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Analysis of High-Resolution CT Diagnosis for Pulmonary Ground-Glass Nodules

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Abstract: *Objective:* To analyze the diagnostic value of high-resolution CT for pulmonary ground-glass nodules. *Methods:* 60 patients with pulmonary ground-glass nodules admitted from June 2021 to December 2022 were selected as research subjects. All patients underwent surgical pathological and high-resolution CT examinations, and the findings observed under high-resolution CT were recorded. The surgical pathology examination results were used as the benchmark in determining the size of the ground-glass nodules and analyzing the detection rate of various signs of benign and malignant lesions and the consistency of the diagnostic results. *Results:* After surgical pathological examination, 42 cases were determined to be malignant lesions, and 18 cases were benign lesions. The maximum diameter of pulmonary ground-glass nodules ranged from 5 to 35 mm (10.79 ± 0.71 mm). The detection rate of malignant lesions was higher than that of benign lesions. The consistency of the results of high-resolution CT examination for lesions was 88.33%, and the misdiagnosis rate was 11.67%. The accurate identification rate of malignant pulmonary ground-glass nodules was higher than that of benign pulmonary ground-glass nodules ($P < 0.05$). *Conclusion:* High-resolution CT is highly accurate in diagnosing pulmonary ground-glass nodules, especially malignant ones.

Keywords: Pulmonary ground-glass nodules; High-resolution CT; Clinical diagnosis

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1. Introduction

The incidence and mortality of lung cancer rank first in China and also globally. The awareness of physical examination has been increasing in recent years, leading to an increase in early lung cancer detection rate. Imaging examinations are often used in lung examinations. For example, high-resolution CT is often used in physical examinations for early lung cancer screening. Early-stage lung cancer can be clinically cured, but the five-year survival rate of late-stage lung cancer is very low, which is less than 5% [1], so early diagnosis is crucial for improving prognosis. Ground-glass opacity (GGO) is characterized by a localized increase in density within the lung parenchyma. Unlike solid masses, GGO retains partial transparency, allowing internal structures like blood vessels and bronchi to remain visible. This opacity pattern can be associated with various conditions such as atelectasis, interstitial thickening, air space disease, increased capillary capacity, or a combination of

these factors. Nodules with GGO in lung CT are pulmonary ground-glass nodules. Studies [2] have shown that there is a clear correlation between pulmonary ground-glass nodules and early lung cancer. Pulmonary ground-glass nodules are likely to be early-stage lung adenocarcinoma or pre-invasive lesions (adenocarcinoma *in situ*, atypical adenomatous hyperplasia). Pulmonary ground-glass nodules can be divided into two types based on the presence or absence of solid components and density uniformity: mixed ground-glass and pure ground-glass nodules. Pulmonary ground-glass nodules have a higher malignancy rate than solid nodules [3]. Early identification of benign and malignant pulmonary ground-glass nodules is critical to treating the disease and improving prognosis. The application of high-resolution CT in diagnosing benign and malignant pulmonary ground-glass nodules was analyzed in this study with a sample size of 60 patients.

2. Materials and methods

2.1. Information

60 patients with pulmonary ground-glass nodules were selected as research subjects (admission period: June 2021 to December 2022), which consisted of 39 male patients and 21 female patients, aged between 21 and 75 years old, with an average age of 55.34 ± 10.13 years old. The clinical imaging and surgical pathological examination data of 60 patients were complete, excluding patients who had received anti-tumor treatment or needle biopsy. All patients gave informed consent to this study.

2.2. Method

High-resolution CT examination was performed using a 64-slice, 128-slice spiral CT scanner (Philips) with volumetric scanning capabilities. During the examination, the patients remained supine with their hands raised above their heads. The scanning parameters were set as follows: The tube rotation speed, tube current, tube voltage, layer thickness, and layer interval were set at 0.4s, 30–150 mA, 120 kV, 5 mm, and 5 mm, respectively. ASIR-V iterative reconstruction is implemented. Image post-processing involved techniques such as multi-plane reorganization and maximum density projection. The interval, layer thickness, and matrix were set at 0.8 mm, 1.0 mm, and 1024 × 1024, respectively. The results were read by two experienced radiologists (intermediate and senior professional titles or above) double-blindly. If their opinions differed, they would discuss each other or have the results evaluated by a higher-level expert.

2.3. Observation indicators

The maximum diameter of pulmonary ground-glass nodules was observed under high-resolution CT.

With the results of surgical pathology examinations as the gold standard, the detection rate of various signs of benign and malignant lesions and the consistency rate of the diagnostic results were analyzed.

The criteria for diagnosing benign and malignant pulmonary ground-glass nodules with high-resolution CT: if three or more of the following seven signs appear, the nodule is likely to be malignant, and vice versa. The signs are as follows: increased CT value (>-556Hu), vacuolar sign/air bubble sign, vascular bundles, pleural indentation, spiculation, lobulation, and interface sign.

2.4. Statistical analysis

The data in the article were input into statistical software (software version: SPSS25.0) for analysis. Measurement data (in line with normal distribution) were represented using mean ± standard deviation and count data were represented as (n [%]). Independent sample t-tests and χ^2 tests were conducted. Statistical significance was considered if $P < 0.05$.

3. Results

3.1. Surgical pathology examination results

Among the 60 patients with pulmonary ground-glass nodules, surgical pathological examination determined that 42 were malignant and 18 were benign. The details are shown in **Table 1**.

Table 1. Surgical pathology examination results [*n* (%)]

Malignant lesions	Number of cases	Benign lesions	Number of cases
Preinvasive lesions (adenocarcinoma *in situ*)	18	Atypical adenomatoid hyperplasia	5
Invasive lesions (invasive adenocarcinoma and minimally invasive adenocarcinoma)	20	Non-neoplastic lesions	10
Squamous cell carcinoma	4	Tuberculosis	2
-	-	Positive granulomatous lesions	1
-	-	Fungal infection	1
Total	42 (70.00)	Total	18 (30.00)

3.2. High-resolution CT examination results

The maximum diameters of the pulmonary ground-glass nodules were 5–35 mm (10.79 ± 0.71 mm). Among the 60 patients, 26 of them showed an increased CT value (>-556Hu), 25 exhibited vacuolar sign/air bronchial sign, 23 had vascular bundles, and 26 showed pleural indentation. Besides, there were 31 cases of spicules, 26 cases of lobulation, and 42 cases of interface signs. Signs were more common among the malignant cases compared to the benign ones ($P < 0.05$), as shown in **Table 2**

Table 2. High-resolution CT examination results [*n* (%)]

	Malignant (*n* = 42)	Benign (*n* = 18)	χ^2	*P*
Increased CT value (>-556Hu)	22 (52.38)	4 (22.22)	4.667	0.031
Vacuolar/air bubble sign	21 (50.00)	4 (22.22)	4.000	0.046
Vascular bundle	21 (50.00)	2 (11.11)	8.061	0.005
Pleural indentation	22 (52.38)	4 (22.22)	4.667	0.031
Spiculation	27 (64.29)	4 (22.22)	8.927	0.003
Lobation	25 (59.52)	1 (11.11)	14.945	0.001
Interface sign	33 (78.57)	9 (50.00)	4.898	0.027

3.3. Rate and consistency of CT diagnosis

Taking the surgical pathology diagnosis results as the gold standard, the high-resolution CT diagnosis results were consistent in 53 cases, with a consistency of 88.33%. 7 cases were misdiagnosed, indicating a misdiagnosis rate of 11.67%. Among the 18 cases diagnosed as benign lesions by pathology, 10 were diagnosed as benign by high-resolution CT, demonstrating a consistency of 55.56%. Among the 50 cases diagnosed as malignant by high-resolution CT diagnosis, 42 cases were diagnosed as malignant lesions by pathology, so the consistency was 84.00%. The comparison showed that high-resolution CT examination was more accurate in identifying malignant pulmonary ground-glass nodules ($\chi^2 = 5.952$, $P = 0.015$).

4. Discussion

Lung cancer is a significant cause of death in China because most lung cancers are already in the advanced stage when diagnosed, and only palliative treatment can be given at this time. Although various new treatment technologies and targeted therapy are constantly being developed, the survival of advanced lung cancer is still very low. The cure rate of surgery for carcinoma *in situ* is very high. If it is stage I lung cancer, the ten-year survival rate after surgery is over 90% [4]. In short, early detection and early treatment are the key to disease treatment. The main manifestation of early-stage lung cancer is ground-glass nodules in the lungs, which have a relatively low metabolic rate. Therefore, it is difficult to diagnose through tumor marker detection. Puncture under CT guidance is invasive and less sensitive. Research [5] has found that observing the edges and morphology of pulmonary ground-glass nodules can determine the nature of the disease.

CT examination is a very common imaging diagnostic method. However, there is some risk of misdiagnosis using conventional CT. High-resolution CT offers higher-definition images attributed to its thinner scanning layer compared to ordinary CT. Commonly used for smaller bones and chest examinations, high-resolution CT is particularly effective in detecting air cavity nodules, ground-glass opacities, and other abnormalities. Biopsies can be conducted based on findings from high-resolution CT examinations, allowing for careful lesion observation. Additionally, the implementation of high spatial frequency algorithm reconstruction further enhances diagnostic efficiency [6]. Atypical adenomatous hyperplasia in pre-invasive lesions is a benign lesion with no distinction between high and low grades. In high-resolution CT imaging, if the diameter of pure ground glass nodules is ≥ 6.8mm, has clear borders, or shows a vacuolar/air bubble sign, etc., they are more likely to be adenocarcinoma *in situ*. There is a certain overlap in CT imaging between minimally invasive adenocarcinoma and adenocarcinoma *in situ*. The lesions of these two pathological types have clean edges and nodular miliary dissemination in the surrounding lung parenchyma. Microinvasive adenocarcinoma usually has a diameter of ≤ 3cm and pathological examination reveals adherent growth with partial or no alveolar collapse, along with residual air-containing alveolar tissue. In these cases, infiltrative lesions within the lesion usually have a maximum diameter of ≤ 5 mm, and there is an absence of tumor necrosis, lymphatic necrosis, or blood vessel necrosis. High-resolution CT images often show mixed ground-glass nodules, with fewer pure and solid nodules [7]. If the pulmonary ground-glass nodules come with pleural indentation, lobation, interface signs, or vacuolar/air bubble signs, minimally invasive adenocarcinoma may be present. Invasive adenocarcinomas are generally mixed ground-glass nodules, mostly irregular in shape, with tumor cell clusters as the main solid component, and also include macrophages accumulated in the alveoli, alveolar collapse, intra-alveolar bleeding, etc. Still, in imaging, it is impossible to effectively differentiate between invasive adenocarcinoma and minimally invasive adenocarcinoma in terms of lesion margin, shape, density, size of the lesion, size of solid components within the lesion, spiculation, vacuolar sign, and pleural indentation.

This study shows that the CT value of malignant pulmonary ground-glass nodules is increased (>-556 Hu). The incidence rates of vacuole sign/air bronchial sign, vascular bundles, pleural indentation, spiculation, lobulation, and interface sign were more common in malignant cases than those in benign cases, and these signs are risk factors for the malignant tendency of pulmonary ground-glass nodules. Vacuolar signs are an indicator of pulmonary ground-glass nodules, a gas-density shadow with a diameter of less than 5 mm within the lesion. These signs can take various shapes, such as dilated small bronchi, residual alveolar spaces, or air-containing lung tissue invaded by tumor tissue. The appearance of vascular bundles is associated with tumor tissue infiltrating toward the bronchus, perivascular sheath, or interlobular septa. Scar formation or fibrosis around the lesion pulls adjacent blood vessels, leading to the concentration of vessels toward the tumor body, resulting in the vascular bundle sign. Pleural indentation is caused by fibrosis and scar formation within the lesion, where

the contractile force of the fibrous interstitium pulls the free visceral pleura, resulting in depression without local pleural adhesion [9].

Spiculation and lobulation are characteristic features observed in the edges of pulmonary ground-glass nodules. Spiculation is attributed to the tumor's desmoplastic reaction, featuring fibrous bands, or tumor cells moving towards adjacent bronchi or perivascular sheaths, often accompanied by local lymphatic infiltration. This sign can be categorized based on the length of the burrs, distinguishing between short burrs (< 5mm) and long burrs (≥ 5mm), with malignant manifestations typically characterized by short, stiff, and radial arrangements. On the other hand, lobulation refers to the uneven outline of the nodule edge and can be classified into shallow lobulation, medium lobulation, and deep lobulation.

The uneven growth rate of the tumor compared to its surroundings, combined with the obstruction by the pulmonary interstitial framework, bronchi, and blood vessels, leads to the more pronounced protrusion and formation of lobules. Pathological examination of specimens reveals fibrous hyperplasia of the interlobular septa. Research indicates that spiculation and lobulation signs serve as characteristic features of malignant pulmonary ground-glass nodules, suggesting their utility in distinguishing between benign and malignant nodules. Additionally, the presence of the interface sign typically indicates malignancy [11]. This sign results from the accumulated growth of tumor cells or pseudomembrane formation in the surrounding lung tissue, delineating the boundary between the lesion and the lung. In contrast, non-tumor lesions often exhibit inflammatory infiltrates, potentially due to exudative changes or localized fibrosis of the alveolar solid interstitium, resulting in a blurred boundary with the surrounding lung tissue [12]. Therefore, the interface sign can act as an indicator of benign and malignant pulmonary ground-glass nodules. In this study, 60 patients with pulmonary ground-glass nodules were pathologically diagnosed; 48 were malignant, and 12 were benign. Using this as the gold standard, the diagnostic accuracy rate of high-resolution CT was 88.33%, and the misdiagnosis rate was 11.67%, among which the accurate identification rate is higher in malignant pulmonary ground-glass nodules.

5. Conclusion

In conclusion, the analysis above indicates that high-resolution CT signs related to the edges, size, and adjacent structures of pulmonary ground-glass nodules are useful for distinguishing between benign and malignant nodules. Internal signs have limited differential value, while signs such as the vacuole sign/air bronchial sign and increased density can aid in differentiation. For older patients with elevated CT values (> -556Hu) and exhibiting signs like vacuole, vascular bundling, pleural depression, spiculation, lobulation, and interface, consideration for malignant pulmonary ground-glass nodules is warranted. Further judgment should be based on individual patient conditions, and early detection and treatment can significantly improve prognosis. In summary, high-resolution CT proves valuable in the detection and differential diagnosis of pulmonary ground-glass nodules.

Disclosure statement

The author declares no conflict of interest.

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