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Effectiveness of Multi-Modal Teaching Based on Online Case Libraries in the Education of Gene Methylation Combined with Spiral CT Screening for Pulmonary Ground-Glass Opacity Nodules

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Abstract: *Objective:* To explore the effectiveness of multi-modal teaching based on an online case library in the education of gene methylation combined with spiral computed tomography (CT) screening for pulmonary ground-glass opacity (GGO) nodules. *Methods:* From October 2023 to April 2024, 66 medical imaging students were selected and randomly divided into a control group and an observation group, each with 33 students. The control group received traditional lecture-based teaching, while the observation group was taught using a multi-modal teaching approach based on an online case library. Performance on assessments and teaching quality were analyzed between the two groups. *Results:* The observation group achieved higher scores in theoretical and practical knowledge compared to the control group ($P < 0.05$). Additionally, the teaching quality scores were significantly higher in the observation group ($P < 0.05$). *Conclusion:* Implementing multi-modal teaching based on an online case library for pulmonary GGO nodule screening with gene methylation combined with spiral CT can enhance students' knowledge acquisition, improve teaching quality, and have significant clinical application value.

Keywords: Multi-modal teaching based on online case library; Pulmonary nodules; Gene methylation; Computed tomography

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1. Introduction

Pulmonary nodules are an early clinical manifestation of lung cancer, with ground-glass opacity (GGO) nodules being a specific radiological feature of early-stage lung cancer. Clinical diagnosis primarily relies on pathological

biopsy via puncture, but small pulmonary nodule diagnoses are often affected by various factors [1]. Studies have shown that combining spiral computed tomography (CT) with gene methylation for the diagnosis of early pulmonary GGO nodules achieves the expected diagnostic value and has a high positive detection rate for small nodules, making it a feasible and commonly used diagnostic approach in radiology. This approach also places high demands on the operational skills of diagnostic physicians [2].

Undergraduate medical education includes medical imaging courses to enhance diagnostic quality. However, existing teaching methods lack diverse and innovative elements, making it difficult to effectively improve students' diagnostic skills. Multi-modal teaching using an online case library emphasizes the importance of case-based learning. This approach integrates diverse teaching methods around typical cases, offering strong comprehensiveness [3].

This study examines the teaching outcomes of multi-modal teaching based on an online case library in the context of gene methylation combined with spiral CT screening for pulmonary GGO nodules. A total of 66 medical imaging students from October 2023 to April 2024 were included in this research.

2. Materials and methods

2.1. General information

From October 2023 to April 2024, 66 medical imaging students were selected as study subjects and randomly divided into two groups of 33 each using a random number table method.

Control group: Average age ranged from 18 to 22 years (20.15 ± 0.66 years). Educational background: 16 students had a college diploma or below, while 17 were undergraduates or above.

Observation group: Average age ranged from 18 to 22 years (20.39 ± 0.59 years). Educational background: 16 students had a college diploma or below, while 17 were undergraduates or above.

There were no statistically significant differences in baseline characteristics between the two groups ($P > 0.05$).

2.2. Methods

Control group: The traditional lecture-based teaching approach was employed. The teaching content was aligned with the syllabus and focused on theoretical knowledge, including the definition, classification, imaging characteristics, anatomical and radiological signs, diagnosis, and differential diagnosis of pulmonary ground-glass opacity (GGO) nodules. The sessions predominantly utilized slide presentations. During the teaching sessions, imaging materials of pulmonary GGOs were intermittently introduced to guide students in writing reports. The final 10 minutes of each session were dedicated to discussing and analyzing challenging cases with the students.

Observation group: A multi-modal teaching method based on an online case library was adopted, incorporating the following approaches:

(1) Online case library development: An online teaching case library was constructed using an electronic medical record system and PACS platform. This library included knowledge about pulmonary GGO nodules, gene methylation, and spiral CT detection. Thirty typical cases were collected from the hospital, covering conditions such as tumors, pneumonia, congenital diseases, and pulmonary connective tissue diseases. For each type, clinical data from five patients (medical history, specialized examinations, imaging findings, pathological results, etc.) were compiled. A web-based teaching material system was established for students to access and review online.

(2) Case-based learning (CBL): Before teaching, three representative cases were selected from the online teaching case library. During the session, students were guided to search the case library, analyze cases in detail, and answer questions based on the syllabus. Students were encouraged to provide feedback on cases, which was evaluated by the instructor. At the end of the session, new questions were posed to stimulate further learning. Students were also instructed to use online tools for review and problem-solving, with unresolved queries addressed in the following class.

(3) AI-assisted teaching: AI software systems were used to analyze cases from the online library. The system facilitated an in-depth study of the imaging characteristics of pulmonary GGO nodules, such as location, size, and density, including features like vacuole signs, air bronchogram signs, and vascular convergence signs. Teachers summarized and explained the AI-assisted analysis, helping students address questions related to the interpretation of pulmonary GGO imaging.

2.3. Observation indicators

(1) A custom-designed assessment questionnaire was used to evaluate students. It included theoretical knowledge (objective and subjective questions) and practical knowledge. The total score was 100, with scores directly proportional to assessment outcomes.

(2) A post-teaching survey assessed teaching quality using a self-designed questionnaire. This included dimensions such as learning enthusiasm, independent problem-solving abilities, foundational imaging knowledge, clinical diagnostic thinking, report writing skills, and teamwork/interactive communication. Each dimension was scored out of 100, with higher scores indicating better teaching quality.

2.4. Statistical methods

Statistical analysis was performed using SPSS 25.0. Measurement data were expressed as mean ± standard deviation (SD) and analyzed using t-tests. Count data were expressed as [*n* (%)] and analyzed using the chi-squared (χ^2) test. Differences were considered statistically significant when $P < 0.05$.

3. Results

3.1. Comparison of assessment results between the two groups

The scores for theoretical and practical knowledge in the observation group were significantly higher than those in the control group ($P < 0.05$), as shown in **Table 1**.

Table 1. Comparison of assessment results between the two groups (mean ± SD, points)

Group	*n*	Theoretical knowledge	Practical knowledge
Control group	33	80.23 ± 4.45	81.61 ± 4.02
Observation group	33	85.56 ± 4.37	91.11 ± 3.39
t		4.909	10.378
P		< 0.001	< 0.001

3.2. Comparison of teaching quality between the two groups

The observation group showed significantly higher teaching quality scores across all dimensions compared to the

control group ($P < 0.05$), as shown in **Table 2**.

Table 2. Comparison of teaching quality between the two groups (mean ± SD, scores)

Group	*n*	Learning enthusiasm	Independent problem-solving	Foundational imaging knowledge	Clinical diagnostic thinking	Report writing skills	Teamwork & interaction
Control group	33	75.28 ± 3.27	78.76 ± 5.51	81.22 ± 5.46	83.31 ± 4.41	85.84 ± 3.33	84.43 ± 4.40
Observation group	33	80.16 ± 3.38	84.47 ± 5.36	88.75 ± 4.49	91.18 ± 3.62	92.64 ± 3.59	95.56 ± 2.79
t		5.961	4.267	6.119	7.924	7.978	12.272
P		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

4. Discussion

Gene methylation combined with spiral CT screening of pulmonary ground-glass nodules is a critical diagnostic procedure in radiology. The accuracy of diagnostic results is closely linked to the operator's experience and technical skills, necessitating educational models that enhance these skills [4,5]. Traditional teaching methods, though effective to some extent, focus predominantly on theoretical knowledge and rely on didactic teaching approaches, which limit students' learning autonomy, independent thinking abilities, and practical imaging interpretation skills. This hampers improvements in teaching quality [6,7]. Therefore, adopting an innovative teaching model is crucial.

Multi-modal teaching based on an online case library integrates typical cases into different teaching methodologies, each with unique structures and processes, to leverage their respective advantages. This approach enables students to comprehensively grasp theoretical and practical knowledge, facilitating a deeper understanding [8,9]. The teaching model encourages students to actively explore relevant knowledge points through typical cases and engage in discussions with instructors, thereby promoting better knowledge retention and fostering teamwork skills [10,11].

In this study, the assessment scores in the observation group were significantly higher, primarily because the multi-modal teaching method based on the online case library incorporates various teaching approaches. The case library itself contains theoretical knowledge taught during the sessions, enabling instructors to guide students in learning and summarizing typical cases. This process allows students to independently and efficiently acquire and master both theoretical and practical knowledge.

Furthermore, the teaching quality scores in the observation group were notably higher. The multi-modal teaching model integrates online and offline modules, using network platforms to complement classroom teaching and address the diverse learning preferences of students [12]. Additionally, the use of AI technology helps create knowledge maps and cognitive frameworks for pulmonary ground-glass nodules, aligning with students' learning psychology and enhancing their enthusiasm for learning. This, in turn, strengthens their teamwork and interactive communication skills [13].

CBL prioritizes students as the focal point of the teaching process, with clinical case problems serving as the foundation and diagnostic reasoning as the main thread. This interactive and open-ended method integrates typical cases into the curriculum, enabling a shift in clinical diagnostic thinking and improving foundational imaging knowledge while cultivating diagnostic reasoning skills [14,15].

5. Conclusion

In conclusion, when teaching clinical medical imaging students about gene methylation combined with spiral CT screening of pulmonary ground-glass nodules, a multi-modal teaching model based on an online case library enhances students' knowledge base, improves teaching quality, and has high clinical application value.

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Disclosure statement

The authors declare no conflict of interest.

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