Supplementary Information

Lymph node metastasis prediction of papillary thyroid carcinoma based on transfer learning radiomics

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Supplementary Table 1. Quantitative indexes of machine experimental results

Machine	AUC	ACC	SENS	SPEC	PPV	NPV	MCC	F1score
GE	0.91	0.83	0.86	0.81	0.77	0.89	0.66	0.81
Kretztechnik	0.87	0.79	0.89	0.73	0.70	0.90	0.61	0.78
SuperSonic	0.84	0.82	0.82	0.81	0.69	0.90	0.61	0.75

Supplementary Table 2. Quantitative indexes of doctor experimental results

Doctor	AUC	ACC	SENS	SPEC	PPV	NPV	MCC	F1score
1	0.92	0.84	0.84	0.84	0.70	0.92	0.65	0.76
2	0.87	0.84	0.74	0.92	0.90	0.80	0.68	0.81
3	0.91	0.90	0.83	0.94	0.86	0.92	0.77	0.84

Supplementary Table 3. Quantitative index comparisons of VGG, ResNet, Inception ResNet, and TLR on three cohorts

Method	AUC	ACC	SENS	SPEC	PPV	NPV	MCC	F1score
Testing set of the main cohort								
VGG	0.77	0.74	0.65	0.80	0.69	0.78	0.46	0.67
ResNet	0.77	0.71	0.47	0.87	0.70	0.71	0.37	0.56
InceptionResNet	0.75	0.71	0.46	**0.89**	0.73	0.71	0.39	0.56
Our model	**0.93**	**0.84**	**0.94**	0.77	**0.73**	**0.95**	**0.69**	**0.82**
Independent testing set 1								
VGG	0.58	0.55	0.33	0.86	0.77	0.47	0.22	0.46
ResNet	0.58	0.55	0.34	0.85	0.77	0.47	0.22	0.47
InceptionResNet	0.56	0.56	0.45	0.71	0.69	0.47	0.16	0.55
Our model	**0.93**	**0.86**	**0.83**	**0.89**	**0.92**	**0.78**	**0.71**	**0.87**
Independent testing set 2								
VGG	0.66	0.65	0.59	0.70	0.59	0.70	0.29	0.59
ResNet	0.59	0.61	0.55	0.65	0.54	0.66	0.20	0.54
InceptionResNet	0.64	0.63	0.43	**0.77**	0.58	0.65	0.21	0.49
Our model	**0.93**	**0.84**	**0.95**	0.75	**0.74**	**0.96**	**0.70**	**0.83**

Supplementary Table 4. Results of the ablation experiments.

Transfer learning (T) and hyperparametric optimization (H)	**AUC value for the comparison of results**		
	Testing set of the main cohort	***Independent testing set 1***	***Independent testing set 2***
T -, H -	0.718	0.604	0.614
T +, H -	0.791	0.650	0.594
T -, H +	0.817	0.808	0.792
T +, H +	0.927	0.928	0.932

Supplementary Table 5. Information of machine used to collect the main cohort

No.	Machine	Total number	Proportion
1	**GE Healthcare**	206	20.34%
2	**SuperSonic Imagine SA**	130	12.83%
3	**Kretztechnik**	107	10.56%
4	Philips Medical Systems	93	9.18%
5	TOSHIBA_MEC	83	8.19%
6	GE Healthcare Austria GmbH & Co OG	78	7.70%
7	MEDISON	78	7.70%
8	SIEMENS	74	7.31%
9	ESAOTE	63	6.22%
10	TOSHIBA_MEC_US	55	5.43%
11	Philips Healthcare	37	3.65%
12	SAMSUNG MEDISON CO.,LTD.	5	0.49%
13	Ultrasonix Medical Corp.	2	0.20%
14	GE Vingmed Ultrasound	1	0.10%
15	MINDRAY	1	0.10%
Total		1013	100.0%

Supplementary Table 6. Information about sonographers involved in collecting the main cohort

No.	Year of experience	Collected cases	Proportion
1	10	98	9.67%
2	5	73	7.21%
3	16	72	7.11%
4	30	66	6.52%
5	10	66	6.52%
6	35	59	5.82%
7	18	57	5.63%
8	8	54	5.33%
9	40	53	5.23%
10	13	48	4.74%
11	10	47	4.64%
12	10	47	4.64%
13	40	46	4.54%
14	30	43	4.24%
15	8	42	4.15%
16	15	38	3.75%
17	10	36	3.55%
18	13	20	1.97%
19	45	19	1.88%
20	5	13	1.28%
21	35	12	1.18%
22	5	4	0.39%
Total		1013	100.0%

Supplementary Note 1. Clinical Statistical Model

The Lasso regression model for LNM prediction was established as following.

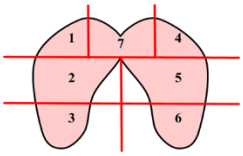
$$\hat{y} = 0.0951x_1 - 0.0097x_2 - 0.0017x_3 + 0.0002319x_4 - 0.0001548x_5 - 0.0000635x_6 + 0.02x_7 - 0.0594x_8 + 0.019x_9 + 0.5722$$

where x_1, x_2, x_3, x_4, x_5, x_6, x_7, x_8 and x_9 denote the quantitative values for gender, age, TSH, TG, TGAb, TPOAB, tumor size, Hashimoto's disease and micro-calcification, respectively.

Supplementary Note 2. Traditional Radiomics Model

The 614 high-throughput features used in our study can be summarized in Supplementary Table 7:

Supplementary Table 7. Summary of high-throughput features

Feature Type	Number of features	Quantitative Description
Demographic information	2	Age, Gender
Size	3	Diameter of an equivalent circle, Area, Ratio of tumor area to its convex hull
Shape	3	Radio of convexity to tumor perimeter, compactness, Rectangle-fitting factor
Margin & Boundary	13	Speculation, Extreme points of radial distance, Lobule number, Moment difference, Edge roughness, Acutance1, Acutance 2, Local window mean, Ratio of deviation inside and outside of tumor (In vs. Out), Mean contrast correlation coefficient of In vs. Out, Standard deviation of In vs. Out, Standard deviation (SD) of the annular region, Signal-to-noise ratio of the annular region
Orientation	3	Elliptical-normalized eccentricity, Elliptical-normalized angle, Length-to-width ratio
Position	7	
	3 (Relative position)	Overlap length with thyroid gland, Overlap area to tissue outside of thyroid gland, Distance to thyroid capsule
Echo pattern	11 (Echo intensity)	Mean tumor contrast, Mean tumor covariance, Mean tumor non-similarity, Mean contrast correlation coefficient, Deviation ratio of the tumor tissue and normal thyroid gland, Relative brightness of the tumor and normal tissue, Relative brightness of tumor and normal muscle, SD of tumor contrast, SD of tumor covariance, SD of tumor non-similarity, SD of contrast correlation coefficient
	69 (Echo texture)	Histogram (16) Gray-level co-occurrence matrix, GLCM (22) Gray-level run-length matrix, GLRLM (13)

		Gray-level size zone matrix, GLSZM (13) Neighborhood gray-tone difference matrix, NGTDM (5)
Posterior echo pattern	11 (Posterior echo distribution)	Relative contrast between posterior region and adjacent tissue (PR vs. AT), Relative brightness contrast between PR vs. AT, Contrast variance between PR vs. AT, Contrast coefficient between PR vs. AT, SD of PR, Mean contrast of PR, contrast SD of PR, Mean covariance of PR, Covariance SD of PR, Mean non-similarity of PR, SD of the non-similarity of PR
	69 (Posterior echo texture)	Same as echo texture
Calcification	11	Calcification area, Minimum calcification area, Maximum calcification area, Total calcification circumference, SD of roundness, Number of calcification points, SD of calcification area, SD of the circumference of calcification points, Minimum distance between calcification points , Maximum distance between calcification points
Wavelet	412	Wavelet feature of original image, wavelet feature of margin, boundary, echo pattern, posterior acoustic pattern, calcification

Three-step feature selection including two-side Wisconsin rank sum test, genetic algorithm and sparse representation was used to select the most relevant features to LNM, and the Support vector machine (SVM) was used to build the LNM diagnosis model.

Supplementary Note 3. Quantitative Evaluation Indexes

Suppose TP, TN, FP, FN represent true positive, true negative, false positive and false negative, then accuracy (ACC), sensitivity (SENS), specificity (SPEC), positive predictive value (PPV), negative predictive value (NPV), and Matthew's correlation coefficient (MCC) can be calculated as:

$$\mathrm{ACC} = \frac{TP + TN}{TP + TN + FP + FN}$$

$$\mathrm{SENS} = \frac{TP}{TP + FN}$$

$$\mathrm{SPEC} = \frac{TN}{TN + FP}$$

$$\mathrm{PPV} = \frac{TP}{TP + FP}$$

$$\mathrm{NPV} = \frac{TN}{TN + FN}$$

$$\mathrm{MCC} = \frac{TP \times TN - FP \times FN}{\sqrt{(TP + FP)(TP + FN)(TN + FP)(TN + FN)}}$$

$$F_1 = 2 \cdot \frac{Precision \cdot Recall}{Precision + Recall}$$