

Comparative Study on the Diagnosis of Thoracic Wall and Rib Involvement in Lung Adenocarcinoma Using ^{99m}Tc -MDP SPECT/CT and MSCT

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Abstract: *Objective:* To compare the diagnostic value of ^{99m}Tc -MDP SPECT/CT and MSCT in detecting thoracic wall and rib involvement in lung adenocarcinoma. *Methods:* A retrospective analysis was conducted on the imaging data of 78 thoracic wall and rib lesions from 66 patients, a total of 32 males and 34 females, aged (53.2 ± 5.6) years old with pathologically confirmed lung adenocarcinoma who underwent both ^{99m}Tc -MDP SPECT/CT and MSCT examinations from March 2017 to September 2023. The diagnostic efficacy of the two imaging modalities was compared using pathological confirmation or clinical follow-up as the gold standard. *Results:* Pathological confirmation or clinical follow-up revealed 74 lesions with thoracic wall bone involvement in lung adenocarcinoma (20 lesions confirmed by surgical pathology and 54 lesions confirmed by clinical follow-up) and 4 lesions without thoracic wall or rib involvement (2 lesions confirmed by surgical pathology and 2 lesions confirmed by clinical follow-up). The diagnostic sensitivity, specificity, and accuracy of ^{99m}Tc -MDP SPECT/CT were 97.3%, 50.0%, and 94.9%, respectively. Its diagnostic sensitivity and accuracy were higher than those of MSCT (72.3% and 74.4%, respectively), with statistically significant differences ($P < 0.05$). The specificity of ^{99m}Tc -MDP SPECT/CT was lower than that of MSCT (100.0%), but the difference was not statistically significant ($P < 0.05$). There were no statistically significant differences in the positive predictive value and negative predictive value between ^{99m}Tc -MDP SPECT/CT and MSCT ($P > 0.05$). ^{99m}Tc -MDP SPECT/CT examination revised the MSCT tumor staging in 14 patients [21.2% (14/66)] with lung adenocarcinoma. *Conclusion:* ^{99m}Tc -MDP SPECT/CT imaging demonstrates superior diagnostic efficacy compared to MSCT in detecting thoracic wall and rib involvement in lung adenocarcinoma. It offers more accurate tumor staging than MSCT, and an accurate diagnosis aids in clinical treatment decision-making.

Keywords: Lung adenocarcinoma; ^{99m}Tc -MDP SPECT/CT; Thoracic wall; Rib involvement

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1. Introduction

Lung cancer is one of the most common malignant tumors worldwide, with a high mortality rate. Non-small

cell lung cancer (NSCLC) accounts for approximately 80% of all lung cancer cases, with lung adenocarcinoma being its primary histological subtype ^[1]. Patients with lung adenocarcinoma classified as T3 due to chest wall invasion have a poorer prognosis compared to those classified as T2 with visceral pleural invasion, with rib invasion of the chest wall being one of the factors contributing to a poor prognosis in lung adenocarcinoma ^[2,3]. The main prognostic factors affecting survival rates in lung adenocarcinoma patients with chest wall and rib invasion include the depth of chest wall infiltration, the extent of surgical resection, and the completeness of the resection ^[4]. Accurate diagnosis of chest wall and rib invasion in lung cancer patients is crucial for clinical staging of lung adenocarcinoma and for selecting appropriate surgical plans. Preoperative examination to establish a clear diagnosis is essential for determining the optimal treatment approach. MSCT examination is a conventional imaging method for diagnosing chest wall and rib invasion in lung adenocarcinoma, offering certain clinical value. However, its diagnostic value for early rib invasion is limited ^[5]. ^{99m}Tc-MDP SPECT/CT combines the advantages of functional imaging and anatomical imaging, effectively improving the accuracy of diagnosing bone lesions ^[6]. The use of ^{99m}Tc-MDP SPECT/CT imaging in diagnosing chest wall and rib invasion in lung adenocarcinoma has received relatively little attention, with limited evidence and reports on its diagnostic value. This study aims to compare the diagnostic value of ^{99m}Tc-MDP SPECT/CT and MSCT in detecting chest wall and rib invasion in lung adenocarcinoma, providing a theoretical basis for clinical treatment decisions.

2. Materials and methods

2.1. Clinical data

A retrospective analysis was conducted on 66 patients pathologically diagnosed with lung adenocarcinoma from March 2017 to September 2023, including 32 males and 34 females, with an average age of (53.2 ± 5.6) years old. All 66 patients with lung adenocarcinoma were highly suspected of having chest wall and rib invasion and underwent both ^{99m}Tc-MDP SPECT/CT and MSCT examinations. Inclusion criteria: (1) All cases were pathologically confirmed as lung adenocarcinoma; (2) CT images indicated that the lung mass was closely adjacent to the chest wall (with no gap between the lesion and the chest wall). Exclusion criteria: A history of thoracic trauma within the past 3 months.

2.2. Inspection methods

Whole-body and local tomographic fusion images were acquired using a Siemens Symbia T16 SPECT/CT machine. After intravenous injection of 740 MBq of ^{99m}Tc-MDP, the examinee was instructed to drink plenty of water and urinate frequently. Three hours after the injection of the imaging agent, the patient was asked to empty their bladder before the examination. The patient then lay supine on the examination table for a ^{99m}Tc-MDP SPECT/CT whole-body planar bone scan. The acquisition conditions for the whole-body bone scan were as follows: matrix size of 128x1024, energy peak at 140 keV, window width of 20%, and a scanning speed of 20 cm/min. The acquisition conditions for local bone tomographic fusion imaging were as follows: parallel acquisition with dual detectors, 20 seconds per frame, and a matrix size of 128x128. The CT scan conditions on the same machine were: voltage of 130 kV and automatic mA current. After post-processing, multi-axial SPECT/CT fusion images were obtained.

Lung CT images were acquired using a GE Lightspeed VCT machine. The MSCT acquisition conditions were as follows: the scanning range extended from the apex to the base of the lungs, with a voltage of 120 kV,

automatic mA current, slice thickness of 5 mm, and an interslice gap of 5 mm.

2.3. Image analysis and diagnostic criteria

The images were independently reviewed by one experienced nuclear medicine physician and one radiologist. A diagnosis of the presence or absence of chest wall bone invasion was made for each lesion. In cases where the two physicians had differing diagnoses for the same case, a final diagnosis was reached through joint discussion and consensus.

Diagnostic criteria for ^{99m}Tc -MDP SPECT/CT [7–10]: Osteolytic, osteoblastic, or mixed bone destruction in the ribs adjacent to the lung adenocarcinoma on the chest wall, with abnormal distribution of the imaging agent (increased or decreased uptake) in the corresponding area of destruction, and exclusion of lesions such as old bone callus and bone islands, is diagnosed as chest wall rib invasion. Abnormal distribution of the imaging agent (increased uptake) in the ribs adjacent to the lung adenocarcinoma on the chest wall on SPECT images, with no abnormal density in the corresponding area of increased uptake on the CT scan of the same machine, is diagnosed as chest wall rib invasion.

MSCT diagnostic criteria [7–10]: Osteolytic, osteogenic, or mixed bone destruction in the ribs adjacent to the chest wall in pulmonary adenocarcinoma, with the exclusion of conditions such as old rib callus and bone islands, is diagnosed as chest wall rib invasion.

Final diagnostic confirmation: Based on surgical or puncture pathology, or clinical follow-up with MSCT and ^{99m}Tc -MDP SPECT/CT imaging for over 6 months.

2.4 Statistical analysis

Statistical analysis was performed using IBM SPSS 24.0 software. Normally distributed measurement data were expressed as mean $\pm$ standard deviation (SD), while categorical variables were expressed as frequencies (percentages). The χ^2 test was used to compare the diagnostic efficacy of the two imaging modalities for chest wall rib invasion in pulmonary adenocarcinoma. When over 20% of the cells had an expected frequency of less than 5, or at least one cell had an expected frequency of less than 1, Fisher's exact probability test was used. A P -value of less than 0.05 was considered statistically significant.

3. Results

3.1. Comparison of pathological or clinical follow-up results and diagnostic efficacy

A total of 78 lesions were identified in 66 patients. Pathological or clinical follow-up for over 6 months confirmed 74 lesions of chest wall rib invasion by pulmonary adenocarcinoma (20 lesions confirmed by surgical pathology and 54 lesions confirmed by clinical follow-up) and 4 lesions without chest wall rib invasion (1 rib bone island and 1 old callus confirmed by pathology, and 1 rib bone island and 1 old callus confirmed by clinical follow-up).

Among the 74 lesions confirmed as chest wall rib invasion by pulmonary adenocarcinoma through pathological or clinical follow-up, the miss rate of ^{99m}Tc -MDP SPECT/CT was lower than that of MSCT; the diagnostic sensitivity of ^{99m}Tc -MDP SPECT/CT was superior to that of MSCT, with a statistically significant difference ($P < 0.05$); the diagnostic accuracy of ^{99m}Tc -MDP SPECT/CT was higher than that of MSCT, with a statistically significant difference ($P < 0.05$); the specificity of MSCT was higher than that of ^{99m}Tc -MDP SPECT/CT, but the difference was not statistically significant ($P > 0.05$); there was no statistically significant difference in

the positive predictive value and negative predictive value between ^{99m}Tc -MDP SPECT/CT and MSCT ($P > 0.05$) (Table 1).

3.2. Comparison of tumor staging results between ^{99m}Tc -MDP SPECT/CT and MSCT

Compared to MSCT staging, ^{99m}Tc -MDP SPECT/CT revised the tumor staging of 14 patients, with an upward adjustment rate of 21.2% (14/66). Among these 14 patients, the T staging was altered, with 3 cases upgraded from T1c to T3, 5 cases upgraded from T2a to T3, and 6 cases upgraded from T2b to T3. The upward adjustment of staging in these 14 patients was diagnosed as positive by ^{99m}Tc -MDP SPECT/CT and negative by MSCT (10 patients were pathologically confirmed to have chest wall and rib involvement by lung adenocarcinoma, and 4 cases were clinically followed up and confirmed to have chest wall and rib involvement by lung adenocarcinoma).

Table 1. Comparison of ^{99m}Tc -MDP SPECT/CT and MSCT in diagnosing chest wall and rib involvement in lung adenocarcinoma

Imaging Modality	Diagnosis	Pathology/Follow-up Results		Sensitivity	Specificity	Accuracy	Positive Predictive Value	Negative Predictive Value
		+	-					
SPECT/CT	+	72	2	97.3%	50.0%	94.9%	97.3%	50.0%
	-	2	2	(72/74)	(2/4)	(74/78)	(72/74)	(2/4)
MSCT	+	54	0	72.3%	100.0%	74.4%	100.0%	16.7%
	-	20	4	(54/74)	(4/4)	(58/78)	(54/54)	(4/24)
χ^2 value				17.298	2.666	12.606	1.482	2.262
P value				< 0.001	0.102	< 0.001	0.223	0.132

4. Discussion

The 5-year survival rate for lung adenocarcinoma staged as T3 is lower than that for early-stage lung adenocarcinoma (T1-2). Patients with T3 tumor staging due to chest wall involvement in lung adenocarcinoma have a worse prognosis than those with T2 tumor staging due to visceral pleural involvement. Lung adenocarcinoma with involvement within the parietal pleura has a better prognosis than that with chest wall involvement, and involvement of the chest wall and ribs has a worse prognosis than involvement of superficial structures of the chest wall. Therefore, improving the accuracy of tumor staging in patients with lung adenocarcinoma and diagnosing chest wall and rib involvement is crucial for formulating clinical treatment plans and improving patients' quality of life and survival rates. MSCT is a conventional imaging method for diagnosing chest wall and rib involvement in lung adenocarcinoma, characterized by its ability to clearly display local rib contours and edge changes through spiral CT thin-slice scanning or reconstruction. However, it has the drawback of false positives^[11,12]. ^{99m}Tc -MDP SPECT/CT provides simultaneous information on bone phosphate metabolism, bone morphology, and anatomical structure. By combining the advantages of functional imaging and anatomical imaging, it effectively improves the diagnostic accuracy of bone lesions and has been widely recognized for its diagnostic value in skeletal lesions^[13].

Currently, few studies have evaluated the diagnostic value of ^{99m}Tc -MDP SPECT/CT in assessing chest wall and rib invasion by pulmonary adenocarcinoma. The results of this study indicate that the diagnostic sensitivity

of ^{99m}Tc -MDP SPECT/CT is 97.3%, which is higher than that of MSCT at 72.3%. The main reason for missed diagnoses by MSCT is that early-stage rib invasion may not yet exhibit bone morphology or density changes, rendering MSCT unable to detect abnormalities. Additionally, data show that the diagnostic specificity of MSCT is 100% (4/4), which is higher than that of ^{99m}Tc -MDP SPECT/CT at 50.0% (2/4). The reason for this is that MSCT, utilizing thin-slice scanning or reconstruction techniques, can more clearly display old bone calluses and bone island lesions compared to the integrated CT of SPECT/CT, resulting in higher specificity. The diagnostic accuracy of ^{99m}Tc -MDP SPECT/CT is 94.9%, which is higher than that of MSCT at 74.4%. This study preliminarily validates that the diagnostic efficacy of ^{99m}Tc -MDP SPECT/CT imaging in diagnosing chest wall and rib invasion by pulmonary adenocarcinoma is superior to that of MSCT. These findings are consistent with the results of a study by Dong et al. ^[14], which analyzed MSCT and SPECT/CT imaging data from 47 lung cancer patients and found that the diagnostic accuracy of SPECT/CT fusion imaging for chest wall bone invasion in lung cancer was 89.4%, significantly higher than that of MSCT at 72.3%. Based on the research, ^{99m}Tc -MDP SPECT/CT, compared to MSCT, can improve the diagnostic accuracy of chest wall and rib invasion by pulmonary adenocarcinoma and has good clinical application value.

The results of this study indicate that ^{99m}Tc -MDP SPECT/CT outperforms MSCT in tumor staging for pulmonary adenocarcinoma. Compared to MSCT tumor staging for pulmonary adenocarcinoma, ^{99m}Tc -MDP SPECT/CT revised the MSCT staging in 21.2% (14/66) of pulmonary adenocarcinoma cases. The T-staging changed in 14 patients, with all 14 patients experiencing an upward revision due to negative MSCT diagnoses (normal bone density in ribs adjacent to pulmonary adenocarcinoma lesions) but positive ^{99m}Tc -MDP SPECT/CT diagnoses (high MDP uptake in ribs adjacent to pulmonary adenocarcinoma lesions). The results of this study indicate that the bone morphology and density of the ribs adjacent to the chest wall in lung adenocarcinoma patients are normal. The ^{99m}Tc -MDP SPECT/CT demonstrated a high diagnostic accuracy of 100% (14/14) in identifying early-stage rib invasion. Compared to MSCT, the primary benefit of ^{99m}Tc -MDP SPECT/CT in tumor staging for rib invasion in lung adenocarcinoma involving the chest wall lies in its ability to assess early-stage chest wall and rib invasion. The reason for this is that during the early stages of rib invasion in lung adenocarcinoma, ^{99m}Tc -MDP SPECT/CT can detect abnormalities in bone phosphate metabolism before bone destruction becomes evident on the ribs and before MSCT can identify any abnormalities in bone density. Changes in bone phosphate metabolism occur earlier than abnormalities in bone morphology and anatomical structure, enabling the detection of early-stage chest wall and rib invasion in lung adenocarcinoma. The findings of this study are consistent with those reported by Zhang et al. ^[15] Their research showed that, after fully considering false-positive factors, SPECT/CT identified bone metastases in two cases where the vertebral morphology and density appeared normal but exhibited high ^{99m}Tc -MDP uptake, aligning with pathological confirmation. The results of this study suggest that ^{99m}Tc -MDP SPECT/CT outperforms MSCT in tumor staging for lung adenocarcinoma, providing crucial scientific evidence for clinical treatment decisions in lung adenocarcinoma.

5. Conclusion

In summary, this study preliminarily validated that ^{99m}Tc -MDP SPECT/CT imaging demonstrates superior diagnostic efficacy compared to MSCT in identifying rib invasion involving the chest wall in lung adenocarcinoma. The value of ^{99m}Tc -MDP SPECT/CT in tumor staging for rib invasion in lung adenocarcinoma involving the chest wall, as compared to MSCT, aids in formulating clinical treatment decisions. The added

value of ^{99m}Tc -MDP SPECT/CT imaging over MSCT in diagnosing rib invasion involving the chest wall in lung adenocarcinoma provides significant scientific evidence for precise staging and clinical treatment decisions in lung adenocarcinoma, thereby further improving patient prognosis and quality of life.

Disclosure statement

The authors declare no conflict of interest.

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