Comparison of Computed Tomographic Imaging-guided hook wire localization and electromagnetic navigation bronchoscope localization in the resection of pulmonary nodules

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Research article

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Abstract

Background: The resection of nodules by thoracoscopic surgery is difficult because the nodules may be hard to identify. Currently, preoperative localization of pulmonary nodules is widely used in the clinic, including Computed Tomographic Imaging (CT)-guided transthoracic approach, hook-wire and coil embolization, but these methods increase radiation exposure and cause complications. Methods: In this study, we retrospectively compared electromagnetic navigation bronchoscopy (ENB) guided and CT guided localization of small pulmonary nodules before resection. Results: Total 157 patients underwent the localization procedure successfully, and the nodules were localized by CT guidance in 105 patients and by ENB in 52 patients. The nodule size of magnetic navigation localization was smaller than that of CT-guided localization (P<0.001). Both CT-guided and ENB localization were well tolerated in all patients, without major complications or mortality (P=0.107). In CT-guided localization group, 6 patients failed to be located while none failed in ENB group (P=0.079). The procedure time was 15.15±3.7 min for CT-guided localization and 21.29±4.0 min for ENB localization (P<0.001). Conclusions: CT-guided localization is simple and feasible for uncertain pulmonary nodules before surgery. ENB localization could identify small lung nodules with high accuracy and low incidence of complications.

Background

Lung cancer is the most lethal disease worldwide. It accounts for one-quarter of all cancer deaths around the world. Although the diagnosis and treatment technologies have improved rapidly in recent years, the prognosis of lung cancer remains poor. The 5-year survival rate of lung cancer is only 18%, which is the lowest in all cancers[1]. With widespread use of computed tomography (CT) in the clinic, the problems of small or faint lesions on CT become significant[2]. The resection of nodules by thoracoscopic surgery is difficult because the nodules may be hard to identify, especially for deep pulmonary small nodules. If the location of nodules cannot be accurately determined during the operation, it will increase the possibility of thoracotomy. Currently, preoperative localization of pulmonary nodules is widely used in the clinic, including CT-guided transthoracic approach, hook-wire and coil embolization, but these methods increase radiation exposure and cause complications[3].

Electromagnetic navigation bronchoscope can reach further peripheral lung compared to conventional electronic bronchoscope, and has a higher accuracy[4, 5]. Combined with the path constructed by electronic navigation bronchoscope, we can mark the location of small pulmonary nodules. This method has better safety and effectiveness. Several studies have reported that electromagnetic navigation bronchoscopy (ENB) guided transbronchial needle biopsy achieved better accuracy and lower complication rates, compared to conventional percutaneous core needle biopsy[6-8]. In this study, we retrospectively compared ENB and CT-guided localization of small pulmonary nodules before resection.

Methods

We retrospectively analyzed patients who underwent localization with CT and ENB followed by Video-assisted thoracoscopic surgery (VATS) at Qilu Hospital of Shandong University from January 2016 to July 2019. Patients were included based on the following criteria: lung tumor requiring preoperative localization of only one pulmonary nodule, requiring surgical intervention according to the surgeon's judgment, and having undergone thoracoscopy after localization. Clinical parameters were recorded, including the gender, age, smoking status, histology, and stage. CT findings were recorded, including lesion size, location, density, and distance from pleural distance (PD). The nodule size was measured directly on CT images, and the longest diameter was the nodule size. The nodule was classified according to the density as pure nodular ground-glass opacity (GGO), 0-50% GGO and >50% GGO.

After general anesthesia with intubation, patients were navigated using the 7th edition Super Dimension Navigation System (Covidien, Minneapolis, MN, USA) to localize and plan a route to the nodules one day before the operation. Thoracoscopic pulmonary surgery was performed immediately after the completion of magnetic navigation surgery.

Percutaneous CT-Guided Localization

CT scan was performed to confirm the presence of nodules before the localization. We used metal markers on the body surface to determine the missing line. Then we used CT and the laser to determine the coronal line. Coronal line represents the CT coronal plane of the lesion, and the intersection of two lines is used to determine the specific location of the nodule (Fig. 1).

ENB planning and surgical procedures

ENB-guided dye-marking was performed for subsolid nodules <10 mm near the pleura or nodules < 20 mm and located >10 mm from the pleural surface. The axial, sagittal and coronal views of CT images were used for planning using super Dimension system (Medtronic, Minneapolis, MN, USA).The primary lung cancer and lymph nodes were dissected by VATS, and all patients received postoperative care. The clinicopathological data, procedure parameters, and complications were evaluated.

Statistical Analyses

Measurement data were presented as mean ± standard deviation and analyzed by ANOVA. Count data were presented as percentage and analyzed by Chi-square test. Statistical analysis was performed using SPSS 23.0 software (SPSS Inc., Chicago, Il, USA). $P<0.05$ was regarded as significance.

Results

Characteristics of the patients

Total 157 patients (88 males and 69 females) underwent the localization procedure successfully, and the nodules were localized by CT guidance in 105 patients and by ENB in 52 patients. Among 157 patients, 95 were smokers and 62 were non-smokers. Clinical characteristics of the patients and lung nodules were listed in Table 1. Each patient had only one nodule, and the 157 nodules included 74 pure GGO nodules, 66 part solid nodules with GGO < 50%, and 17 part-solid nodules with GGO > 50%. The nodule size was 6.99 ±1.37 mm (range 5.0–12.0 mm). The nodule size of magnetic navigation localization was smaller than that of CT-guided localization. Magnetic navigation was more often applied in smaller nodules, while ENB was more often applied to joints near the lung surface. The nodules covered all the lobes, including 16 nodules in the left upper lobe, 26 nodules in the left lower lobe, 58 nodules in the right upper lobe, 17 nodules in the right middle lobe, and 40 nodules in the right lower lobe. The imaging diagnosis of 157 nodules was as follows: 29 benign lesion, 76 AIS, 44 MIA and 8 IA.

Localization of the nodules

Both CT-guided and ENB localization were well tolerated in all patients, without major complications or mortality. The incidence of asymptomatic hemopneumothorax was 7.6% (8/105), symptomatic hemopneumothorax was 3.8% (4/105), hemoptysis was 0.9% (1/105) and decoupling was 0.9% (1/105) in CT-guided localization group. Under the same observation conditions, we did not find any complications in ENB group (P=0.107). In addition, in CT-guided localization group, 6 patients failed to be located while none failed in ENB group (P=0.079). The procedure time for CT-guided localization was 15.15 ±3.7 min (range 10–26 min), while the procedure time for ENB localization was 21.29±4.0 min (range 12–29 min) (P<0.001). In CT-guided hookwire localization group, there were 6 hookwires pass through the nodule and 99 hookwires beside the nodule. The time of needle-carrying time for patients receiving CT-guided localization was 37.12±17.29 min (P<0.001) (Table 2).

Discussion

Because of the application of high resolution CT, the rate of detecting small pulmonary lesions has increased. Therefore, it is important to accurately locate the sublobar or non-anatomical resection using a variety of approaches[9-12]. Currently used localization methods have several advantages and disadvantages. For example, percutaneous hook wire implantation has the advantages of simple operation, accurate location and less complications, but it still an invasive operation. Recently developed methods such as ENB could accurately access peripheral lung lesions beyond the reach of conventional bronchoscopy. In addition, ENB-guided location can reduce complications such as pneumothorax, hemothorax and hemoptysis, compared with traditional location methods. Therefore, ENB-guided location is regarded as a promising tool in thoracic surgery[13, 14]. In this study we compared CT-guided localization and ENB-guided localization for lung nodules in patients with lung cancer.

In our study, 52 patients with magnetic navigation positioning had no complications, while 14 patients with CT-guided puncture hook positioning had complications. The most common complication was

hemopneumothorax, but no catastrophic complications occurred. Magnetic navigation positioning technology has higher safety and operability, because all operations can be carried out in the operating room, while CT-guided positioning need a certain space distance and time interval, which increases the risk of whole positioning process. In addition, 6 (5.7%) patients in CT-guided localization group failed to be located, mostly because of the deviation of the puncture hook position. Patients in ENB group need more time, because path setting has to be done before, and the operation of bronchoscopy is not particularly skilled for us. As the number of patients increases, the proficiency of ENB will be further improved, so we think that it is only a learning curve problem.

Puncture hook positioning method has additional problems. For example, when we complete the positioning, we usually cannot perform the operation immediately, and the patients need carry a puncture hook in the ward waiting for next surgical resection, which increases the complexity and risk of the operation. However, the procedure does not require additional facilities such as radiotracer, contrast injection or coil insertion. Therefore, CT-guided puncture hook positioning method is still simple and feasible, low cost, and widely used in clinical applications.

In contrast, navigational method has disadvantages of requiring much labor and experience to master and having low cost-effectiveness, but it has the advantages of small trauma, accurate location and safety. Moreover, ENB shows the potential for interventional lung surgery[13, 15-18]. Therefore, magnetic navigation and positioning technology has a good application prospect.

List Of Abbreviations

Computed Tomographic Imaging: CT; electromagnetic navigation bronchoscopy: ENB; Video-asssisted thoracoscopic surgery: VATS; distance from pleural distance: PD; ground-glass opacity (GGO)

Declarations

Ethics approval and consent to participate: This study was approved by the Ethics Committee of Qilu Hospital of Shandong University. The consent we obtained from study participants were written.

Consent for publication: The participates whose identifying images, CT scan images and specimen picture were used in this article provided the constant for publication.

Availability of data and materials: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: TH designed research; TY, LM, YWM and SLB conducted research; LM, YWM and LSH analyzed data; TY and LL wrote the paper; TH had primary responsibility for final content. All authors have read and approved the manuscript.

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Tables

Table 1 Clinical characteristics and demographics of two matched groups.

Variables	CT-Guided Localization	ENB	P*
age			0.459
>60	51	22	
<60	54	30	
Gender			0.527
Male	57	31	
Female	48	21	
Smoking			0.116
No	46	16	
Yes	59	36	
Location			0.066
RUL	44	14	
RML	11	6	
RLL	20	20	
LUL	13	3	
LLL	17	9	
Nodule size			<0.001
<6mm	8	11	
6-8mm	43	38	
>8mm	54	3	
Nodule depth			0.007
0 cm	3	0	
0-3cm	61	43	
>3cm	41	9	

Nodule density			0.567
Pure GGO	47	27	
>50%GGO	45	21	
<50%GGO	13	4	
Pathological Diagnosis			0.117
Benign lung tumor	15	14	
AIS	50	26	
MIA	33	11	
IA	7	1	

* Chi-square test

Table 2 Localization and surgery results for the ENB and CT groups.

Variables	CT-Guided Localization	ENB	P*
Complications			0.107
No complications	91	52	
Asymptomatic hemopneumothorax	8	0	
Symptomatic hemopneumothorax	4	0	
Hemoptysis	1	0	
Decoupling	1	0	
Failed to localization	6	0	0.079
Localization time(min)	15.15 ± 3.7	21.29 ± 4.0	<0.001
Hookwire station			-
Through the nodule	6	-	
Beside the nodule	99	-	
Needle-carrying time(min)	37.12±17.29	0	<0.001

* Chi-square test

Figures

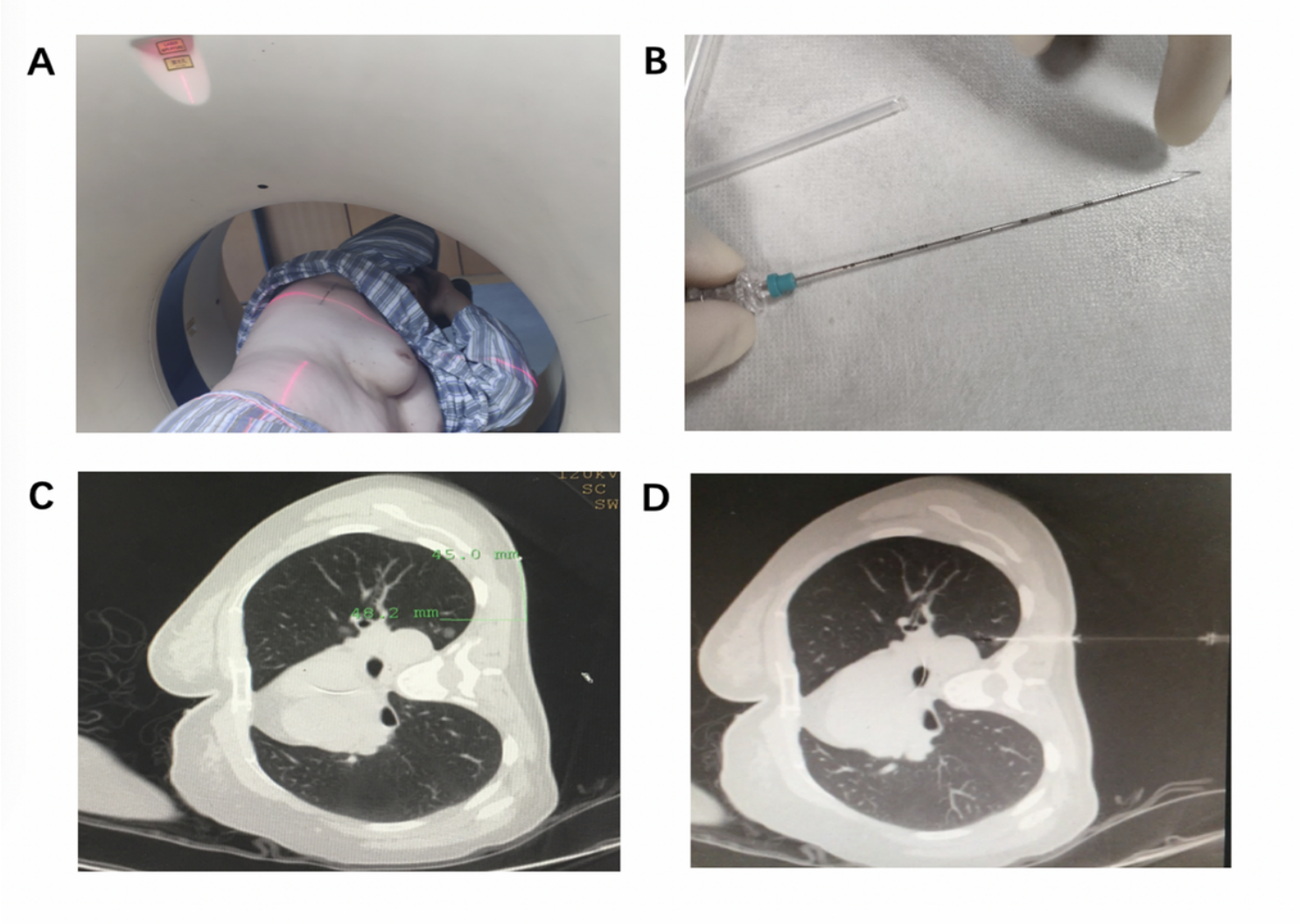

Figure 1

(A) Coronal location by CT and Sagittal marking with steel needles. (B). The picture of steel needle. (C) Measuring the distance of puncture point and locating the distance between steel needle and puncture point in coronal position of CT image. (D) The results of puncture were confirmed by CT and the complications were detected.

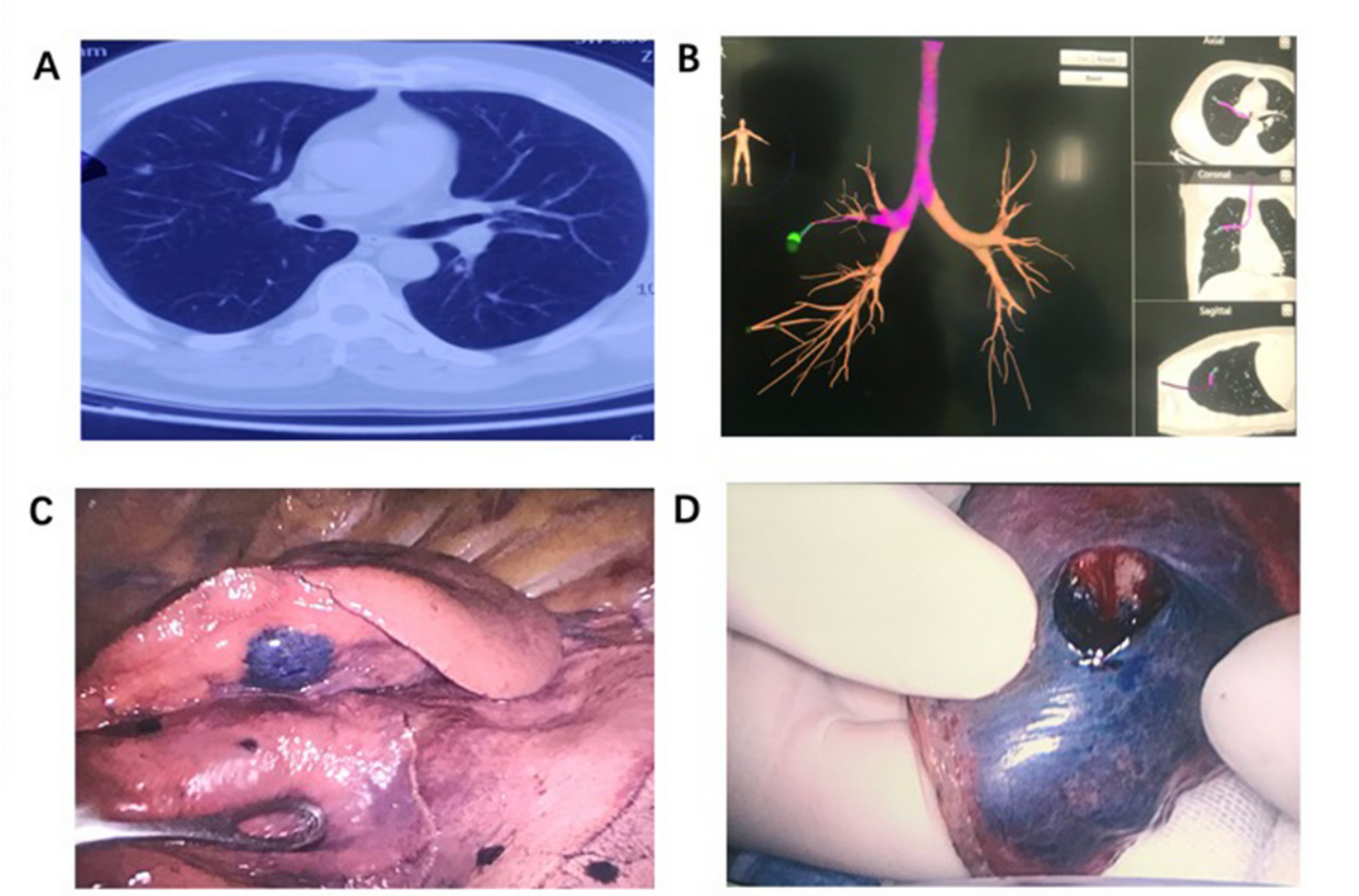

Figure 2

(A) A small pulmonary nodule is located in the right upper lobe. (B)Before operation, magnetic navigation software was used to design magnetic navigation location path. (C) According to the designed path, the magnetic navigation probe was stained with methylene blue after reaching the lesion location. (D) The accuracy of localization was verified after thoracoscopic surgery.

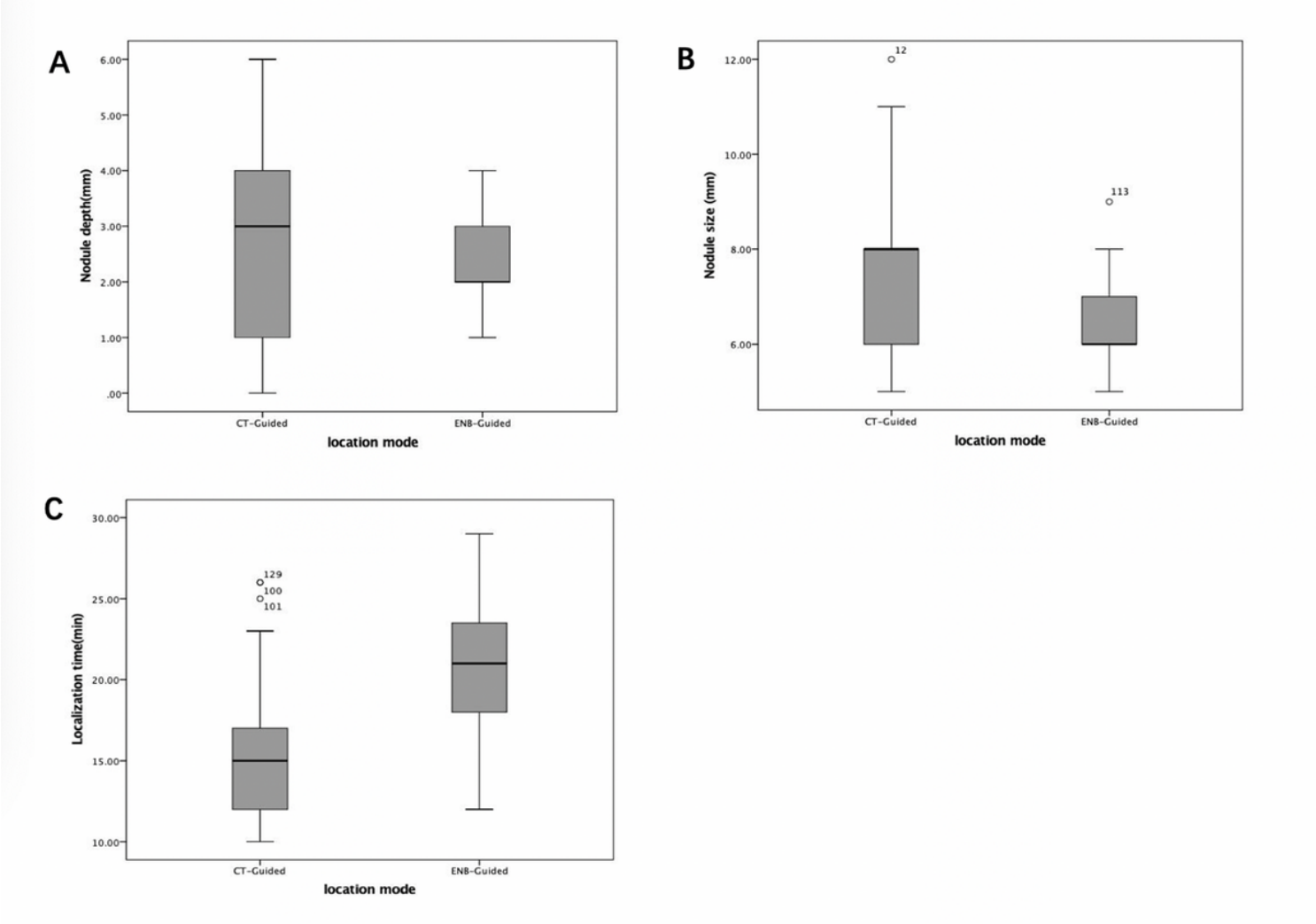

Figure 3

Characteristics of 107 pulmonary nodular lesion of two matched groups. (A)Nodule depth. (B) Nodule size (C) Localization time.