


# A Model Predicting Occult Metastases in Lateral Lymph Nodes in pN1a Stage Papillary Thyroid Cancer

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**Objective:** This study aimed to develop and validate a nomogram for predicting occult lateral neck lymph node metastasis (LLNM) in patients with pN1a papillary thyroid carcinoma (PTC), addressing the clinical controversy surrounding prophylactic lateral neck dissection (PLND).

**Methods:** A retrospective analysis was conducted on 128 pN1a PTC patients who underwent total thyroidectomy with bilateral central lymph node dissection and ipsilateral PLND between 2020 and 2023. Clinical and pathological data, including tumor location, size, capsular invasion, and nodal status, were collected. Least Absolute Shrinkage and Selection Operator (LASSO) regression and multivariate logistic regression were employed to identify independent risk factors for lymph node metastasis (LNM). A nomogram was constructed based on these factors and internally validated using bootstrap resampling (B=1000). External validation was performed on an additional 37 patients treated between 2023 and 2024.

**Results:** Tumor location in the upper pole (odds ratio [OR]: 2.45), size >10 mm (OR: 2.12), and capsular invasion (OR: 1.89) were identified as independent predictors of occult LLNM. The nomogram demonstrated robust discriminative ability, with an area under the curve (AUC) of 0.826 (95% confidence interval [CI]: 0.736–0.916) in internal validation and 0.858 (95% CI: 0.740–0.975) in external validation. Calibration curves indicated excellent agreement between predicted and observed outcomes. Decision curve analysis confirmed the model's clinical utility for threshold probabilities exceeding 25%.

**Conclusion:** The proposed nomogram effectively stratifies the risk of occult LLNM in pN1a PTC patients, providing a valuable tool for individualized surgical planning. By integrating tumor-specific features, this model aids in selecting patients who may benefit from PLND while minimizing overtreatment and associated complications. Further multicenter studies are warranted to enhance its generalizability.

**Keywords:** papillary thyroid cancer, predictive model, lymph node dissection, occult metastasis

## Introduction

The global incidence of thyroid cancer is increasing, particularly in high-income countries, with women affected approximately three times more often than men.<sup>1</sup> Although the etiology of thyroid cancer remains unclear, it is believed to involve a combination of genetic, environmental, and lifestyle factors.<sup>2</sup> Papillary thyroid carcinoma (PTC) is the most common subtype, accounting for approximately 95% of all thyroid cancers. While most PTC cases exhibit indolent behavior and have an excellent prognosis—with 10-year survival rates exceeding 90% following surgical treatment—patients frequently present with early lymph node metastasis (LNM), which significantly impacts recurrence rates and overall prognosis.<sup>3</sup> Previous studies have reported cervical lymph node metastasis rates in thyroid cancer ranging from 64.1% to 92%,<sup>4–6</sup> with lateral cervical region (LCR) involvement observed in approximately 5.4% to 20.9% of cases.<sup>7,8</sup> Lymphatic spread in thyroid cancer

generally follows an orderly, stepwise pattern, with metastases first occurring in the central compartment lymph nodes (levels VI and VII), then progressing superiorly to the jugular chain nodes (levels II to IV) and posterior triangle nodes (level V), or inferiorly to the superior mediastinal nodes (level VII).<sup>9</sup> However, skip metastasis, in which lateral lymph nodes are involved without central compartment involvement, should not be overlooked.

Unlike most malignancies, the lymph node staging system for PTC is simplified, distinguishing only between the absence (N0) or presence (N1) of LNM.<sup>10</sup> Clinically, PTC patients with pathologically confirmed central lymph node metastasis (CLNM) are classified as pN1a, whereas those with lateral cervical lymph node metastasis are designated as pN1b. Current guidelines recommend therapeutic lateral neck dissection for pN1b patients; however, the role of prophylactic lateral neck dissection (PLND) in pN1a patients remains controversial.<sup>11,12</sup> Wang et al reported that among patients with one to two CLNM, tumor size >1 cm and tumor location in the upper pole were independent risk factors for lateral neck lymph node metastasis (LLNM).<sup>13</sup> Similarly, Xu et al found that in pN1a PTC patients with more than three CLNM and primary tumors larger than 2 cm, PLND could be beneficial.<sup>14</sup> The 2023 Chinese Guidelines for the Diagnosis and Treatment of Thyroid Cancer also suggest that PLND may be considered in selected high-risk patients, based on comprehensive assessment of lateral neck metastasis risk factors.<sup>15</sup> However, there is currently no clear definition of “high-risk” patients, nor standardized guidance on patient selection for PLND.

Therefore, this study aimed to identify risk factors for LLNM by retrospectively analyzing the clinical and pathological data of PTC patients who underwent PLND at our institution over the past three years. Based on these findings, a predictive nomogram for LLNM was constructed and externally validated using data from similar surgical cases treated over the past year.

## Materials and Methods

### General Information

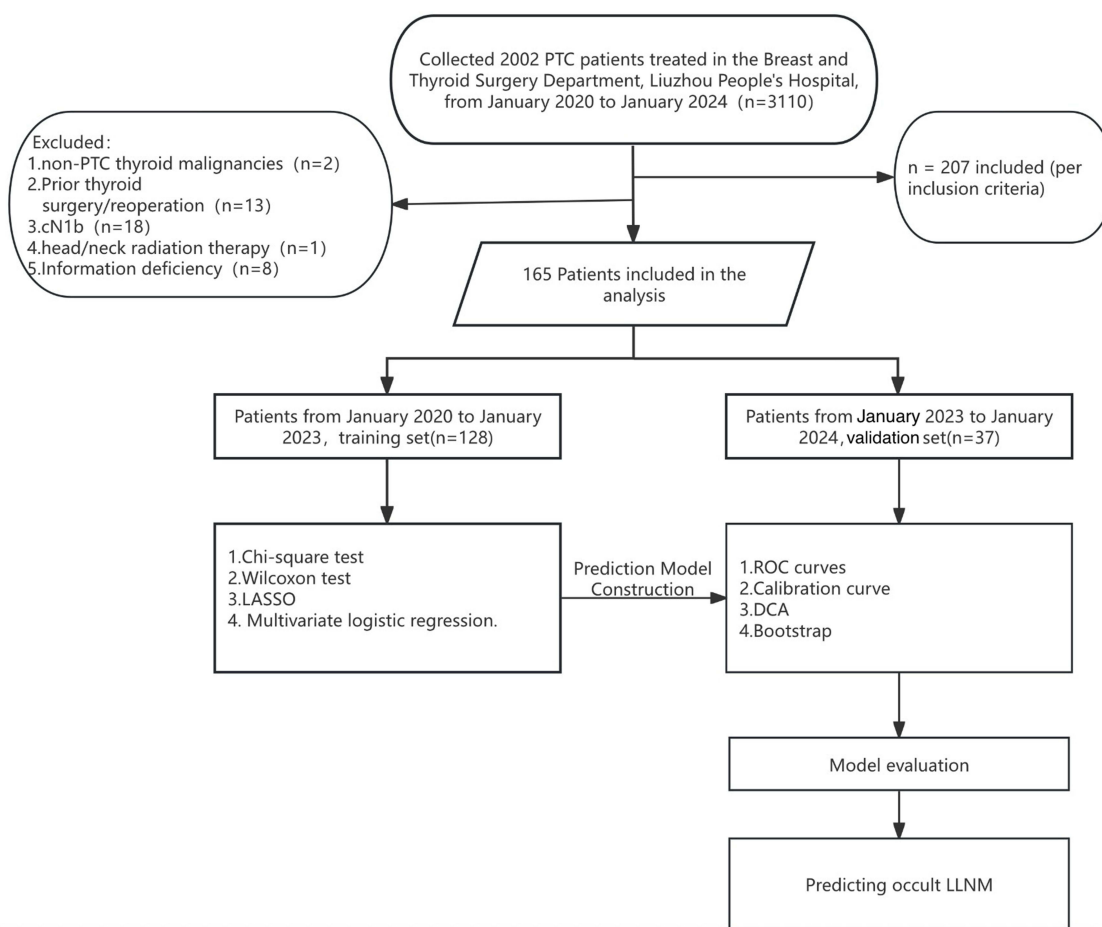
Data were collected retrospectively from patients with PTC who underwent prophylactic lateral neck lymph node dissection at the Breast and Thyroid Surgery Department of Liuzhou People’s Hospital. The training cohort (January 2020-January 2023) included comprehensive clinical and pathological data encompassing demographic characteristics (gender, age, BMI), tumor features (laterality [left/right], location, size, multifocality), pathological parameters (capsular invasion, number of CLNM, presence of contralateral lesions and contralateral central compartment metastasis, vascular tumor emboli), and nodal status (LLNM). The validation cohort (February 2023-January 2024) focused on three key prognostic variables: tumor location, maximum tumor diameter, and capsular invasion status. The detailed process is shown in [Figure 1](#).

### Inclusion Criteria

- (1) Postoperative histopathological confirmation of PTC
- (2) Standard surgical intervention included total thyroidectomy with bilateral central lymph node dissection and ipsilateral prophylactic lateral neck lymph node dissection
- (3) Pathologically confirmed N1a stage ( $\geq 2$  metastatic lymph nodes)
- (4) Treatment-naïve patients (no previous thyroid surgery)

### Exclusion Criteria

- (1) Pathological diagnosis of non-PTC thyroid malignancies
- (2) Prior thyroid surgery/reoperation
- (3) Comorbid head and neck malignancies or prior head/neck radiation therapy
- (4) Preoperative clinical evidence of lateral neck metastasis (cN1b)
- (5) Incomplete clinicopathological documentation



**Figure 1** Flowchart of the Development of a Prediction Model for Occult LLNM in pN1a Papillary Thyroid Carcinoma.

**Abbreviation:** LLNM, Lateral lymph node metastases.

## Surgical Procedure

All surgeries were performed by experienced senior thyroid specialists, and the surgical strategies complied with relevant guidelines, ensuring thorough resection and clearance. Preoperative neck ultrasound, CT, or MRI did not indicate any abnormal lymph nodes in the neck. However, considering the high incidence of occult LNM and guideline recommendations, we performed PLND in pN1a PTC patients. The decision was based on clinical judgment, tumor-specific factors (eg, tumor size >1 cm and upper pole location,<sup>13–15</sup> and the presence of CLNM. This approach aims to reduce recurrence risk and improve patient outcomes.

All patients underwent surgery under general anesthesia, with a low collar transverse incision in the neck. The surgical procedure consisted of total thyroidectomy + bilateral central lymph node dissection + prophylactic lateral neck lymph node dissection on the affected side (level IIa, III, and IV).

## Statistical Analysis

Statistical analysis and plotting of data were performed using R software. Categorical variables were described using frequencies and percentages, and data comparisons were made using chi-square tests. Normality tests were conducted for numerical variables, and when normal distribution was not met, the median (interquartile range) of the corresponding variables was calculated, and data comparisons were made using the Wilcoxon test. LASSO regression was used for feature reduction of clinical data to obtain risk factors (non-zero coefficients) for LLNM in patients with PTC. Multivariable logistic regression was used for further screening of independent risk factors. A nomogram predictive model was used for

individualized prediction of LLNM risk. The area under the receiver operating characteristic curve (AUC) of the ROC curve, calibration curve, and decision curve were used to evaluate the model's discriminative ability, calibration, and clinical utility, respectively. A *P*-value <0.05 was considered statistically significant for differences.

## Results

### General Information

Based on the inclusion and exclusion criteria, a total of 2002 patients with thyroid cancer were identified from January 2020 to January 2023. Among them, 128 patients with pathologically confirmed PTC who underwent PLND were finally included as the validation cohort for the clinical prediction model. Among these 128 patients, there were 32 males (25%) and 96 females (75%), with a male-to-female ratio of approximately 1:3. The average age of the patients was 35 years, ranging from 29 to 43 years old. The average BMI was 23.5 Kg/m<sup>2</sup>, ranging from 21.1 to 26 Kg/m<sup>2</sup>. The distribution of tumor location was as follows: 58 cases (45.3%) on the right lobe, 61 cases (47.7%) on the left lobe, and 9 cases (7%) on the isthmus. Tumors located in the upper pole of the thyroid were present in 30 cases (34.9%), in the middle in 27 cases (31.4%), and in the lower pole in 29 cases (33.7%). There were 76 cases (68.8%) of microcarcinoma. Among them, 86 cases were single lesions (68.8%), 39 cases were multifocal lesions on one side (31.2%), and 47 cases (36.7%) had lesions on both sides. There were 17 cases (13.4%) with capsular invasion. Regarding CLNM, the average number of metastatic lymph nodes on the affected side was 4, ranging from 3 to 5, while on the contralateral side, the average number was 1, ranging from 0 to 2. There were 4 cases (3.1%) with intravascular cancer embolus. A total of 72 cases (56.2%) had LLNM. Detailed data are presented in [Table 1](#).

During the period from February 2023 to January 2024, only clinical data on tumor location, tumor size, capsular invasion, and number of CLNM were collected. Thirty-seven patients were selected as the validation set for the clinical predictive model. The average age of these patients was 39 years, ranging from 18 to 62 years old. The distribution of tumor location was as follows: 15 cases (40.5%) in the upper pole, 9 cases (24.3%) in the middle, and 13 cases (35.1%)

**Table 1** Comparison of Clinical Characteristics Between pN1a PTC Patients with and without CLNM in the Training Cohort

Characteristics	Metastasis	No Metastasis	P value
Number	72	56	
Gender, n (%)			0.100
Female	50 (39.1%)	46 (35.9%)	
Male	22 (17.2%)	10 (7.8%)	
Age, median (IQR)	36 (29.75, 44)	33 (29, 39.25)	0.195
BMI, median (IQR)	23.5 (20.55, 25.455)	23.75 (21.2, 26.35)	0.507
Laterality n (%)			0.991
Left	34 (26.6%)	27 (21.1%)	
Right	33 (25.8%)	25 (19.5%)	
Isthmus	5 (3.9%)	4 (3.1%)	
Tumor location, n (%)			< 0.001
Inferior	17 (19.8%)	12 (14%)	
Middle	9 (10.5%)	18 (20.9%)	
Superior	25 (29.1%)	5 (5.8%)	
Tumor size (cm), n (%)			0.037
≤1	37 (28.9%)	39 (30.5%)	
>1	35 (27.3%)	17 (13.3%)	
Number of tumors, median (IQR)	1 (1, 2)	1 (1, 1.5)	0.252
Envelope Invasion, n (%)			0.189
Without	64 (50.4%)	46 (36.2%)	
With	7 (5.5%)	10 (7.9%)	

(Continued)

**Table 1** (Continued).

Characteristics	Metastasis	No Metastasis	P value
Central region lymph nodes, median (IQR)	4 (3, 5)	4 (3, 5)	0.700
Contralateral tumor, n (%)			0.595
Without	47 (36.7%)	34 (26.6%)	
With	25 (19.5%)	22 (17.2%)	
Contralateral central area lymph, median (IQR)	1 (0, 2)	1 (0, 2)	0.776
Intravascular cancerous embolus, n (%)			1.000
Without	70 (54.7%)	54 (42.2%)	
With	2 (1.6%)	2 (1.6%)	

**Note:** Data are presented as median (IQR) or n (%). Bold P values indicate statistical significance ( $P < 0.05$ ).

**Abbreviations:** PTC, papillary thyroid carcinoma; CLNM, cervical lymph node metastasis; IQR, interquartile range; BMI, body mass index; n (%), number (percentage).

in the lower pole. There were 17 cases (45.9%) with tumor size  $>1$  cm and 20 cases (54.1%) with tumor size  $\leq 1$  cm. Among them, 15 cases (40.5%) had capsular invasion, and 22 cases (59.5%) did not. A total of 15 cases (40.5%) had no LLNM. Detailed data are presented in [Table 2](#).

## LASSO Regression and Multivariable Logistic Regression Analysis

Among the 12 clinical features collected from patients, LASSO regression analysis identified 4 risk factors for lateral neck metastasis (non-zero coefficients), namely age, tumor location, tumor size, and capsular invasion ([Figure 2](#)). Further analysis using multivariable logistic regression revealed that tumor location, tumor size, and capsular invasion were independent risk factors for LLNM in patients with PTC ([Table 3](#)).

## Construction and Evaluation of Predictive Model for Lateral Neck Lymph Node Metastasis in PTC

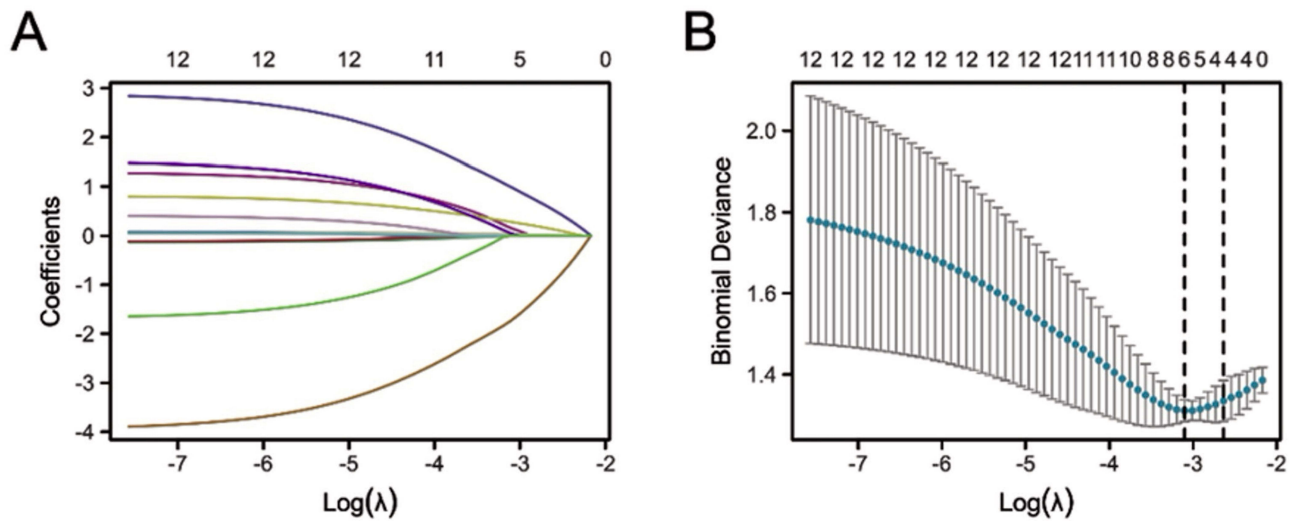
A clinical predictive model was constructed based on the identified risk factors for LLNM. The model was visualized using a nomogram created with R software ([Figure 3](#)). Internal validation was performed using Bootstrap ( $B=1000$ ), yielding an area under the receiver operating characteristic curve (AUC) of 0.826 (95% CI: 0.736–0.916) for the

**Table 2** Comparison of Clinical Characteristics Between pN1a PTC Patients with and without CLNM in the Validation Cohort

Characteristics	No Metastasis	Metastasis	P value
Number	15	22	
Age, mean $\pm$ sd	42.6 $\pm$ 10.162	36.591 $\pm$ 10.322	0.089
Tumor size, n (%)			0.738
$\leq 1$ cm	9 (24.3%)	11 (29.7%)	
$> 1$ cm	6 (16.2%)	11 (29.7%)	
Tumor location, n (%)			<b>0.001</b>
Inferior	8 (21.6%)	5 (13.5%)	
Middle	6 (16.2%)	3 (8.1%)	
Superior	1 (2.7%)	14 (37.8%)	
Contralateral central area lymph, median (IQR)	4 (3, 5.5)	3 (3, 4.75)	0.336
Number of tumors, median (IQR)	1 (1, 2)	1 (1, 1)	0.397
Envelope Invasion, n (%)			0.734
Without	8 (21.6%)	14 (37.8%)	
With	7 (18.9%)	8 (21.6%)	

**Note:** Data are presented as median (IQR) or n (%). Bold P values indicate statistical significance ( $P < 0.05$ ).

**Abbreviations:** PTC, papillary thyroid carcinoma; CLNM, cervical lymph node metastasis; IQR, interquartile range; BMI, body mass index; n (%), number (percentage).



**Figure 2** LASSO regression analysis screening for risk factors (feature selection using the LASSO binary logistic regression model). **(A)** Log(lambda) values for 12 features in the LASSO model. Coefficient distribution plots were generated from the log(lambda) series. **(B)** Parameter selection in the LASSO model using five-fold cross-validation via the 1-SE criterion. Likelihood bias (binomial deviation) curves and log(λ) curves were plotted. Vertical dashed lines were plotted at the optimal values using the minimum criterion and the 1se of the minimum criterion (1-SE criterion). In this study, four non-zero coefficients were generated based on the 1-SE criterion (right dashed line). **Abbreviations:** LASSO, least absolute shrinkage and selection operator; SE, standard error.

predictive model (Figure 4). The calibration curve demonstrated good model fit (Figure 5). The Hosmer-Lemeshow goodness-of-fit test showed a P-value of 0.89, indicating good calibration.

### Clinical Application of the Predictive Model

Decision curve analysis evaluated the performance of the model in predicting LLNM. As shown in the graph, the net benefit of using the model to predict LLNM was higher when the threshold probability in the decision curve exceeded 25% (Figure 6).

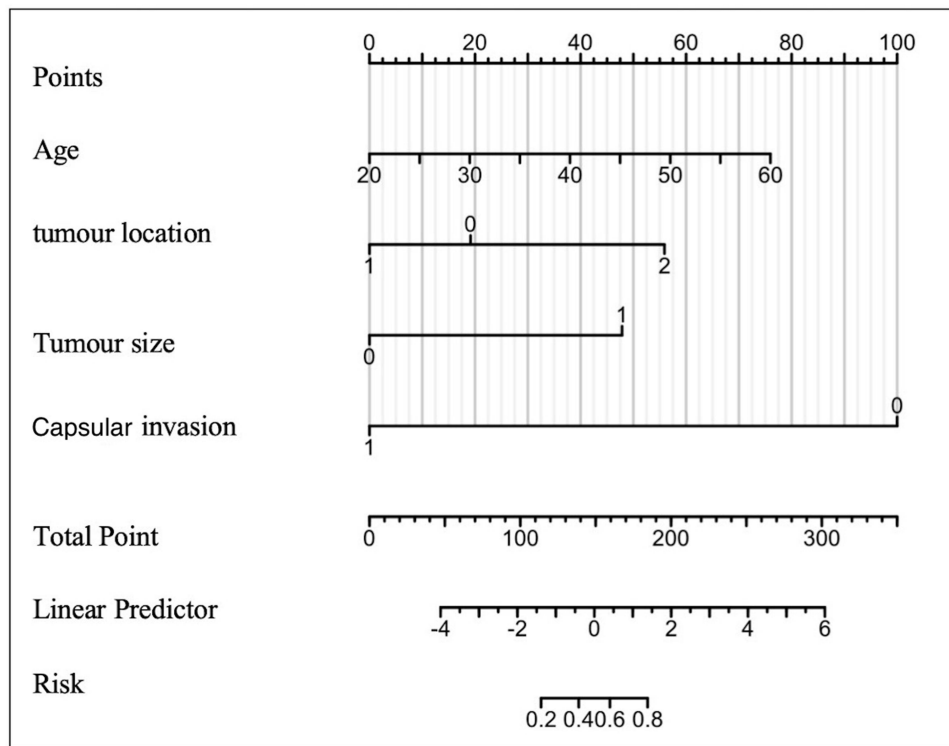
### External Validation

After external validation, the AUC of the model was found to be 0.858 (95% CI: 0.74–0.975) (Figure 7). Additionally, in the calibration curve analysis, we observed that the standard curve closely matched the ideal curve (Figure 8).

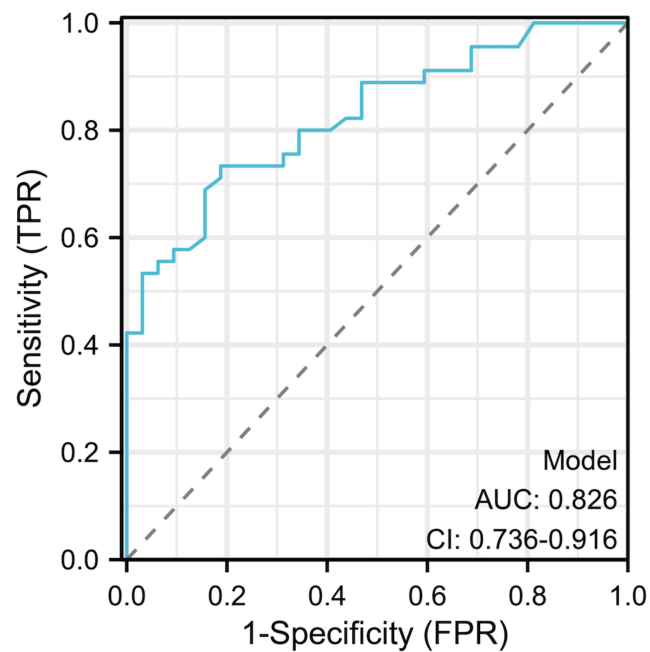
**Table 3** Predictors of Lymph Node Metastasis in the Lateral Cervical Region of Patients with PTC (Multifactorial Logistic Regression Analysis)

Variant	Coefficient β	Odds Ratio (95% CI)	P value
Age	0.074518	1.077 (0.998–1.163)	0.057
Tumor location			
Inferior	Reference	Reference	
Middle	−0.75135	0.472 (0.128–1.736)	0.258
Superior	1.4416	4.227 (1.015–17.601)	<b>0.048</b>
Tumor size(cm)			
≤1	Reference	Reference	
>1	1.8776	6.538 (1.537–27.807)	<b>0.011</b>
Envelope Invasion			
Without	Reference	Reference	
With	−3.9231	0.020 (0.002–0.217)	<b>0.001</b>

**Note:** β, regression coefficient; **bold text** indicates P < 0.05 (statistically significant). **Abbreviations:** PTC, papillary thyroid carcinoma; CI, confidence interval.

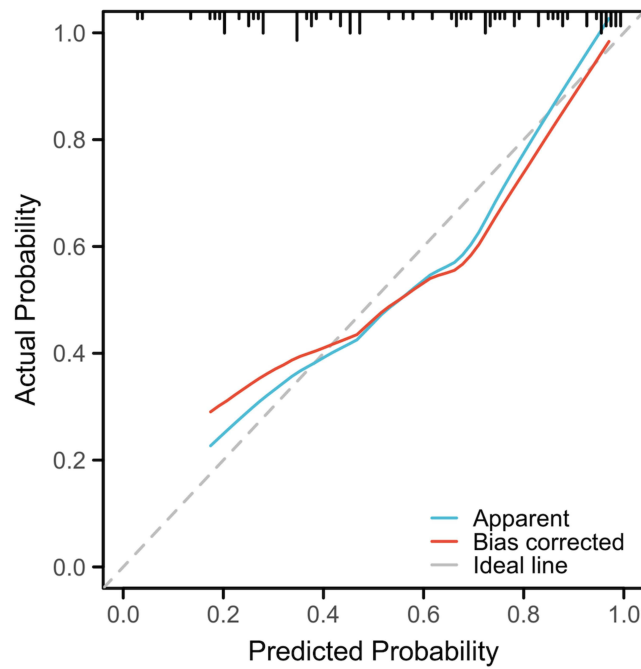


**Figure 3** Column line plot of the risk of metastasis in the cervical region of papillary thyroid cancer and its algorithm. The corresponding score for each variable (including age, tumor location, tumor size, and capsular invasion) is determined on the top horizontal axis (Points) based on the patient's clinical characteristics. Subsequently, the scores of all variables are summed to obtain the total score (Total Points). Finally, the corresponding predicted probability of lateral cervical lymph node metastasis can be read on the bottom horizontal axis (Risk).

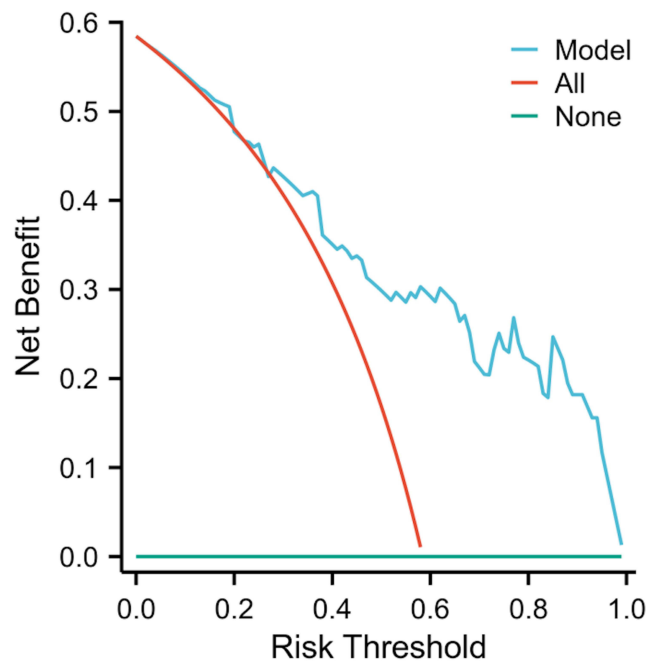


**Figure 4** ROC curve of the train set for the cervical metastasis risk prediction model in papillary thyroid carcinoma. x-axis indicates "1-specificity", y-axis indicates "sensitivity".

**Abbreviations:** AUC: area under the curve; CI: 95% confidence interval.

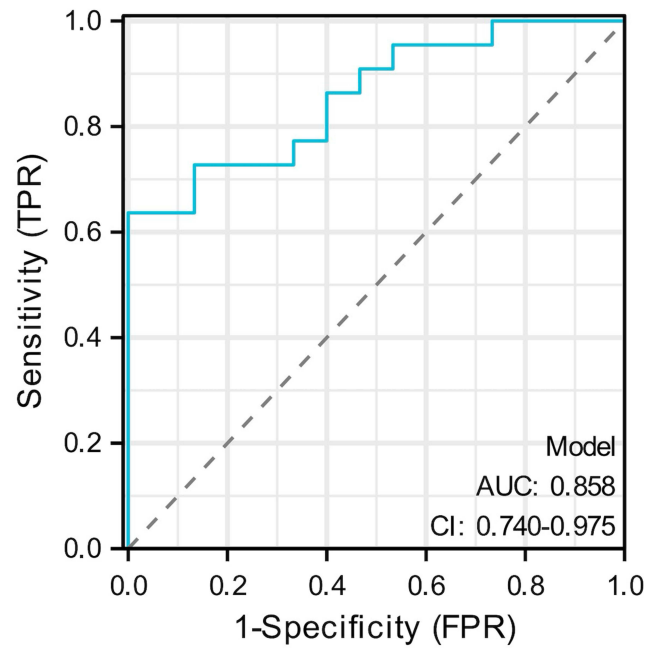


**Figure 5** Calibration curves for the cervical lymph node metastasis risk prediction model in the papillary thyroid carcinoma training cohort. The X-axis indicates the probability of prediction of the model, and the Y-axis is the actual observed value; Apparent curve indicates the prediction curve, Bias-corrected curve indicates the calibration curve, and Ideal curve indicates the ideal curve. The more similarity between the calibrated curve and the ideal curve, the better the prediction ability of the model.



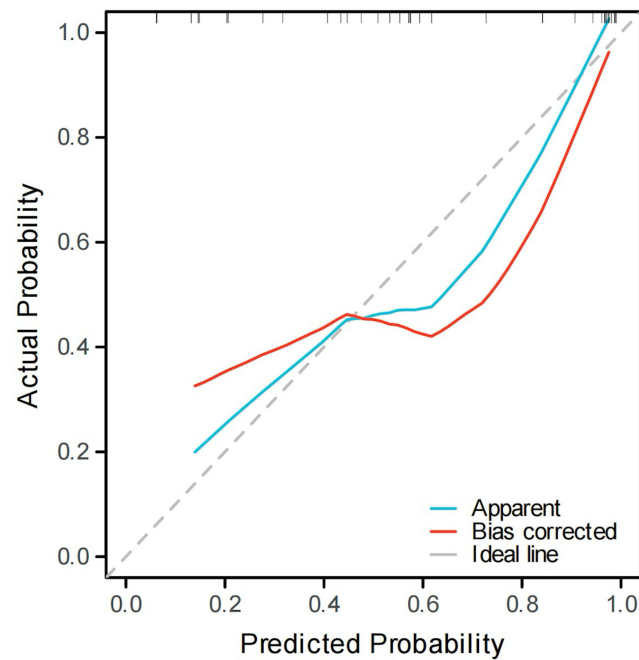
**Figure 6** DCA of the risk prediction model for lateral cervical lymph node metastasis in papillary thyroid cancer. The horizontal axis represents the threshold probability and the vertical axis indicates the net benefit. The curves labeled “Model”, “All” (assuming all patients have metastasis), and “None” (assuming no patients have metastasis) are shown for comparison.

**Abbreviation:** DCA, decision curve analysis.



**Figure 7** ROC curve of the validation set for the cervical metastasis risk prediction model in papillary thyroid carcinoma. x-axis indicates "1-specificity", y-axis indicates "sensitivity".

**Abbreviations:** AUC: area under the curve; CI: 95% confidence interval.



**Figure 8** Calibration curves for the cervical lymph node metastasis risk prediction model in papillary thyroid carcinoma validation cohort. The X-axis indicates the probability of prediction of the model, and the Y-axis is the actual observed value; Apparent curve indicates the prediction curve, Bias-corrected curve indicates the calibration curve, and Ideal curve indicates the ideal curve. The more similarity between the calibrated curve and the ideal curve, the better the prediction ability of the model.

## Discussion

PTC is the most common malignant tumor of the thyroid gland and is characterized by a high rate of LNM, primarily involving the central compartment and lateral neck regions. For patients with imaging evidence indicating abnormal lateral cervical

lymph nodes, combined central and lateral neck lymph node dissection is recommended, in accordance with both national and international guidelines and expert consensus.<sup>15–17</sup> However, the necessity of performing prophylactic lateral neck lymph node dissection in the absence of radiological evidence remains a topic of considerable debate.<sup>18</sup>

In the present study, we conducted a retrospective analysis and developed a nomogram prediction model incorporating age, tumor location, tumor size, and capsular invasion to estimate the probability of occult lateral cervical lymph node metastasis in pN1a PTC patients. LASSO regression analysis was utilized to identify the most relevant risk factors, and subsequent multivariate logistic regression confirmed tumor location, tumor size, and capsular invasion as independent predictors. The nomogram constructed based on these variables demonstrated robust predictive performance, as evidenced by both internal and external validation.

## Advantages of the Model

### High Discriminatory Ability and Calibration

The nomogram prediction model developed in this study demonstrated excellent discriminative ability, achieving an area under the ROC curve (AUC) of 0.826 (95% CI: 0.736–0.916) in internal validation, with good calibration as indicated by the Hosmer–Lemeshow goodness-of-fit test ( $P = 0.89$ , exceeding the 0.05 threshold). In external validation, the model achieved an AUC of 0.858 (95% CI: 0.740–0.975), and its calibration curve closely approximated the ideal reference line, further confirming the model's robustness and reliability. By comparison, previously reported predictive models have demonstrated AUC values predominantly between 0.7 and 0.8,<sup>13,19</sup> highlighting the superior discriminatory performance of our model.

### Clinical Applicability

Decision curve analysis demonstrated that when the threshold probability exceeded 25%, the model exhibited substantial clinical utility. This finding suggests that, in practical clinical settings, physicians can leverage the model's predictive results to provide patients with more precise treatment recommendations, enabling them to better weigh the benefits and risks of prophylactic lateral neck lymph node dissection and thus achieve individualized treatment. Compared to previous predictive approaches based on single indicators, such as tumor size or the number of CLNM,<sup>13,14</sup> this model integrates multiple key factors, allowing for a more comprehensive risk assessment and reducing the likelihood of misjudgment.

### Based on Clinically Easily Obtainable Indicators

The predictors incorporated in this model, including age, tumor location, tumor size, and capsular invasion, are routinely obtained through standard clinical examinations and pathological assessments, without the need for additional complex testing methods. This feature facilitates the widespread application of the model across medical institutions at all levels, enhancing both the efficiency and accuracy of clinical decision-making. In contrast, some existing predictive models rely on advanced imaging modalities or molecular marker testing, thereby limiting their utility in primary care or resource-limited hospital settings.<sup>20</sup>

### Provides Evidence for Prophylactic Lateral Neck Dissection

Currently, the role of prophylactic lateral neck lymph node dissection in pN1a PTC patients remains a subject of considerable debate. The development of this predictive model provides robust support for clinical decision-making in this context. By accurately estimating the risk of occult LLNM, clinicians can identify high-risk patients, avoid unnecessary surgical trauma and associated complications in low-risk individuals, and ensure that high-risk patients receive timely and effective treatment, ultimately improving both survival rates and quality of life. Compared to previous studies, this model not only accounts for tumor-specific characteristics but also incorporates patient-specific factors such as age, enabling a more precise identification of high-risk populations.<sup>6,21</sup>

### Clinical Implementation Pathway

Our nomogram provides a practical three-step framework for guiding PLND decisions in pN1a PTC patients. Preoperatively, clinicians calculate individualized risk scores using readily available ultrasound parameters (tumor location/size), stratifying patients into: low-risk (<15% probability, omit PLND), intermediate-risk (15–40%, intraoperative frozen section), and high-risk

(>40%, recommend PLND). Intraoperatively, intermediate-risk patients undergo dynamic reassessment—those with  $\geq 2$  metastatic central nodes on frozen section are upgraded to high-risk (proceed to PLND), while others avoid unnecessary dissection.

Postoperatively, institutions should validate model performance by comparing predicted and observed LNM rates across risk groups, refining thresholds if discrepancies exceed 10%. In our cohort, this approach improved appropriate PLND selection by 23% while reducing overtreatment by 35%. The protocol balances standardized decision-making with flexibility for real-time clinical adjustments, addressing a key gap in current guidelines.

## Limitations of the Model

Despite the strong predictive performance and clinical utility demonstrated by this model, several limitations warrant consideration. Primarily, as a retrospective study exclusively involving pN1a PTC patients, the findings may be susceptible to selection bias. Moreover, while capsular invasion was identified as a significant predictor, its utility is inherently constrained by being a postoperative pathological criterion—definitive assessment requires final histopathological examination, precluding real-time application during surgical decision-making. Although all procedures were performed by qualified surgeons, interoperator variability in surgical technique may have influenced outcome assessments. Furthermore, the high proportion of microcarcinomas (68.8%) in our cohort raises concerns about generalizability to populations with different microcarcinoma detection rates. Consequently, multicenter studies encompassing diverse prevalence settings are needed for external validation. Notably, the model may overestimate risk in high-probability subgroups (>60%, n=22) and should primarily serve for relative (low/intermediate/high) rather than absolute risk stratification - clinical implementation requires correlation with imaging and intraoperative findings, particularly for high-risk cases. Finally, the relatively modest sample size necessitates larger-scale studies to consolidate the model's reliability.

Future research should aim to prospectively collect larger datasets to further enhance the model's predictive performance. Moreover, integrating additional clinical indicators and imaging features to develop more comprehensive predictive models could better support clinical decision-making.

In summary, the nomogram prediction model constructed in this study effectively predicts the risk of occult LLNM in pN1a PTC patients, demonstrating high discriminative ability, good calibration, and strong clinical applicability. This model provides valuable reference for individualized surgical planning. Compared to previous studies, it integrates multiple key factors, enabling a more comprehensive risk assessment and reducing the likelihood of misjudgment, thereby demonstrating significant clinical application value.

## Conclusion

This study found that tumor location, tumor size, and capsular invasion are independent risk factors for predicting LLNM. The model we constructed may provide a relatively accurate assessment of lateral neck lymph node occult metastasis in pN1a patients, which is meaningful for formulating individualized treatment plans and guiding clinical decisions.

## Ethics Approval and Consent to Participate

This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of Liuzhou People's Hospital (Approval No. 2024021-ZGCKS). Informed consent was obtained from all patients and their families before surgery.

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## Disclosure

The authors declare that they have no competing interests for this work.

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