 4-6 was moderate pain, 7-10 was severe pain], and observe whether the coil was displaced during VATS (no displacement: coil shedding, see Figure 5).

VATS operation index: Record the operation time, conversion to thoracotomy rate, one-time nodule resection rate (one wedge resection means complete nodule resection with sufficient margin range), wedge resection lung tissue volume (after wedge resection lung tissue, measure the longest, widest and highest point of lung tissue with a ruler in natural state, and record it as its length, width and height respectively, and calculate the volume of wedge resection lung tissue by the product of length, width and height).

Pathological examination results: the detection rate of lung cancer, atypical tumor-like hyperplasia, hamartoma, inflammatory lesions and other diseases.

**Statistical analysis**

SPSS 18.0 software was used for statistical analysis. The measurement data of normal distribution was expressed by means ± standard deviation (SD), and the comparison between groups was made by t-test. Frequency and percentage were used for statistical description of counting data, and \( \chi^2 \) test was used for comparison between groups. P<0.05 was statistically significant.

**Results**

**Comparative analysis of basic information between two groups**

A total of 147 patients with GGO were enrolled, including 78 patients in the intracavity group, 44 women and 34 men, with an average age of (58.7±11.8) years, ranging from 32 to 79 years old, with an average nodule diameter of (5.02±1.15)mm, there were 33 patients with pure GGO (pGGO) and 45 patients with partial solid GGO (mixed GGO, mGGO). The average distance between nodules and pleura was (3.03±1.75)cm. In the extracavity group, there were 69 cases, including 40 females and 29 males, with an average age of (56.3±10.0) years, ranging from 34 to 81 years, with an average nodule diameter of (5.07±1.17)mm. There were 31 patients with pGGO and 38 patients with mGGO. The average distance between nodules and pleura was (2.94±1.46)cm. There was no statistical difference in the basic information between the two groups. See Table 1 for details.
### Table 1
Comparative analysis of basic information of two groups of patients

|                          | Intracavity group(n=78) | Extracavity group(n=69) | Statistic | p value |
|--------------------------|--------------------------|--------------------------|-----------|---------|
| Age                      | 58.7±11.8                | 56.3±10.0                | t=1.335   | 0.184   |
| F/M                      | 44/34                    | 40/29                    |           |         |
|                          |                          |                          | χ² = 0.036| 0.849   |
| Nodule diameter (mm)     | 5.02±1.15                | 5.07±1.17                | t=0.243   | 0.808   |
| Nodule nature            | pGGO 33                  | 31                       |           |         |
|                          | mGGO 45                  | 38                       |           |         |
| Nodule position          | Upper lobe of left lung  | 19                       |           |         |
|                          |                           | 17                       |           |         |
|                          | Lower lobe of left lung  | 17                       |           |         |
|                          |                           | 16                       |           |         |
|                          | Upper lobe of right lung | 26                       |           |         |
|                          |                           | 23                       |           |         |
|                          | Middle lobe of right lung| 3                        |           |         |
|                          |                           | 3                        |           |         |
|                          | Lower lobe of right lung | 13                       |           |         |
|                          |                           | 10                       |           |         |
| Distance from nodule to pleura(cm) | 3.03±1.75 | 2.94±1.46 | t=0.343   | 0.732   |

Values were shown as counts or means± standard deviations.

**Comparative analysis of related indexes of the CT-guided puncture between the two groups**

Comparison showed that the proportion of patients in supine and prone position in intracavitary group was significantly higher than that in extracavity group (82.1% vs. 60.9%), while the proportion of patients in lateral position in intracavitary group was significantly lower than that in extracavity group (17.9% vs. 39.1%), and the difference was statistically significant. However, there was no significant difference between the two groups in puncture times, puncture positioning time, distance between coil head and nodule, and positioning success rate. See Table 2 for details.
Comparative analysis of related indexes of CT-guided puncture positioning between two groups of patients

|                           | Intracavity group (n=78) | Extracavity group (n=69) | Statistic | p value |
|---------------------------|--------------------------|--------------------------|-----------|---------|
| **Puncture position**     |                          |                          |           |         |
| Supine position           | 40                       | 24                       | $\chi^2 = 8.481$ | 0.037*  |
| Prone position            | 24                       | 18                       |           |         |
| Left lateral position     | 9                        | 18                       |           |         |
| Right lateral position    | 5                        | 9                        |           |         |
| **Puncture times**        |                          |                          |           |         |
| 1                         | 55                       | 50                       | $\chi^2 = 0.132$ | 0.936   |
| 2                         | 20                       | 16                       |           |         |
| 3                         | 3                        | 3                        |           |         |
| **Positioning time (min)**| 19.56±3.94               | 18.75±3.35               | t=1.335   | 0.184   |
| **Distance between head of coil and nodule (mm)** | 1.72±0.45 | 1.76±0.44 | t=0.566 | 0.572 |
| **Position success rate (%)** | 100                     | 100                      | --        | --      |

Comparing and analyzing the complications after puncture positioning between the two groups, the results showed that the incidence of intrapulmonary hemorrhage, chest pain and coil displacement in the intracavitary group was significantly lower than that in the extracavity group (intrapulmonary hemorrhage: 28.2% vs. 46.4%; chest pain: 19.2% vs. 39.1%; microcoil displacement: 1.3% vs. 11.6%); however, there was no significant difference in the incidence of pneumothorax between the two groups (26.9% vs. 29.0%). See Table 3 for details.
### Table 3
Comparison of CT puncture complications between two groups

|                          | Intracavity group (n=78) | Extracavity group (n=69) | Statistic | p value |
|--------------------------|--------------------------|--------------------------|-----------|---------|
| **Pneumothorax**         |                          |                          |           |         |
| Mild                     | 18                       | 18                       | $\chi^2 = 0.077$ | 0.781   |
| Severe                   | 3                        | 2                        |           |         |
| No                       | 57                       | 49                       |           |         |
| **Intrapulmonary hemorrhage** |                        |                          |           |         |
| Mild                     | 17                       | 29                       | $\chi^2 = 5.202$ | 0.023*  |
| Severe                   | 5                        | 3                        |           |         |
| No                       | 56                       | 37                       |           |         |
| **Chest pain**           |                          |                          |           |         |
| Mild                     | 12                       | 19                       | $\chi^2 = 7.104$ | 0.008*  |
| Moderate                 | 3                        | 7                        |           |         |
| Severe                   | 0                        | 1                        |           |         |
| No                       | 63                       | 42                       |           |         |
| **Microcoil displacement** |                        |                          |           |         |
| Drop                     | 1                        | 8                        | $\chi^2 = 6.774$ | 0.013** |
| No                       | 77                       | 61                       |           |         |

**Fisher's exact probability method was adopted**

### Comparison of VATS operation indexes between the two groups

Comparative analysis of VATS operation indexes between the two groups showed that the VATS time and conversion rate of thoracotomy in intracavity group were significantly lower than those in extracavity group, and the difference was statistically significant. However, there was no significant difference between the one-time resection rate of nodules and the volume of lung tissue after wedge resection. See Table 4 for details.
Table 4
Comparative analysis of VATS operation indexes

|                                | Intracavity group (n=78) | Extracavity group (n=69) | Statistic | p value |
|--------------------------------|--------------------------|--------------------------|-----------|---------|
| Time of VATS                   | 103.4±21.0               | 112.2±17.3               | t=2.761   | 0.007*  |
| The rate of conversion to thoracotomy | 0(0%)                  | 4(5.8%)                  | χ²=4.648  | 0.046** |
| One-time resection rate of nodules | 100%                    | 100%                     | --        | --      |
| Excised lung tissue volume(cm³) | 127.05±58.24            | 141.26±53.11             | t=1.538   | 0.126   |

Discussion

Current research situation of puncture location

With the wide application of low-dose CT, the detection rate of GGO increased significantly. Clinically, it was necessary to determine its benign/malignant nature before further treatment. However, due to the small GGO, clinical needle biopsy and imaging cannot clearly and accurately study nodules qualitatively. The Fleischner Society GGO treatment guidelines suggested that isolated pGGO and mGGO with a diameter greater than 6mm should be reexamined after 6-12months and 3-6months, separately. If the lesion was enlarged or the lesion density was increased, surgical treatment should be taken, and Uniportal VATS wedge resection of lung tissue, segmental and subsegmental pneumonectomy was recommended[13]. Studies had shown that about 50% of solitary pulmonary nodules were malignant, which should be treated early to prevent further deterioration[14]. Studies had shown that the GGO of stage IA lung adenocarcinoma was more than 50% on CT images, and the prognosis of GGO was better than that of solid nodules after resection, 5-year overall survival up to 97%[15]. Therefore, VATS provided a new choice for early treatment of pulmonary nodules, and it also made accurate positioning of pulmonary nodules an urgent problem to be solved[16]. At present, the localization methods for pulmonary nodules were diversified, including imaging localization method, injecting liquid material-mediated localization method[17] and percutaneous placement of solid materials[18]. Each localization method had its own advantages and disadvantages. Imaging positioning methods include intraoperative ultrasonic positioning[19], near-infrared fluorescence imaging positioning[20] and surgical navigation puncture robot system[21], but the requirements for equipment and the technical level of operators were high, which was difficult to be widely popularized. However, injection of liquid material-mediated localization method, including injection of lipiodol[22], methylene blue[23], medical glue[24], indocyanine green fluorescent agent[25] and other liquids, had some shortcomings such as short retention time, easy diffusion and uncontrollable injection dose, and had not received more attention from thoracic surgeons.
However, percutaneous placement of solid materials was similar to injection of liquid materials-mediated localization, which needed to puncture to the vicinity of nodules under the guidance of CT and other auxiliary equipment, and place or inject corresponding markers in order to find and accurately locate nodules during operation. Among them, solid materials include hook-wire\[26\], microcoil\[27\] and other materials. Hook-wire was special for breast nodule positioning\[28\], due to there was no special instrument for lung nodule positioning before in the world, it was had to use hook-wire for lung nodule positioning. Moreover, the hook-wire was quite hard, which obviously increased the risk of pneumothorax, intrapulmonary hemorrhage and chest pain. However, the microcoil had the characteristics of good flexibility and elasticity, and the spiral structure did not affect the expansion of the surrounding lung tissue to compress the puncture point, thus reducing the occurrence of the above complications\[29\]. In addition, the artificial fiber hairs on the surface of the microcoils can increase the friction force, so that the microcoils were firmly fixed in the lung tissue, and the displacement and shedding were reduced\[16\]. Asamura et al. reported for the first time that microcoils were used to locate pulmonary nodules before VATS\[11\]. In recent years, many studies had confirmed the effectiveness of this method\[30, 31\].

In the past, most of the microcoil was placed around nodules, and pleural display still cannot directly show the location of nodules. In the present more researchers prefer to locate nodules by placing the end of microcoil in the pleural cavity, which can clearly show the location of coils in VATS, and had obvious advantages over previous methods. In this study, the application of this method for localization was analyzed retrospectively. The results showed that 147 patients with GGO were located preoperatively in the two groups, and the total success rate of nodule localization was 100%, and the incidence of total complications was low, including pneumothorax: 27.9%, intrapulmonary hemorrhage: 36.7%, chest pain: 28.6%, and coil displacement: 6.1%.

### The basic situation of two groups of patients was comparable

The results showed that there was no statistical difference between the two groups in age, sex composition, nodule diameter, nodule nature, nodule location and the distance between nodule and pleura, so the two groups were comparable. The results showed that the average age of patients in both groups was over 55 years old, and the gender composition showed that female patients were higher than male patients (57.1% vs. 42.9%). The reasons for choosing such patients in the experiment were as follows: first, the elderly women over 55 years old in China had a higher proportion of lung cancer screening, and high-resolution CT found that pGGO and mGGO were higher in female patients\[32\]; secondly, studies by foreign scholars showed that women over 50 years old were the risk factors for judging the malignancy of pulmonary nodules\[33, 34\]. Therefore, women over 55 years old were mostly selected in this study.

However, the average diameter of nodules in both groups was larger than 5mm, and the proportion of mGGO was slightly higher than that of pGGO (56.5% vs. 43.5%). These kinds of patients were selected because pGGO and mGGO with diameters larger than 5mm were first reviewed after 3 months. If the
lesion was enlarged or the lesion density was increased, the proportion of malignant lesions was higher, which required surgical treatment, so the proportion of patients with mGGO was higher. However, data such as nodule location and distance from nodule to pleura had not mentioned in many prediction models that may affect the judgment of benign and malignant diseases.

**The puncture position may affect the position of the end of the coil**

Comparison between the two groups showed that the ratio of supine and prone positions in the intracavity group was 82.1%, which was significantly higher than that in the extracavity group (66.7%). There was no significant difference in other puncture times, positioning time, distance between the head of the coil and the nodule, and puncture success rate. Therefore, we consider that the end of the coil was finally placed inside or outside the pleural cavity, to a certain extent, which may be related to the patient's puncture position. We suspect that when the patient was in supine and prone position, the body was relatively fixed, so it was difficult to move the position. Therefore, in the process of gradually withdrawing the needle according to the measured distance between the needle tip and the pleura, the needle withdrawal distance was accurate, and it was difficult to place the tail end outside the pleural cavity. On the contrary, when the patient adopts the lateral position, it was easy to move slightly, which led to inaccurate needle withdrawal distance and the situation that the tail end of the spring coil may place outside the pleural cavity.

In addition, we found that the positioning time of the intracavity group was slightly shorter than that of the extracavity group, and the distance between the head of the coil and the nodule in the intracavity group was slightly lower than that in the extracavity group. Although there was no statistical difference, we speculated that the proportion of patients who might take the lateral position with the extracavity group was higher than that in the intracavity group, which led to the patient's intolerance of puncture, which led to a slight shortening of the positioning time and a slight increase in the distance between the coil and the nodule. Therefore, it may be a better choice to choose a more stable body position for puncture positioning.

**The proportion of pulmonary hemorrhage, chest pain and coil displacement in extracavity group was higher than that in intracavity group**

The total incidence of complications after CT-guided puncture was lower in both groups, including pneumothorax (27.9%), pulmonary hemorrhage (36.7%), chest pain (7.5%) and coil displacement (6.1%). Compared with previous studies, the incidence of pneumothorax, bleeding and moderate and severe pain in Hookwire positioning method was 48.5%, 24.2% and 24.2%, respectively. Our research results showed that the incidence of bleeding was a little more than that in Hookwire positioning method, while the incidence of other complications was significantly lower than that in Hookwire positioning method. Considering the application of microcoil positioning method, the incidence of complications was significantly lower than that in Hookwire positioning method. Compared with other centers using microcoils, the incidence of pneumothorax, bleeding and moderate and severe pain was 15.2%, 7.6% and
6.3%, which were also significantly lower than our experimental results. The possible reason was that the nodules selected by other centers were superficial according to the pleural position, which was less than 1cm, while our nodules were about 3cm away from the pleura, which was significantly higher than the previous research results. Therefore, it may lead to more puncture paths passing through pulmonary vessels, and the incidence of bleeding was slightly higher than the previous experimental results. In addition, the average age of our patients was higher than the average age of the patients in the above study, which may lead to a slightly higher incidence of complications than the previous experimental results. Another study selected patients with an average age of over 60 years, and the incidence of pneumothorax was as high as 60%[35], which was significantly higher than our experimental results, which may support our conjecture.

However, the comparison of the incidence of complications after puncture between the two groups showed that there was no statistical difference in the incidence of pneumothorax. We consider that the puncture needle was thin, which causes less damage to the pleura, and whether the end of the micro coil was placed inside or outside the pleural cavity, it can block the puncture point to a certain extent, which will not lead to pneumothorax, so there was no significant statistical difference in the incidence of pneumothorax between the two groups. However, the proportion of bleeding, pain and coil displacement after puncture in extracavity group was higher than that in intracavity group, and the difference was statistically significant. First of all, we consider that the proportion of patients in the extracavity group who use lateral position for puncture was higher than that in the intracavity group. As mentioned above, patients may have slight displacement, which may lead to needle displacement, resulting in vascular damage around nodules and a small amount of bleeding; Secondly, the end of the coil was placed in the soft tissue in the chest wall, so the coil had certain elasticity and may rebound. During the rebound process, the coil may damage the small blood vessels in the puncture path and cause slight bleeding. For the reason of high incidence of pain, we consider that the end of the coil was placed in the soft tissue of chest wall and the head was placed in the lung tissue. When there was relative movement between the two parts, the coil will rub against the pleura, which may obviously stimulate the pleura and cause high incidence of pain, which can also explain the easy displacement of the coil. Although the above complications occurred to some extent, according to the American interventional radiology complication management standard, no further treatment was needed[35].

The VATS time and the rate of conversion to thoracotomy in intracavity group were significantly lower than those in extracavity group

Our results showed that the VATS time and the rate of conversion to thoracotomy in the intracavity group were significantly lower than those in the extracavity group. We consider that when patients in the extracavity group perform VATS, they need to remove the coil on the chest wall to the pleura and then perform wedge resection like those in the intracavity group, which may increase the VATS operation time of patients in the extracavity group. Another reason may be related to the easy displacement of the coil head. If the coil shifts or even falls off, it was difficult to accurately locate the nodule through the coil during operation. In addition, if the nodules with fallen coils and deep distance from pleura cannot be
accurately located, they may be converted to open chest for surgery. Therefore, the rate of conversion to thoracotomy in patients with extracavity group was significantly higher than that in patients with intracavity group. However, the total conversion rate of thoracotomy was 2.7%, which was within the acceptable range[36, 37].

The results showed that the volume of lung tissue after wedge resection in extracavity group was slightly higher than that in intracavity group, which may also be related to the displacement of coils or transfer to thoracotomy, but there was no statistical difference, which needed further study. Nodules in both groups were resected at one time, which avoided the risk of reoperation and reduced the physiological and economic burden of patients. Therefore, CT-guided positioning of microcoils was of great significance to VATS surgery.

**Conclusion**

CT-guided positioning of microcoil pulmonary nodules was a very practical, simple and convenient positioning method with high success rate and few complications. The best position was supine or prone position in the positioning process, and placing the end of coil in the pleural cavity has more auxiliary effect on VATS operation, with lower incidence of complications, shorter operation time and lower rate of conversion to thoracotomy. Therefore, it was a better positioning method to place the end of coil in the thoracic cavity before VATS. However, this experiment also has limitations. First of all, this paper adopts the method of retrospective study, hoping to make forward-looking research in the future and reduce recall bias. Secondly, the selected cases were all from patients who have undergone surgery, and whether or not to undergo surgery depends on doctors’ experience and patients’ wishes, and there was a bias in choice. Finally, this study was a single center and small sample. With the increase of research factors, the sample size needs to be increased. In the future, it was still necessary to expand the time range of research objects, increase the sample size and reduce bias.

**Declarations**

**Ethics approval and consent to participate**

This study was approved by the Medical Ethics Committee of the Qinhuangdao Municipal No.1 Hospital, because it was a retrospective study without signing an informed consent form.

**Consent for publication**

Not applicable.

**Availability of data and materials**

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.
Competing interests

The authors had no conflicts of interest to declare.

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None.

Authors’ contributions

JL A, YC D, ZB Z, JP W, Y T and Z C contributed to the design of the study and the development of the study protocol, YC D and YG L coordinated the study. JL A and HT N performed the systematic review, including data collection and data analysis. All authors contributed to data interpretation, manuscript drafting and review. YC D drafted the first version of the manuscript.

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**Figures**

**Figure 1**

A 61-year-old female patient presented with a 14mm GGO in the right lower lobe of the lung. The end of the coil was placed in the pleural cavity and a VAST wedge resection was performed, as shown in A, B showed the end of the coil below the pleural surface, C showed the wedge-shaped resection of lung tissue(5cm*4cm*3cm), and D showed the patient's pathological findings: preinvasive carcinoma.

**Figure 2**

A was a 51-year-old woman with a 15-mm mGGO in the upper lobe of the right lung. B was the end of the coil placed outside the pleural cavity, in the soft tissue of the chest wall, C showed that the end of the coil was still in the chest wall when the lung tissue was removed by VATS. D showed the patient's pathological findings: adenocarcinoma.

**Figure 3**

A showed a 58-year-old woman with a 5mm pGGO in the lower lobe of her right lung. Mild pneumothorax appeared after puncture. The distance between visceral pleura and the chest wall was no more than 2cm. The final pathological result was adenocarcinoma; B showed a 51-year-old male with a 9mm pGGO in the right lower lobe. Severe pneumothorax occurred after the puncture. The visceral pleura was more than 2cm away from the chest wall. The final result showed microinvasive adenocarcinoma.

**Figure 4**

A showed a 58-year-old female with an 8 mm pGGO in the right upper lung. There was a small amount of bleeding after puncture. A new ground-glass lesion was seen around the top of the coil in the lung. The original GGO could still be seen, the pathological findings were: invasive adenocarcinoma; B showed a 65-year-old woman with a 1 cm-diameter pGGO in the right upper lung, the pathological finding was invasive adenocarcinoma.

**Figure 5**
A shows a 56-year-old female with an 8mm pGGO in the left lower lung, B showed the end of the coil lodged in the soft tissue of the chest wall, and C showed VATS was performed to remove the lung tissue. The coil was released from the lung tissue and lodged in the chest wall. The patient was eventually converted to thoracotomy, the pathological finding was adenocarcinoma.