Original Research Article

Correlation of ACR-TIRADS(thyroid imaging, reporting and data system)-2017 and cytological/ Histopathological (HPE) findings in evaluation of thyroid nodules

Yashraj P. Patil[1], Rubab Kaur Sekhon[2*], Rajesh S. Kuber[3], Chirag R. Patel[4]

[1]Associate Professor, Department of Radiodiagnosis, Dr DY Patil Medical College, Hospital and Research Center, Pune, India
[2]Resident, Department of Radiodiagnosis, Dr DY Patil Medical College, Hospital and Research Center, Pune, India
[3]Professor and Head Department of Radiodiagnosis, Dr DY Patil Medical College, Hospital and Research Center, Pune, India
[4]Resident, Department of Radiodiagnosis,Dr DY Patil Medical College, Hospital and Research Center, Pune, India

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Abstract

Background: Thyroid nodules are one of the most common lesions in the daily practice of a radiologist. The frequency of thyroid nodules is also increasing with time as thyroid disorders are rising. As the Ultrasound technology is advancing, so is the detection of thyroid lesions, even if they are as small as few millimeters in size. While fine needle aspiration cytology(FNAC) is the standard procedure for thyroid nodules diagnosis; it involves risks and unnecessary costs. But a benefit that we cannot ignore is that ultrasound guided aspiration reduces the number of unnecessary thyroid surgeries. While individual characteristics which increase the suspiciousness of malignancy, have been studied repeatedly but are inconclusive, we therefore need a comprehensive system of stratifying thyroid nodules and characterizing them with confidence so that we can reduce the number of needless painful aspiration and biopsy procedures. But only 3-7% nodules have specific characteristics of malignancy. TheACR-TIRADS (American College of Radiology- Thyroid imaging reporting and data system)2017 is score-based and assigns points according to the composition, echogenicity, shape, margins, and echogenic foci of thyroid nodules on ultrasound, which makes it easy and reliable. **Method:** B-mode sonography and Doppler evaluation of 104 thyroid lesions was performed on Aloka Arietta S-60 equipped with a 5-13 MHz high frequency linear array transducer.**Results:** Individual characteristics like solid composition (P value0.001), hypo-echogenicity (P value <0.0001), irregular borders, taller than wide shape and micro-calcifications (P value 0.067) were highly predictive of malignancy.**Conclusion:** Our study shows that the ACR-TIRADS 2017 is a good predictor of malignancy with just 1 false positive in the TR-5 category and 0 false negatives in the TR-1 or 2 categories. Also, it can help in stratifying patients according to their size so that timely management of critical cases is possible and unnecessary invasive procedures can be avoided for a section of patients who are advised follow up.

Keywords: ACR-TIRADS, thyroid, nodules, FNAC, taller-than-wide, microcalcifications, solid, hypoechoic.

**Correspondence*
Dr. Rubab Kaur Sekhon
Resident,
Department of Radiodiagnosis
Dr. DY Patil Medical College, Hospital and Research Center, Pune, India.
E-mail: sekhon.rubab@gmail.com

Introduction

Thyroid nodules are one of the most common lesions in the daily practice of a radiologist. Thyroid carcinoma is the most common endocrine malignancy. "With palpation alone, we can detect almost 2-6% of the thyroid lesions, 19-35% with ultrasound, and 8-65% on autopsy."[1]. As the Ultrasound technology is advancing, so is the detection of thyroid lesions, even if they are as small as few millimeters in size. While fine needle aspiration cytology (FNAC) is the standard procedure for thyroid nodules diagnosis, it involves risks and often unnecessary costs.[2]The first evaluation of thyroid nodules should always aim at excluding malignancies if any.[3] "We often come across reports that are non-diagnostic in as many as 10-20% of the aspirations done, which can turn out to be malignant later".[4]In addition, around 3-7 per cent of thyroid HPEs have definite malignancy characteristics. Also, the results are operator dependent and vary according to their skill and the composition of the nodule, that is, if it is tough to conduct invasive procedures. We therefore need a comprehensive system of stratifying thyroid nodules and characterizing them with confidence so that we can reduce the number of needless painful aspiration and biopsy procedures.

ACR-TIRADS (American College of Radiology-Thyroid imaging reporting and data system) 2017, inspired from BIRADS (Breast imaging reporting and data system) is a score-based and assigns points according to the morphological features of thyroid nodules on ultrasound. [5, 6] The system also gives guidelines to conduct FNAC whenever required according to the TIRADS category, which avoids unnecessary invasive procedures in case of benign lesions. Furthermore, there are recommendations for follow up, if needed for all the TIRADS categories according to the size of the lesion.

Method

Place of study: Dr. D. Y. Patil Medical College and Hospital and Research Centre, Pimpri, Pune
Type of study: Analytical
Period of study: September 2018 to August 2020
Period required for data collection: 2 years
Sample Size: 104
Study Design: Cross sectional
Method of diagnosis: Aloka Arietta S-60 equipped with high frequency linear array transducer.
Informed consent obtained from all the patients.

Inclusion Criteria

All patients with palpable thyroid nodules or clinical suspicion of thyroid disease referred for an ultrasound of the neck.

Exclusion Criteria

- Operated cases of Thyroid nodules/carcinoma.
- Patients presently or previously on radiation therapy.

USG technique

On Aloka Arietta S-60, fitted with a 5-13 MHz high frequency linear array transducer, B-mode sonography and Doppler evaluation of thyroid lesions was carried out. The characteristics examined were the thyroid nodule size, number of nodules, nodule's internal echogenicity, nodule's heterogeneity, margins and existence of cystic changes, calcifications and vascularity.

An informed written consent was then taken from the patient informing the patient about how the FNAC would be performed using a small hypodermic needle.

For the procedure, the patient was lying supine with an extended neck supported by a pillow. The neck was cleansed with spirit and topical lidocaine applied on the skin overlying the nodule. FNAC was then performed from the nodule using a 23/25 gauge hypodermic needle using non-aspiration capillary action technique. The needle was withdrawn from the neck after material was seen in the syringe and was smeared onto the glass slides. Slide is fixed with 95% ethyl alcohol and modified PAP staining.

The final report of the FNAC as reported by the pathologist was then used to compare with the ultrasound features of the nodule and categorized as benign or malignant.

Statistical analysis

The data collected was analysed using the software version of SPSS 25.The following were calculated-

- Sensitivity
- Specificity
- Positive predictive value
- Negative predictive value
- Positivity likelihood ratio
- Negativity likelihood ratio
- Odds Ratio
- Accuracy
- P-value

$P < 0.05$ was taken to be relevant in all tests. It was measured using Student's t-test.

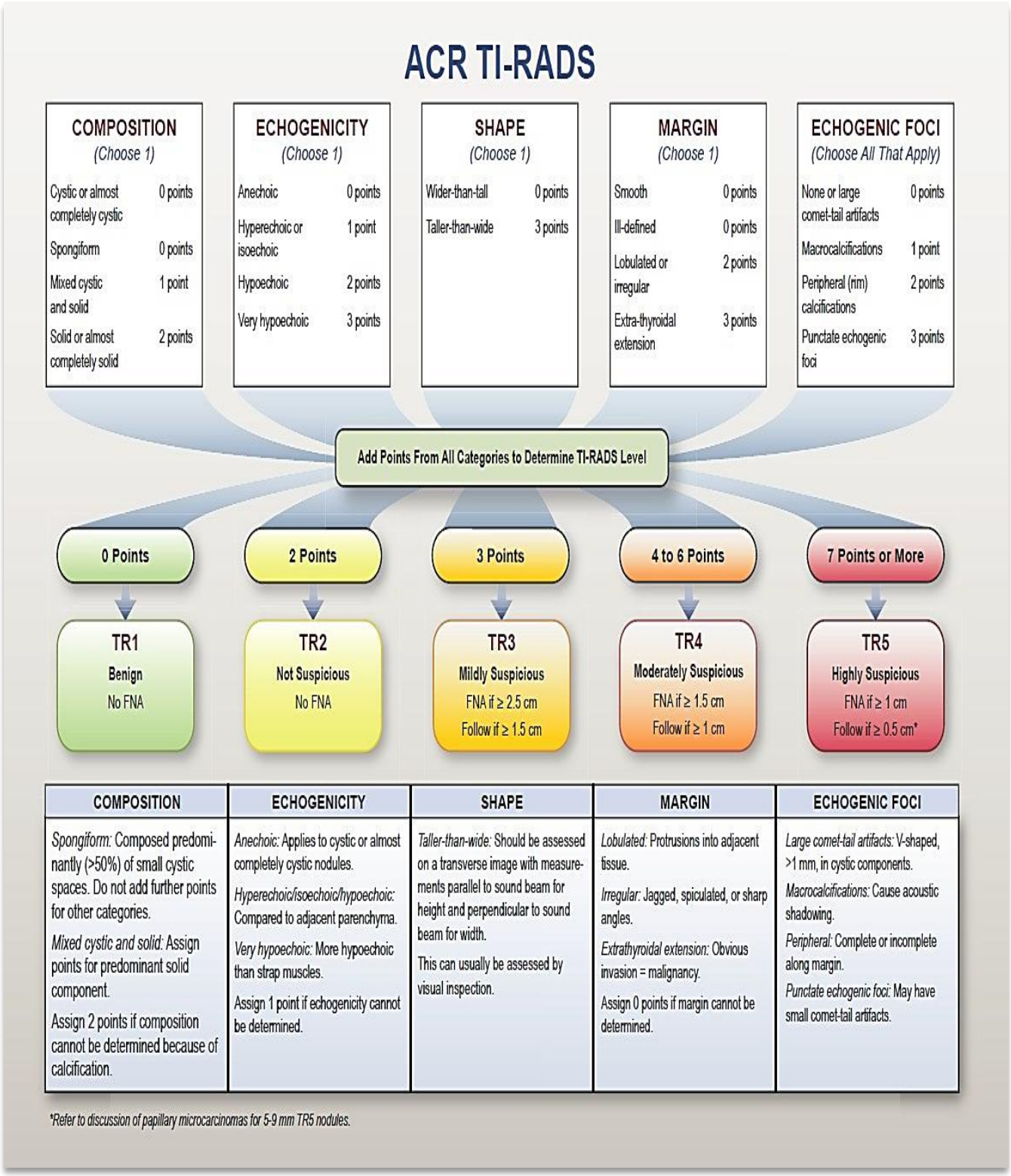

Fig 1: ACR TIRADS 2017 lexicon

Results

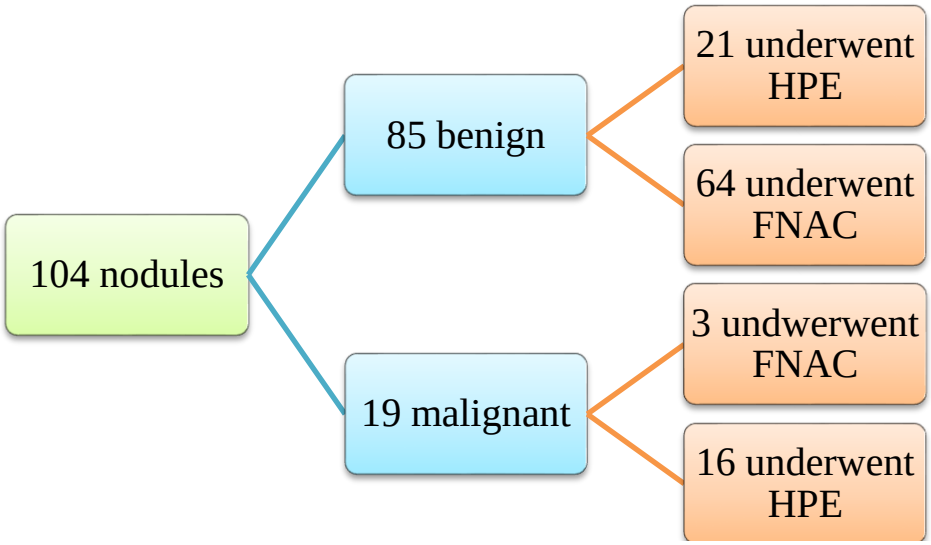

Fig 2:Nodules

Table 1: Comparison of risk of malignancy according to ACR- TIRDAS 2017 category

ACR-TIRADS category	Number of benign lesions	Number of malignant lesions	Total	Risk of malignancy (%)
1	4	0	4	0
2	5	0	5	0
3	27	2	29	6.8
4	48	13	61	21.3
5	1	4	5	80
	85	**19**	**104**	

Table 2: Comparison of risk of malignancy according to ACR TIRADS 2017 score

ACR TIRADS SCORE	Number of benign nodules	Number of malignant nodules	TOTAL	Risk of malignancy (%)
0 points	**4**	**0**	**4**	**0**
2 points	**5**	**0**	**5**	**0**
3 points	**27**	**2**	**29**	**6.8**
4 points	**19**	**2**	**21**	**9.5**
5 points	**18**	**7**	**25**	**28**
6 points	**11**	**4**	**15**	**26.6**
8 points	**1**	**1**	**2**	**50**
10 points	**0**	**2**	**2**	**100**
11 points	**0**	**1**	**1**	**100**

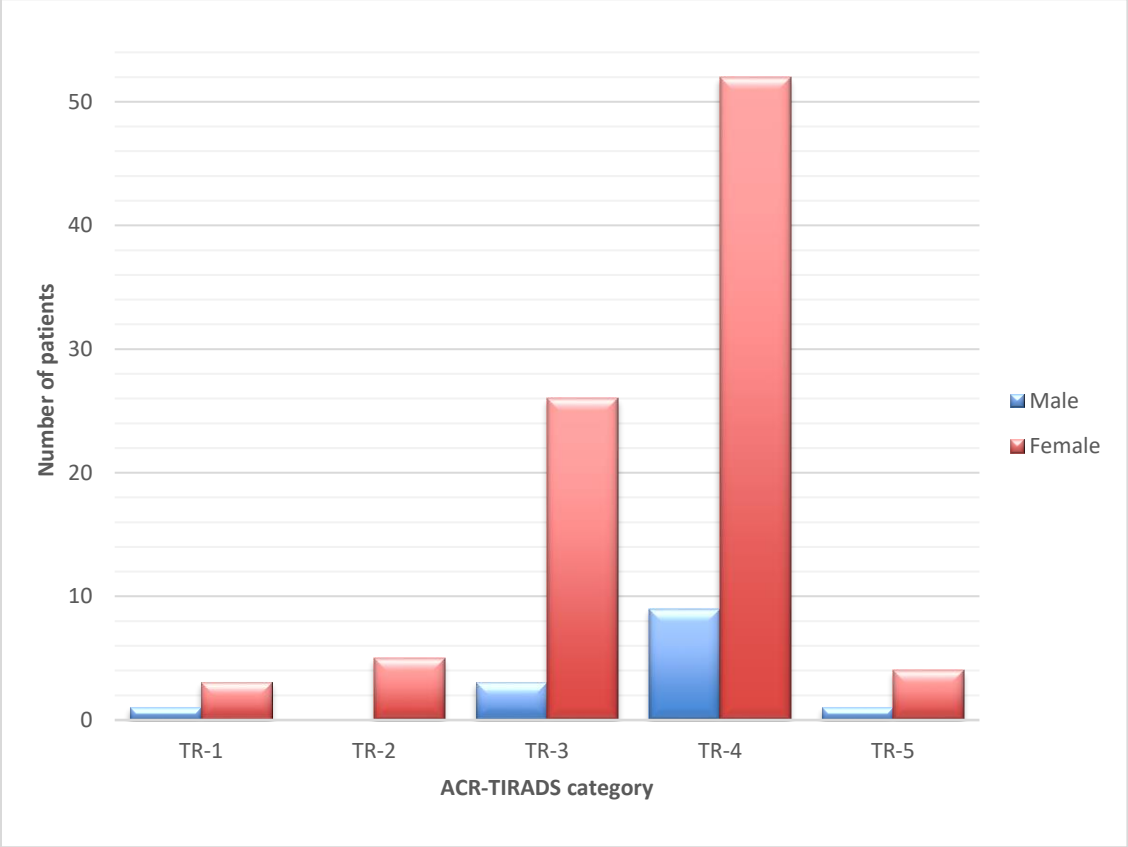

Fig 3: Bar chart showing gender wise distribution of thyroid nodules according to ACR-TIRADS 2017

Table 3: Frequency of individual Ultrasound feature occurring in thyroid nodules

USG feature		Number of cases	Frequency (%)
Composition	Cystic or predominately cystic	3	2.8
	Spongiform	8	7.6
	Mixed solid-cystic	44	42.3
	Solid or predominately cystic	49	47.1
Echogenicity	Anechoic	3	2.8
	Hyperechoic or isoechoic	75	72.1
	Hypoechoic	24	23
	Very hypoechoic	2	1.9
Shape	Wider than tall	94	90.3
	Taller than wide	10	9.6
Margins	Smooth	84	80.7
	Ill-defined	11	10.5
	Lobulated/irregular	6	5.7
	Extra-thyroidal extension	3	2.8
Echogenic foci	None/Comet tail artifact	85	81.7
	Macrocalcifications	13	12.5
	Peripheral rim calcifications	3	2.8
	Punctate echogenic foci	3	2.8

Table 4: Comparison of risk of malignancy for individual USG feature included in ACR TIRADS 2017

USG Features		Benign	Malignant	Total	Risk of malignancy (%)
Composition	Cystic or predominantly cystic	3	0	3	0
	Spongiform	8	0	8	0
	Mixed solid-cystic	41	3	44	6.8
	Solid or predominantly solid	33	16	49	32.6
Echogenicity	Anechoic	3	0	3	0
	Hyperechoic or isoechoic	72	3	75	4
	Hypoechoic	10	14	24	58.3
	Very hypoechoic	0	2	2	100
Shape	Wider than tall	83	11	94	11.7
	Taller than wide	2	8	10	80
Margins	Smooth	76	8	84	9.5
	Ill-defined	7	4	11	36.3
	Lobulated/irregular	2	4	6	66.67
	Extra-thyroidal extension	0	3	3	100
Echogenic foci	None/Comet tail artifact	73	12	85	14.1
	Macrocalcifications	9	4	13	30.7
	Peripheral rim calcifications	2	1	3	33.3
	Punctate echogenic foci	1	2	3	66.6

Table 5: Statistical results of ACR TIRADS suspicious descriptors for predicting malignancy in thyroid nodules

Ultrasound Feature	Sensitivity(%)	Specificity (%)	PPV(%)	NPV (%)	PLR	NLR	OR	Accuracy (%)	P value
Solid composition	84.2	61.1	32.6	94.5	2.15	0.26	**8.4**	**65.38**	**0.001**
Hypo-echogenicity	84.2	88.2	61.5	96.1	7	0.18	**40**	**87.5**	**<0.0001**
Taller than wide shape	42.1	97.6	80	88.3	14	0.59	**30.2**	**87.5**	**0.0001**
Lobulated or irregular margins	21	97.6	66.67	84.6	7	0.81	**11**	**83.6**	**0.0083**
Extra-thyroidal extension	15	100	100	84.1	∞	0.85	**36.2**	**84.6**	**0.0194**
Punctate echogenic foci	10.5	98.8	66.67	83.1	8.95	0.91	**9.8**	**82.7**	**0.067**
Calcification	36.8	85.9	36.8	85.88	2.61	0.74	**3.54**	**76.9**	**0.025**

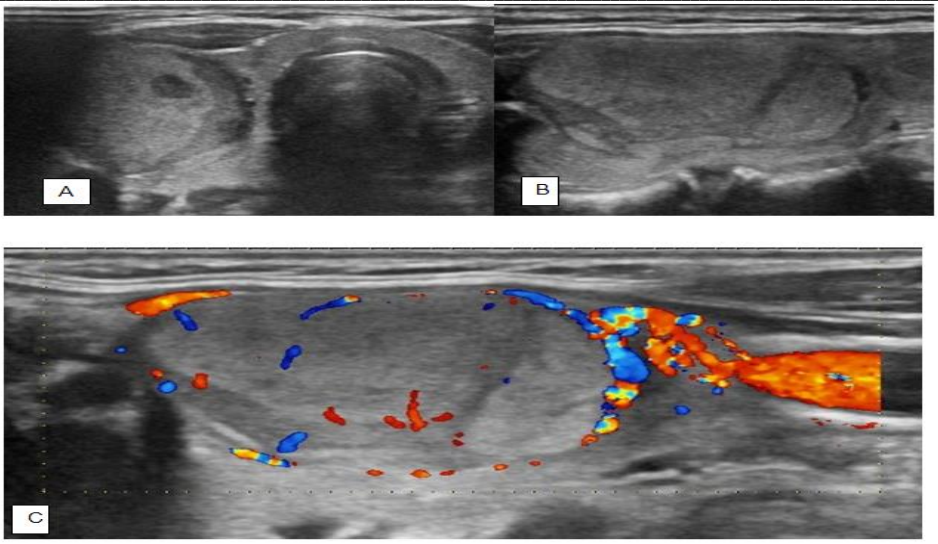

Fig 4: In a 40 years old female A. Axial section of the right thyroid lobe showing a well-defined, solid, heterogeneously hyperechoic nodule. B. The longitudinal section of the same nodule shows its wider than tall shape and smooth margins. C. On colour Doppler, the nodule shows internal and peripheral vascularity
On USG: TIRADS 3
On cytology: Follicular adenoma

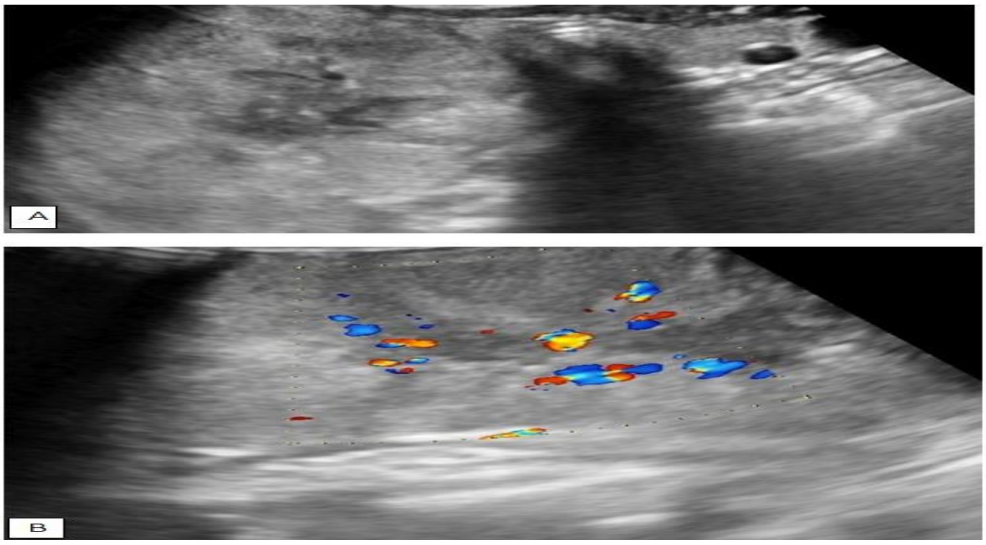

Fig 5: In a 54 years old male, A. Longitudinal section of the right thyroid lobe shows an irregularly bordered solid hypoechoic nodule with microcalcifications within. B. Axial section of the same nodule shows raised vascularity on colour Doppler in the nodule
On USG: TIRADS 5
On Histopathology: Papillary carcinoma.

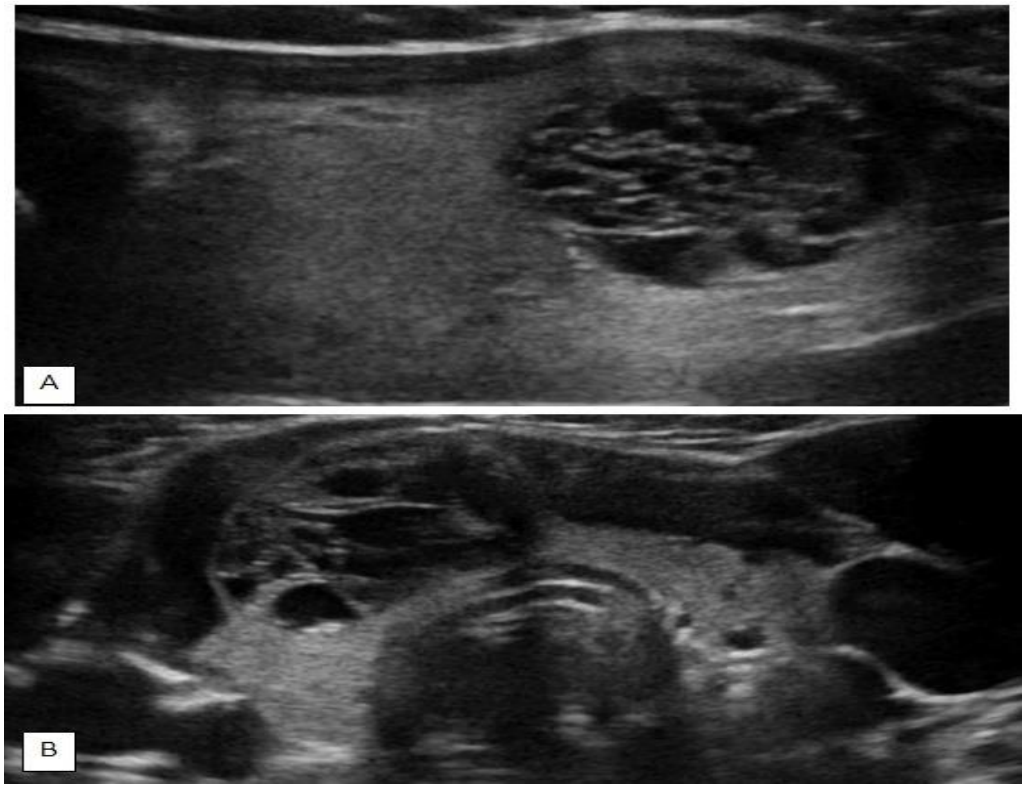

Fig 6: In a 35 years old female, A. Axial section of the thyroid showing spongiform nodule in the right lobe with smooth margins. B. Longitudinal section of the same nodule.
On USG: TIRADS 1
On cytology: Hyperplastic nodule

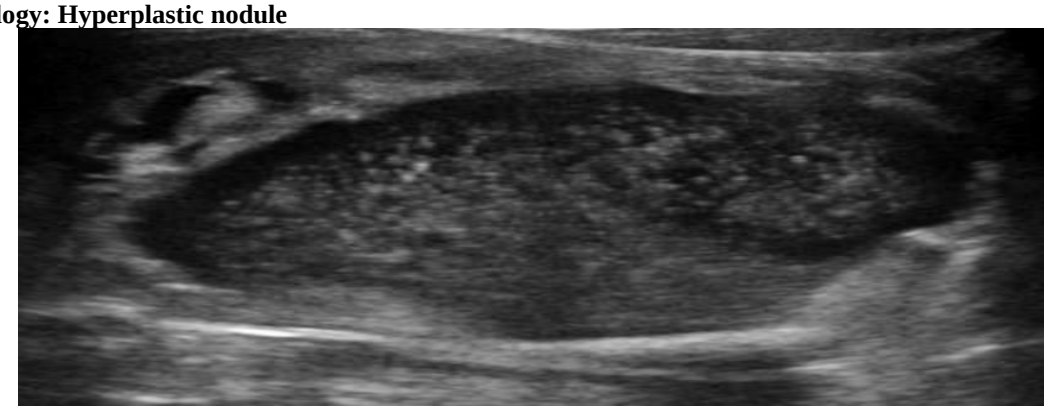

Fig 7: In a 55 years old female, a well-defined nodule with multiple small echogenic foci showing "comet tail artefact" suggestive of colloid material. It has smooth margins and is wider than tall in shape.
On USG: TIRADS 2
On cytology: Colloid nodule

Discussion

Thyroid nodules are extremely common and present a diagnostic challenge. The incidence of thyroid cancers has doubled in the last 30 years, most likely due to advanced screening methods. Therefore, timely diagnosis with carefully structured screening method is of utmost importance to reduce mortality and

morbidity.Increased use of high frequency sonography also leads to identification of non-palpable nodules in non-thyroid sonographic examinations as well. In our study ultrasound characteristics of thyroid nodules according to ACR-TIRADS 2017 were studied for 100 patients on ultrasound examination for the neck. There were total 104 nodules detected that were sent for histopathological examination. Out of the 104 nodules, 85 turned out to be benign whereas, 19 were malignant. The incidence of malignancy in our study was 18.2%.The incidence of malignancy in males was 35.7% and in females was 15.5%, even though females made the major chunk of the study population coming for examination for thyroid nodules i.e. 6.4 times that of the number of males. Of the 19 detected malignant nodules, 15 (78.9%) were papillary carcinoma, 2 were follicular carcinoma, 1 was poorly differentiated carcinoma and 1 was carcinoma of the medullary system.Therefore, the most common thyroid malignancy detected was papillary carcinoma, which is also shown by Razmpa et al (2002) [7], Papini et al (2002) [8], and Khoo et al (2002) [9].

Table 6: Frequency of various kinds of malignant thyroid nodules in our study.

HPE diagnosis	Total number	Frequency (%)
Papillary carcinoma	15	14.4
Follicular carcinoma	2	1.9
Poorly differentiated carcinoma	1	0.9
Medullary carcinoma	1	0.9

Table 7: Frequency of various kinds of benign thyroid nodules in our study.

HPE DIAGNOSIS	Total number	Frequency (%)
Colloid nodules/ goitre	34	32.6
Nodular goitre	15	14.4
Hashimoto's thyroiditis	13	12.5
Hyperplastic nodules	7	6.7
Benign Follicular lesions	5	4.8
Adenomatous nodules	6	5.7
Granulomatous thyroiditis	1	0.9
Atypical	2	1.9
Subacute thyroiditis	1	0.9
Lymphocytic thyroiditis	1	0.9

As the cumulative TIRADS score of the thyroid nodule as seen on ultrasound examination increased. The PPV for malignancy for TIRADS category 1,2,3,4 and 5 in our study was 0%, 0%, 6.8%, 21.3% and 80%, respectively.

It was observed that the solid composition was related to higher risk of malignancy i.e. 32.6%. Out of the 19 malignant nodules, 16 were completely solid. 84.2% of malignant nodules were solid.Razmpa et al (2002) [7] also proved that most of the cystic and mixed lesions (on ultrasonography) were benign. 85% of the solid nodules in their study were malignant. 53% of the solid-cystic nodules in their study were benign.61.5% of the hypoechoic nodules were found to be malignant. The observed P value was <0.0001. This proves that it is the most significant parameter to predict malignancy in a thyroid nodule with 84% sensitivity, 88% specificity and accuracy 87.5%. The Odds ratio is also the highest for hypo-echogenicity i.e. 40.In studies by Alam et al. (2014) [10] and Nabahati et al. (2019) [11], the rates observed were (42% sensitivity and 75% specificity), (53% sensitivity, 77% specificity), respectively. Another study contradictory to ours by Sankhla et al., (2001) [12], found 33% of hypoechoic nodules to be malignant and 11% of hyperechoic nodules as malignant.It was noted that taller than wide shape was highly specific for malignancy with a specificity of 97.6% and accuracy 87.5%. This was consistent with studies done by Moon et al. (2011) [13], Ren et al., (2015) [14], Nabahati et al., (2019) [11] and which demonstrated that taller than wide shape was a good predictor of malignancy**.** In our study the differences in risk of malignancy in anechoic, isoechoic/ hyperechoic, hypoechoic were significant which were 0.0%, 4% and 61.5% respectively. Lobulated or irregular margins were associated with high risk of malignancy which is 66.7% with high specificity of 97.6% with an accuracy of 83.6%. Extra-thyroidal extension was seen in just 3 cases, all of which turned out to be malignant nodules, hence 100% specific. We found calcifications in 18.2% nodules, out of which 6.7% were malignant and 11.5% were benign.

Out of the various types of calcifications, punctate echogenic foci/ micro-calcifications showed a specificity of 98.8% for malignancy with a low sensitivity of just 10.5%. Out of the malignant nodules with calcifications, 28% had microcalcifications, out of which 18.67% were malignant and 9.3% were benign indicating that microcalcifications point more towards malignancy.On the other hand, dense or macrocalcifications were found in higher number in benign nodules, with 69% of the nodules showing macrocalcifications being benign and 31% being malignant.Other studies like Koike et al., (2001) [15] and Ram et al. (2015) [16] showed that calcification had higher sensitivity, 88.7% and 80% respectively and a lower specificity which is again contradictory to our study.

In our study, extra-thyroid extension and very hypo-echoic echogenicity were the most vulnerable to malignancy (100%) among the suspicious characteristics, accompanied by taller than large form (80%), punctate echogenic foci and lobulated irregular margins (66.6%), hypo-echogenicity (58.3%), solid composition (32.6%) in that order.

Colloid nodules or colloid goitre is the most common form of thyroid nodules/ lesions encountered on ultrasound. In our study colloid nodules made for as much as 32.6% of all lesions. The next most common benign lesions, i.e. nodular goitre made up 14.4% of the total nodules. There was one false positive seen in category TR-5.

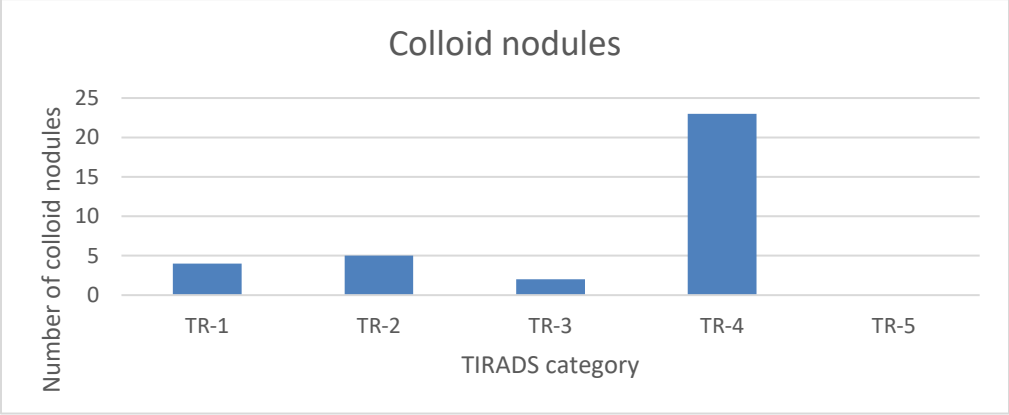

Fig 8: Bar chart representing number of colloid nodules belonging to all the TIRADS categories.

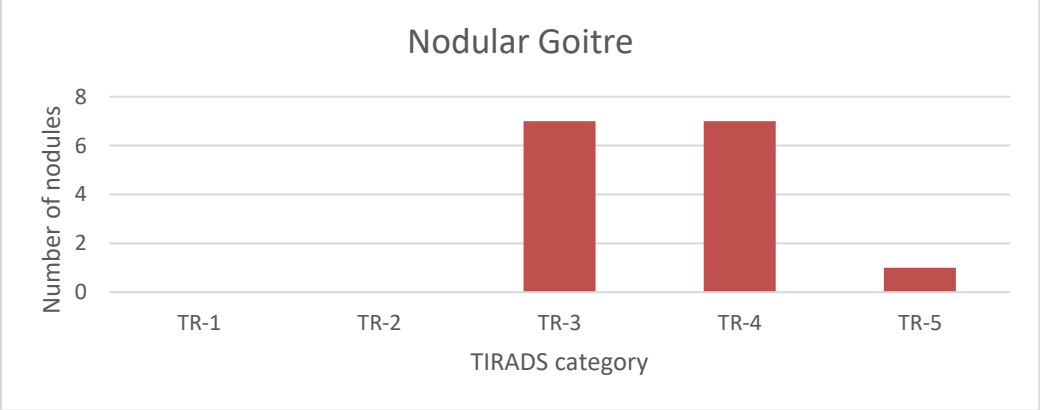

Fig 9: Bar chart representing number of Nodular goiter belonging to all the TIRADS categories.

Table 8: Comparison between various studies between suspicious TIRADS features in our study and their risk of malignancy

Suspicious ultrasound feature		On ultrasound	Malignant nodules		Total	Risk of Malignancy (%)
			Present	Absent		
Solid composition	Kwak et al (2011) [17]	Present	255	805	1060	24
		Absent	169	508	598	
	Chandramohan et al (2014) [18]	Present	102	87	189	53.9
		Absent	41	24	83	
	Srinivas et al (2016) [19]	Present	13	14	37	35.1
		Absent	12	326	338	
	Our study	Present	16	33	49	32.6
		Absent	3	52	55	
Calcification	Kwak et al (2011)[17]	Present	178	230	408	43.6
		Absent	97	1153	1250	
	Chandramohan et al (2014) [18]	Present	66	32	98	67.3
		Absent	52	122	174	
	Srinivas et al (2016) [19]	Present	10	31	41	24.3
		Absent	15	309	324	
	Our study	Present	7	12	19	36.8
		Absent	12	73	85	
Hypoechogenicity	Kwak et al (2011)[17]	Present	169	508	677	24.9
		Absent	106	875	981	
	Chandramohan et al (2014) [18]	Present	41	24	65	63
		Absent	77	130	207	
	Srinivas et al (2016) [19]	Present	5	88	93	5.3
		Absent	20	252	272	
	Our study	Present	16	10	26	61.5
		Absent	3	75	78	
Microcalcifications Or punctate echogenic foci	Kwak et al (2011)[17]	Present	111	51	162	68.5
		Absent	164	1332	1496	
	Chandramohan et al (2014) [18]	Present	41	9	50	82
		Absent	77	145	222	
	Srinivas et al (2016) [19]	Present	10	5	15	66.67
		Absent	15	335	350	
	Our study	Present	2	1	3	66.67
		Absent	17	84	101	

Table 9: Table comparing statistical analysis comparing suspicious USG features of thyroid nodules in various studies with our study

		Sensitivity (%)	Specificity (%)	PPV (%)	OR	P-value
Solid Composition	Kwak et al (2011)[17]	92.7	41.7	24	9.15	<0.0001
	Chandramohan et al (2014) [18]	86.4	43.5	53.9	4.9	<0.0001
	Srinivas et al (2016) [19]	52	95.8	48.1	25.2	<0.0001
	Our study	**84.2**	**61.1**	**32.6**	**8.4**	**0.001**
Hypoechogenicity	Kwak et al (2011)[17]	61.4	63.2	24.9	2.7	<0.0001
	Chandramohan et al (2014) [18]	34.7	84.4	63	2.8	0.0003
	Srinivas et al (2016) [19]	20	74.1	5.3	0.7	0.51
	Our study	**84.2**	**88.2**	**61.5**	**40**	**<0.0001**
Microcalcification	Kwak et al (2011)[17]	40.3	96.3	68.5	17.6	<0.0001
	Chandramohan et al (2014) [18]	34.7	94.1	82	8.5	<0.0001
	Srinivas et al (2016) [19]	40	98.5	66.7	44.6	<0.001
	Our study	**10.5**	**98.8**	**66.7**	**9.8**	**0.067**
Calcification	Kwak et al (2011)[17]	64.7	83.3	43.6	9.1	<0.0001
	Chandramohan et al (2014) [18]	55.9	79.2	67.3	4.8	<0.0001
	Srinivas et al (2016) [19]	40	90.8	24.3	6.6	<0.0001
	Our study	**36.8**	**85.9**	**36.8**	**3.54**	**0.025**

Table 10: Table showing risk of malignancy in thyroid nodules according to ACR TIRADS 2017 category

ACR-TIRADS 2017 category	Risk of malignancy	Follow up recommendation	FNAC recommendation
1	<2%	--	No
2	<5%	≥1.5cm	≥2.5 cm
3	5.1-20%	≥ 1 cm	≥1.5 cm
4	>20%	≥ 0.5 cm	≥1 cm

Conclusion

Thyroid malignancies are the seventh most common malignancy in the world. Papillary carcinoma is three times more common in females than males. But males are associated with more thyroid cancer related morbidity and mortality and have lower chances of being disease free and have less survival rate. Thyroid disease in women is more common in the reproductive age groups but as age advances, the gender disparity reduces. Characterizing the nodules by ultrasound based on the different characteristics such as number of nodules, internal pattern, echogenicity, calcifications and raised vascularity can be done to tentatively differentiate them into benign and malignant nodules.FNAC correlation under USG guidance can then be performed from suspicious nodules to get a definitive diagnosis. FNAC's main downside is that it can't distinguish between a follicular adenoma and follicular carcinoma. Our study shows that the ACR-TIRADS 2017 is a good predictor of malignancy with just 1 false positive in the TR-5 category. Individual characteristics like solid composition (P value 0.001), hypo-echogenicity (P value <0.0001), irregular borders, taller than wide shape and micro-calcifications (P value 0.067) were highly predictive of malignancy.Also, it can help in stratifying patients according to their size so that timely management of

critical cases is possible and unnecessary invasive procedures can be avoided for a section of patients who are advised follow up.

Abbreviations

US: Ultrasound
USG: Ultrasonography
FNAC: Fine needle aspiration cytology
HPE: Histopathology
TIRADS: Thyroid imaging reporting and data system
BIRADS: Breast imaging reporting and data system
ACR- American College of Radiology
TR: TIRADS category
PAP: Papanicolaou
SPSS: Statistical Package for the Social Sciences
i.e.: that is
ETE: Extrathyroidal extension
TFT: Thyroid function test

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References

1. Dean DS, Gharib H. Epidemiology of thyroid nodules. Best Pract Res Clin Endocrinol Metab. 2008; 22:901–11.
2. Ardakani AA, Gharbali A, Mohammadi A. Classification of benign and malignant thyroid nodules using wavelet texture analysis of sonograms. J Ultrasound Med. 2015; 34:1983–9.
3. Chow LS, Gharib H, Goellner JR, van Heerden JA. Nondiagnostic thyroid fine-needle aspiration cytology: Management dilemmas. Thyroid. 2001; 11:1147–51
4. Bonavita JA, Mayo J, Babb J, Bennett G, Oweity T, Macari M, et al. Pattern recognition of benign nodules at ultrasound of the thyroid: Which nodules can be left alone? AJR Am J Roentgenol. 2009; 193:207–13.
5. Horvath E, Majlis S, Rossi R, Franco C, Niedmann JP, Castro A, et al. An ultrasonogram reporting system for thyroid nodules stratifying cancer risk for clinical management. J Clin Endocrinol Metab. 2009;94:1748–51.
6. Park JY, Lee HJ, Jang HW, Kim HK, Yi JH, Lee W, et al. A proposal for a thyroid imaging reporting and data system for ultrasound features of thyroid carcinoma. Thyroid. 2009;19:1257–64.
7. E. Razmpa, H. Ghanaati, B. Naghibzadeh, P. Mazloom and A. Kashfi. Comparison of ultrasound findings with cytologic results in thyroid nodules. Acta Medica Iranica, 2002;40(3): 146-151.
8. Enrico Papini, Rinaldo Guglielmi, Antonio Bianchini et all. Risk of malignancy in nonpalpable thyroid nodules: Predictive value of ultrasound and colour Doppler features. J. Clin Endocrinol Metab 2002, 87: 1941-1946.
9. Mark Khoo, Sylvia L, Ian J, Jeremy L et all. Thyroid calcification and its association with thyroid carcinoma. Head and Neck 2002: 651-655.
10. Alam T, Khattak YJ, Beg M, Raouf A, Azeemuddin M, Khan AA. Diagnostic accuracy of ultrasonography in differentiating benign and malignant thyroid nodules using fine needle aspiration cytology as the reference standard. Asian Pacific Journal of Cancer Prevention. 2014; 15(22):10039.
11. Nabahati M, Moazezi Z, Fartookzadeh S, Mehraeen R, Ghaemian N, Sharbatdaran M. The comparison of accuracy of ultrasonographic features versus ultrasound-guided fine-needle aspiration cytology in diagnosis of malignant thyroid nodules. Journal of Ultrasound. 2019; 1 22(3):315-21.
12. Sankhla DK, Hussein SS, Bererhi H, El Shafie O, Woodhouse NJ, Nirmala V. Are scintigraphy and ultrasonography necessary before fine-needle aspiration cytology for thyroid nodules?. SQU Journal for Scientific Research-Medical Sciences. 2001;3(1):29.
13. Moon HJ, Kwak JY, Kim EK, Kim MJ. A taller-than-wide shape in thyroid nodules in transverse and longitudinal ultrasonographic planes and the prediction of malignancy. Thyroid. 2011; 21 (11):1249-53.
14. Ren J, Liu B, Zhang LL, Li HY, Zhang F, Li S, Zhao LR. A Taller-Than-Wide Shape Is a Good Predictor of Papillary Thyroid Carcinoma in Small Solid Nodules. Journal of Ultrasound in Medicine. 2015;34(1):19-26.
15. Koike E, Noguchi S, Yamashita H, Murakami T, Ohshima A, Kawamoto H, Yamashita H. Ultrasonographic characteristics of thyroid nodules: prediction of malignancy. Archives of surgery. 2001; 136(3):334-7.
16. Ram N, Hafeez S, Qamar S, Hussain SZ, Asghar A, Anwar Z, Islam N. Diagnostic validity of ultrasonography in thyroid nodules. J Pak Med Assoc. 2015;65(8):875-8.

17. Kwak JY, Han KH, Yoon JH, Moon HJ, Son EJ, Park SH, Jung HK, Choi JS, Kim BM, Kim EK. Thyroid imaging reporting and data system for US features of nodules: a step in establishing better stratification of cancer risk. Radiology. 2011; 260(3):892-9.
18. Chandramohan A, Abhishek K, Bhari P, Mj P. Positive predictive value and inter-observer agreement of TI-RADS for ultrasound features of thyroid nodules. European Congress of Radiology 2014;3(5):90.
19. Srinivas MN, Amogh VN, Gautam MS, Prathyusha IS, Vikram NR, Retnam MK, Balakrishna BV, Kudva N. A prospective study to evaluate the reliability of thyroid imaging reporting and data system in differentiation between benign and malignant thyroid lesions. Journal of clinical imaging science. 2016; 6(1):98.

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