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Comparison of the Patient Demographics, High-Resolution Computed Tomography Features of the Pulmonary Ground-Glass Opacity and Its Diagnostic Value Analysis

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Introduction: Pulmonary ground-glass opacity (GGO) observed on computed tomography (CT) is widely regarded as a diagnostic feature of lung adenocarcinoma; however, a significant radiological predictive sign remains controversial. In this retrospective study, we conducted a comprehensive analysis of 206 patients with GGO to establish a correlation analysis model between CT images and diagnosis of GGO nodules.

Methods: Histopathologic specimens were obtained from 206 patients (130 women, 76 men; age range 24–77). The clinical data, pathologic findings, and thin-section CT features of solid, pure GGO (pGGO), and mixed GGO (mGGO) nodules were compared using rigorous statistical methods, such as *t*-test, Fisher's exact test, or univariate logistic regression analysis.

Results: Significant differences were observed among the 3 groups in terms of patient demographics, including gender ($P = 0.016$), smoking history ($P = 0.002$), and nodule size ($P = 0.002$). Morphologic CT characteristics, such as the presence of spiculated sign, lobulated sign, vascular sign, bubble-lucency sign, or pleural retraction, exhibited significant differences among the solid nodule, pGGO, and mGGO groups. However, no significant differences were observed in terms of air-bronchogram sign. Notably, the incidence of malignancy was significantly higher in pGGO nodules (76.52%) than in solid (48.48%) and mGGO (73.86%) nodules. Patients with mGGO had up to 2.988 times higher

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hazard of malignant lesions than those with solid nodules [$P = 0.036$, hazard ratio (HR) = 2.988]. Similarly, the hazard of malignant lesions was 2.941 times higher in patients with pGGO than in those with solid nodules ($P = 0.007$, HR = 2.941).

Conclusion: Clinical, pathological, and thin-section CT features of solid, pGGO and mGGO nodules were found to be significantly different. Based on our comprehensive analysis, patients presenting with a mGGO or pGGO on CT scans were more likely to be diagnosed with lung cancer.

Key words: Lung cancer – High-resolution computed tomography (HRCT) – Patient demographics – Ground-glass opacity (GGO) – Pulmonary nodules

Recently, with the worldwide use of low-dose computed tomography (CT) in early lung cancer screening, more and more early lung adenocarcinoma or preinvasive lesions in the form of ground-glass opacity (GGO) are being identified.[1,2] GGO is defined as hazy increased opacity of the lung with preservation of bronchial and vascular margin.[3,4] According to the guidelines proposed by the International Association for the Study of Lung Cancer/American Thoracic Society/European Respiratory Society (IASLC/ATS/ERS) system, early-stage lung adenocarcinomas can be classified into 3 histological subtypes namely, preinvasive lesions [*i.e.,* adenocarcinoma in situ (AIS) and atypical adenomatous hyperplasia (AAH)], minimally invasive adenocarcinoma (MIA), and invasive adenocarcinoma (IAC), which could be observed as a persistent GGO nodule at CT.[5,6] However, besides malignant lesions, some types of benign lesions also can be observed as similar hazy opacity manifestation, such as focal interstitial fibrosis, inflammation, and hemorrhage.[7,8] Radiographic nondeterminacy makes GGO a nonspecific finding, and due to the malignant potential and heterogeneous characteristics, GGO nodule diagnosis is a challenging task for radiologists.

Many studies have reported that preoperative CT scan findings are related to pathological features and postoperative prognosis.[9–12] By using quantitative imaging features and machine-learning classifiers, these studies built different models, which aims to determine the pathologic character of GGO nodules effectively in CT scan preoperatively.[13] Some types of image features in CT scans are supposed to be strongly suggestive of a malignant early lung tumor, for example, spiculated sign, lobulated sign, vascular sign, bubble-lucency sign, air-bronchogram sign, and pleural retraction.[14] However, whether these findings can be applied to classify between benign nodules and malignant GGO nodules is still controversial.[15–17] Thus, it is necessary to develop a correlation analysis model between CT images and histopathological subtypes of GGO nodules.

Here, the purpose of our study was to retrospectively analyze the clinical, pathological, and high-resolution CT features of persistent solitary or multiple GGO nodules from 206 postoperative patients with pulmonary GGO and to provide some insight into the preoperative GGO diagnosis strategy.

Methods

Patients

A total of 235 patients with a solitary or multiple GGOs of maximum diameter <2 cm on chest CT including high-resolution CT (HRCT) at the Department of Thoracic Surgery of The First Affiliated Hospital of Xiamen University between January 2017 and December 2019 were enrolled. All pathology files and clinical information and radiology information system records from patients with pathology findings for at least 1 GGO nodule were collected, including solid nodules, mixed GGO (mGGO), and pure GGO (pGGO). Most patients were identified by low-dose CT screening for lung cancer. However, before our analysis, we excluded 29 patients still evaluated by follow-up or lack of information on radiologic-pathologic correlation and excluded another 126 patients detected with lung nodules by outpatient CT who declined to undergo inpatient surgery treatment in the knowledge of their condition and selected periodical monitoring by chest CT screening, which was thus performed on 206 patients (66 solid nodules, 52 pGGOs, and 88 mGGOs; 159 solitary GGOs and 47 multiple GGOs).

The demographic and clinical data of patients with GGO nodules were recorded (*i.e.*, age and sex, smoking history, family history, and number of primary lung nodules).

This study was approved by the institutional review board of the hospitals involved; the requirement for patients' informed consent was waived in this retrospective study.

CT Imaging Analysis

Chest CT images were obtained on a 256-slice Philips Brilliance iCT Elite FHD machine (Philips, Jiangsu, China) or Somatom Definition Flash dual-source CT scanner (Siemens, Shanghai, China). Images were obtained using a window level of 600 Hounsfield units (HU), a window width of 1500 HU (lung window), and a level of 30 HU and a width of 400 HU (mediastinal window). Conventional CT images were obtained from the thoracic inlet to the lung base using a 5-mm section thickness and a 5-mm section spacing, and HRCT images were obtained at a section thickness of 1 mm. Two pulmonologists and 2 radiologists identified GGO sizes and margins and decided on the presence of a solid portion. GGO lesions were classified as solid nodule, pGGO, or mGGO based on the presence of a solid component within a nodule on an HRCT image at a lung window level.

All CT images were reviewed by 2 chest radiologists with 8 and 7 years of experience of chest CT interpretation, respectively. Both were unaware of clinical information. Decisions on CT findings were reached by consensus. One radiologist measured lesion sizes and solid portions within GGO nodules. The following thin-section CT findings were recorded for each lesion: (1) lesion size, (2) percentage of GGO component, (3) shape (round or oval, polygonal, irregular), (4) margin (smooth, lobulated, spiculated), (5) border (well-defined, ill-defined), and (6) presence of air-bronchogram, bubble-lucency, or pleural retraction. Lesion size was defined as the longest lesion dimension. Percentage of GGO component was defined as the greatest diameter of the solid portion divided by the greatest diameter of the lesion including the GGO area.

In addition, 36 of all 206 samples preoperatively detected other concomitant separate lung primaries by HRCT. Among multiple pulmonary nodules with an individual patient, only the most predominant lung lesion (largest nodule diameter in pGGO or most solid component proportion in mGGO) on CT imaging or the most malignant lesion confirmed by pathologic diagnosis was included. For each individual patient, only a single lesion was included in the analysis.

Histopathology and Pathologic Diagnosis

All of the patients recruited obtained surgical resection at the Department of Thoracic Surgery of The First Affiliated Hospital of Xiamen University after primary diagnosis and preoperative CT scan. Pathologic specimens were obtained by lobectomy in 144, segmentectomy in 18, and wedge resection in 44 nodules. Fresh tissues were immediately snap-frozen and stored at −80°C or fixed and embedded in paraffin. Samples were formalin-fixed, paraffin-embedded, and then diagnosed and confirmed by at least 2 lung cancer pathologists.

All 206 patients included in our study were postoperatively diagnosed and had not undergone any pathological biopsy preoperatively.

Statistical Analysis

Comparisons between the imaging and histopathological findings of the preinvasive lung adenocarcinomas were analyzed using SPSS 20.0 software (SPSS Inc., Chicago, IL). The χ^2 and Fisher tests were used for comparison analyses. All possible factors including clinical and radiologic characteristics were used with the logistic regression method to make a differential diagnosis among solid, pGGO, and mGGO nodules. Two-tailed P values of less than 0.01 were considered to indicate statistical significance.

Results

Demographic Findings of Patients With GGO

Of the 206 patients with pulmonary GGO lesions, 66 had solid nodules, 52 had pGGOs, and 88 mGGOs. Regarding patient demographics, gender ($P = 0.016$), smoking history ($P = 0.002$), and nodule size ($P = 0.002$) were significantly different among the 3 groups. According to the results, the patients with pGGOs showed the highest female-to-male ratio (75.0%) and lowest smoking ratio (3.8%). Mean pulmonary GGO nodule diameter showed 12.76 ± 6.87 mm in the solid nodule group, 8.24 ± 3.02 mm in the pGGO group, and 11.45 ± 6.91 mm in the mGGO group. However, because of the heterogeneity of variance, it is unavailable to use 1-way analysis of variance test. Additionally, the significant difference in pulmonary GGO mean diameter was revealed again under univariate logistic regression analysis.

Besides, no significant differences were observed in terms of age stratification or the presence of lung cancer family history ($P = 0.051$, $P = 0.323$, respectively),

Table 1 Clinicopathologic characteristics of the patients with ground-glass opacity

		CT features of pulmonary nodules				
	Patients (%)	Solid	pGGO	mGGO	χ^2	*P* value
All	206	66	52	88		
Age						
≤40	30	7	15	8	15.440	0.051
41–50	61	23	15	22		
51–60	64	21	12	31		
61–70	44	14	8	23		
≥71	7	1	2	4		
Gender						
Female	130	33	39	58	8.326	0.016
Male	76	33	13	30		
(Positive rate[a])		50.0%	75.0%	65.9%		
Smoking history						
Yes	26	16	2	8	12.707	0.002
No	180	50	50	80		
(Positive rate)		24.24%	3.8%	9.1%		
Family history						
Yes	6	3	0	3	2.259	0.323
No	200	63	52	85		
Amount						
Solitary	159	49	40	70	0.605	0.739
Multiple	47	17	12	18		
Nodule size, mm						
≤10	128	35	43	50	12.723	0.002
>10	78	31	9	38		
Mean diameter (mm)		12.76 ± 6.87	8.24 ± 3.02	11.45 ± 6.91		Heterogeneity of variance

CT, computed tomography; mGGO, mixed ground-glass opacity; pGGO, pure ground-glass opacity.
[a]The positive rate refers to the proportion of female in each subgroup.

or in mode of detection for multiple and solitary GGO nodules ($P = 0.739$) (Table 1).

Comparisons of the Solid Nodule, pGGO, and mGGO Groups in Terms of HRCT Features

The results showed that a significant difference in morphologic CT characteristics (*e.g.*, spiculated sign, lobulated sign, vascular sign, bubble-lucency sign, or pleural retraction) was found among the solid nodule, pGGO, and mGGO groups ($P = 0.001$, 0.007, 0.010, 0.005, 0.001, respectively, Table 2). However, no significant differences were observed in terms of air-bronchogram sign ($P = 0.097$, Table 2). Based on our data, solid nodules of 66 patients were more frequently observed to have a spiculated margin, lobulated shape, or pleural retraction at thin-section CT scan (positive rate = 74.24%, 75.76%, 56.06, respectively), whereas the mGGO nodules more frequently showed a micrangium vascular sign or bubble-lucency sign in the CT manifestation (positive rate= 94.31%, 40.91%, respectively). Compared with the other 2 groups, pGGO nodules showed few specific features at thin-section CT scan, presence of a smooth margin, intact constitute or a nummular shape were more frequent for pGGO nodules. The lowest positive rate of spiculated sign (44.23%), lobulated sign (51.92%), air-bronchogram sign (9.62%), and pleural retraction (20.00%) was detected in the pGGO nodules group.

Pathologic Findings of Patients With GGO

Pathologic diagnoses of solid, pGGO, and mGGO nodules are summarized in Table 3. After postoperative pathologic diagnosis, AAH or other benign lesions (*e.g.*, inflammation, calcification, or tuberculosis) were regarded as the benign group, whereas AIS, MIA, IAC, or other early-stage lung cancer were included in the malignant group. Of the 206 pulmonary nodules, 137 (66.50%) were diagnosed as lung cancer. From the results, a significant difference in the nodule histologic character among solid, pGGO, or mGGO groups was detected ($P = 0.001$, Table 3). The percentage of malignant nodules diagnosed in each group is 48.48% (solid),

Table 2 Comparisons of the solid nodule, pGGO, and mGGO groups in terms of HRCT features

		CT features of pulmonary nodules				
	Patients (%)	Solid	pGGO	mGGO	χ^2	*P* value
All	206	66	52	88		
Spiculated						
Yes	134	49	23	62	13.497	**0.001**
No	72	17	29	26		
(Positive rate[a])		74.24%	44.23%	70.45%		
Lobulated						
Yes	143	50	27	66	10.038	**0.007**
No	63	16	25	22		
(Positive rate[a])		75.76%	51.92%	75.00%		
Vascular sign						
Yes	182	52	47	83	9.117	**0.010**
No	24	14	5	5		
(Positive rate[a])		78.79%	90.38%	94.31%		
Bubble-lucency						
Yes	63	11	16	36	10.442	**0.005**
No	143	55	36	52		
(Positive rate[a])		16.67%	30.76%	40.91%		
Air-bronchogram						
Yes	34	9	5	20	4.658	0.097
No	172	57	47	68		
(Positive rate[a])		13.63%	9.62%	22.72%		
Pleural retraction						
Yes	82	37	11	34	14.878	**0.001**
No	124	29	41	54		
(Positive rate[a])		56.06%	20.00%	38.64%		

CT, computed tomography; mGGO, mixed ground-glass opacity; pGGO, pure ground-glass opacity.
[a]The positive rate represents the proportion of significant imaging features that can be observed in each subgroup.

76.52% (pGGO), and 73.86% (mGGO). The highest malignant rate was observed in the pGGO group, whereas the solid nodules come out as the most benign radiologic implication.

Univariate Logistic Regression Analysis of Patient Demographics and Radiologic Features of Patients With GGO

The univariate logistic regression analysis proceeded to reveal the hazard ratio (HR) of the demographics and radiologic features of 206 included pathologic diagnosed patients; the results are shown in Table 4. Based on our analysis, patients who were found with a mGGO or pGGO at CT scan were more likely to be diagnosed with lung cancer. The hazard of a malignant lesion was as high as 2.988-fold higher for patients with mGGO compared with those with solid nodules ($P = 0.036$; HR = 2.988; Table 4). Similarly, the hazard of a malignant lesion was as high as 2.941-fold higher for patients with pGGO compared with those with solid nodules ($P = 0.007$; HR = 2.941; Table 4). The results showed that the higher nodule diameters should be regarded as

Table 3 Pathologic findings of patients with GGO

		CT features of pulmonary nodules				
	Patients	Solid	pGGO	mGGO	χ^2	*P* value
All	206	66	52	88		
Outcome of nodule pathology						
Benign Lesion	69	34	12	23	14.294	**0.001**
Malignancy	137	32	40	65		
Malignancy rate	66.50%	48.48%	76.92%	73.86%		

CT, computed tomography; mGGO, mixed ground-glass opacity; pGGO, pure ground-glass opacity.

Table 4 Univariate logistic regression analysis of patient demographics and radiologic features of patients with GGO

	B	SE	Wald	*df*	*P* value	Odds ratio	95% CI for odds ratio	
							Lower	Upper
Age ≤40			2.393	4	0.664			
41–50	0.504	1.015	0.247	1	0.619	1.656	0.227	12.104
51–60	0.217	0.966	0.051	1	0.822	1.243	0.187	8.248
61–70	0.833	0.965	0.745	1	0.388	2.300	0.347	15.245
≥71	0.744	0.997	0.556	1	0.456	2.103	0.298	14.841
Gender*	−0.789	0.434	3.304	1	0.069	0.454	0.194	1.064
Smoking history	−0.152	0.625	0.059	1	0.808	0.859	0.252	2.927
Family history	−0.435	1.222	0.127	1	0.722	0.647	0.059	7.103
Characteristics Solid			16.270	2	0.000			
pGGO	1.225	0.453	7.297	1	**0.007**	**2.941**	1.121	6.715
mGGO	1.095	0.522	4.392	1	**0.036**	**2.988**	1.073	8.316
Size	0.088	0.036	6.090	1	**0.014**	**1.092**	1.018	1.171
Amount	0.751	0.449	2.806	1	0.094	2.120	0.880	5.108
Spicules of margin	−0.762	0.440	3.008	1	0.083	0.467	0.197	1.104
Lobulated shape	−0.613	0.431	2.023	1	0.155	0.542	0.233	1.261
Vascular sign	−1.247	0.606	4.239	1	**0.040**	**0.287**	0.088	0.942
Vacuole sign	0.138	0.429	0.104	1	0.747	1.148	0.495	2.663
Bronchogram sign	−0.539	0.579	0.867	1	0.652	0.583	0.187	1.814
Pleural indentation	−0.273	0.422	0.417	1	0.518	0.761	0.333	1.742

CI, confidence interval; SE, standard error.
*Gender is for female compared with male individuals.

another significant risk factor for patients with GGOs. Along with every 1-mm diameter of pulmonary nodules increasing, the hazard of a malignant diagnostic would be increased 9.2% ($P = 0.014$; HR = 1.092; Table 4). However, the vascular sign of GGO at CT scan was more likely to be regarded as a benign sign. Compared with the pulmonary nodules without a vascular sign, a patient with a vascular sign GGO had 0.287-fold lower HR to be diagnosed as a malignant lesion. In addition, there was no significant difference in the age, gender, smoking, family history, presence of solitary or multiple nodules, and other radiologic implications (*e.g.*, spiculated sign, lobulated sign, air-bronchogram sign, bubble-lucency sign, or pleural retraction) ($P > 0.05$) (Table 4).

Discussion

Recently, the use of chest CT for lung cancer screening and early-stage adenocarcinoma detection has increased, with a subsequent increase in the detection of pulmonary GGO.[1,2,18] Several studies have shown that persistent GGO confers a high risk of malignancy, and created considerable interest in the relation between the CT feature of GGO and lung cancer tentative diagnostic.[19,20] For small or faint lung lesions such as one showing GGOs on thin-section CT scan, it is not rare for physicians to speculate histological diagnoses before surgery.[21] It also makes a difference on a patient's decision to receive surgery. Thus, it is necessary to treat such lesions by nonsurgical modalities to accurately speculate their histological characteristics. Here, we attempted to elucidate the association of demographic findings, CT features of patients with GGO, and its diagnostic.

Based on our data, female patients predominated (63.11%) in this study, which may have been associated with a higher lung cancer screening rate compared with men, because GGO cases were almost asymptomatic and were detected by routine screening by low-dose chest CT. However, the results showed that female sex and nonsmoker status were significantly more frequently associated with pGGO nodules. Several studies have reported that gender and smoking history make no difference among pGGO and mGGO groups.[22–24] Another study reported by Kim *et al*[14] reveals that female sex, nonsmoker status, and multiple primary lung cancers were significantly more frequently associated with multiple GGO nodules, whereas they did not make a distinction between nodule manifestation on CTs. The difference among conclusions may be due to the various patient cases analyzed. In the present study, we provide partial evidence between demographic findings and presence of pulmonary GGO, an enlarged range of cases would be further analyzed.

Another interest when we undertook this study was to investigate the nodule size of GGOs and to identify whether the GGO size could predict benignity or malignancy. As the results show in Table 1, we first observed that pulmonary GGO sizes among solid nodules, pGGOs, and mGGOs were significantly different. Solid nodule groups were found to have the highest mean pulmonary diameter (12.76 ± 6.87 mm) compared with others. Furthermore, from our univariate logistic regression analysis results, we had determined that higher nodule diameter was a significant risk factor for the hazard of a malignant GGO lesion. In addition, with every 1-mm diameter of pulmonary nodules increasing, the hazard of a malignant diagnostic would be increased 9.2% ($P = 0.014$; HR = 1.092; Table 4). However, in present relevant studies, the value of the size of GGO for the diagnosis of lung cancer has been controversial, and no standard has been confirmed to date.[25] Naidich *et al*[26] suggested that a detected pGGO smaller than 5 mm in diameter was more likely to be diagnosed as benign, which was similar to the aforementioned results. In other studies, the size of GGO lesions proved to be a significant predictive factor.[27,28] Indeed, we were not able to identify whether the nodule size we found on thin-section CT should be a significantly independent predictive radiologic factor without survival analysis, but we did reveal that the size of GGO lesions should be considered as a key risk factor for preoperative screening of patients.

Several conflicting reports have been issued regarding the predilections of malignant pulmonary lesions for mGGOs and pGGOs.[15–17] However, whether the classification of GGOs can be applied to identify between benign nodules and malignant GGO nodules is still unknown. Thus, in the present study, we developed a univariate logistic regression analysis to reveal the HR of the radiologic features of 206 patients with GGOs. Our results have determined that patients found with an mGGO or pGGO at CT scan were more likely to be diagnosed with lung cancer compared with patients with solid pulmonary nodules. As the control group, solid nodules had the lowest positive rate for the incidence of lung cancer based on our cases. In addition, the hazard of a malignant lesion was as high as 2.988-fold and 2.941-fold higher for patients with mGGOs and pGGOs, respectively. Consistent with our results, Moon *et al*[23] have reported that the pGGO on chest CT should be considered as a significant predictive factor for invasive adenocarcinoma. Another study reported by Oh *et al*[24] demonstrated that the malignancy rate for mGGOs (30.2%) appeared higher than that of pGGOs (19.4%), but the conclusion was without significance unfortunately, which may have been because of the limited cases of pGGOs analyzed. In addition, several studies have provided evidence that a hazy increased opacity that appears as part-solid GGO nodules on thin-section CT was more frequently associated with early-stage invasive lung adenocarcinoma,[29,30] and anatomic resection has been recommended over lobectomy for treating these tumors. However, because it is difficult to differentiate the part-solid GGO from mGGO nodules on CTs, we still considered that clinical surgeons should be on the alert for an mGGO nodule appearing on CT scan.

Lobulation and spiculation were regarded as specific signs of malignant tumors traditionally. The lobulation and spiculation margin are generated when a portion of the lesion's surface formed a wavy or scalloped configuration and the presence of stranding extended from the nodule margin into the lung parenchyma.[20,31] In the present study, solid nodules of 66 patients were more frequently observed to have a spiculated margin, lobulated shape, whereas the pGGO nodules showed the lowest positive rate of spiculated sign and lobulated sign. Interestingly, the results also showed that lobulation and speculation were not significantly associated with early-stage lung adenocarcinoma. After consideration, we raise a hypothesis that lobulation and spiculation would occur only when the primary lung tumor enters the invasion stage, whereas these 2 signs were more likely to indicate a benign state on the early-stage nodules. In fact, the focal fibrous connective tissue proliferations of several benign lesions were frequently regarded as tumor lobulation and speculation, such as interstitial fibrosis, inflammation, or even tuberculosis, which are morphologically similar. Another study reported by Xing *et al*[32] revealed that the rate of lobulation and speculation showed no significant difference between AIS and AAH in the mGGO groups, whereas AIS exhibited a higher rate of lobulation and speculation in the pGGO group. The results suggested that more data about analyzing morphological differences between mGGO and pGGO should be considered in the future studies.

It is widely known that angiogenesis, the formation of new blood vessels, is essential for tumor growth and metastasis.[33] The immature tumor vessels also display high vascular permeability, thus the tumor tissue is edematous, containing extravasated plasma components. In addition to edema, the expansion of cancer tissue results in increased interstitial pressure, causing impaired tumor blood flow.[34] Based on our data, the pGGO nodules showed the highest positive rate of vascular sign,

compared with other 2 groups. However, the cases in our logistic regression analysis showed that the vascular sign of GGO at CT scan was significantly associated with benign lesions. In our opinion, the opposite results may have been due to the inevitable boundedness of bidimensional CT scanning. Different from vascular sign, the vessel convergence sign of isolated pulmonary nodules may more precisely detect the angiogenesis of malignancy. Two indispensable conditions, the 3-dimensional reconstruction and enhanced vessel development, were required for the detection of vessel convergence sign, which may increase the cost of CT imaging. However, several studies have reported that vessel convergence signs were identified as independent predictors of malignant pulmonary focal GGO,[35–37] which is suggested to be regarded as a significant sign in future examination. Another possible inevitable limitation of our data may be due to the recognition of the vascular sign. Different transparency and vague margin of pGGO, mGGO, and solid nodules greatly affects the detection and discrimination of vascular signs, which may result in bias of our statistics. Future studies with more tridimensional radiological imaging and with assessment of vessel convergence sign may provide more accurate results.

A recent study reported that patients with invasion lung adenocarcinoma and GGO lesions have a higher incidence of pleural retraction than those with AIS/MIA.[38] In the present study, although pleural retraction could be observed in all groups of patients with GGO, the highest incidence of pleural retraction was observed in solid nodules, and the pGGO and mGGO groups showed a relatively low incidence. Even the logistic regression analysis showed no significant association between pleural retraction and malignant lung tumor. The negative results may be due to the limited cases collected in studies; however, our results may suggest that people should pay more attention to an unknown pGGO/mGGO nodule without pleural retraction.

Several limitations of the present study require consideration. First, a retrospective study design was used. Second, the data were collected from a single institution and the number of cases was relatively limited. However, all data in this study are recent, since 2017, and bias should be relatively low because management was performed according to the same protocol. Third, the postoperative follow-up was deficient, therefore we were unable to evaluate patient survival or disease recurrence. Last, our study was restricted to surgical patients. More comprehensive analysis might proceed if pathologic analysis of patients with pGGO who did not undergo surgery was made, which was not practically possible in the present study; we still consider our results to be significant.

In conclusion, our present study demonstrated significantly different radiological signs among 206 patients with solid, pGGO, or mGGO nodules. Based on our data, pGGO nodules have significantly the highest malignant incidence compared with solid and mGGO nodules, whereas the solid nodules exhibited the most benign tendency. Compared with solid nodules, mGGOs and pGGOs had nearly 3-fold higher hazard diagnosed as malignant lesions. In patients with these findings, lobectomy is preferable to limited resection. However, future studies that collect data from larger sample sizes are needed to confirm these findings.

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