



Color doppler ultrasonography of superior thyroid artery and its relation between normal and abnormal thyroid functional state

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Abstract

Introduction: High resolution ultrasonography (USG) is the most sensitive imaging modality available for examination of the thyroid gland and associated abnormalities. Ultrasound scanning is non-invasive, widely available, less expensive, and does not use any ionizing radiation. In pathological conditions such as Graves' disease, thyroid enlargement and hyperfunction are accompanied by a markedly increased blood flow. As mentioned in the 2011 ATA (American Thyroid Association) guideline, the Color Doppler Flow Sonography (CDFs) of thyroid, as an indicator of thyroid blood flow status, has some practical values in the differentiation of thyrotoxicosis. This study intends to find doppler indices of superior thyroid arteries (STAs) and compare between euthyroid and abnormal thyroid functional state subjects.

Aims and objectives: To find the doppler indices of superior thyroid artery and compare it between euthyroid and abnormal thyroid functional state individuals.

Materials and methods: This hospital based prospective observational study was conducted by including 50 patients of different age groups and from both sexes. Study was conducted in the Department of Radiodiagnosis, Muzaffarnagar Medical College, Muzaffarnagar, U.P. Duration of the study was for eighteen months (April 2019 to Sep 2020). After explaining the entire radiological procedure to the patient, informed consent was obtained. A detailed clinical history was recorded. B scan of thyroid gland was performed using ultrasonography machine - Alpinion Ecube8 with 7-12 MHz linear probe. Subsequently, superior thyroid artery was identified and doppler scan was performed.

Results: This study included 50 subjects in total. Most of the cases were in the age group of 21-30 years (44%), 2nd largest were in the group of 31-40 years (26%) and smaller numbers were in the age group of 11-20 years (10%), 41-50 years (12%) and 51-60 years (8%). Out of 50 subjects studied, 5 males (10%) and 22 females (44%) were hyperthyroid; 1 male (2%) and 7 females (14%) were hypothyroid; 6 males (12%) and 9 females (18%) were euthyroid. There were no significant differences in the descriptive statistics of parameters (mean \pm SD) between the right and left STAs: PSV (49.76 ± 23.95 vs 51.22 ± 25.99 cm/s, $p = 0.06$), PI (0.86 ± 0.08 vs 0.86 ± 0.08 , $p = 0.89$) and RI (0.60 ± 0.03 vs 0.61 ± 0.04 , $p = 0.10$). The average PSV of bilateral STAs was significantly higher in patients with hyperthyroidism than in those with euthyroidism: PSV (21.12 ± 1.82 vs 73.14 ± 4.33 cm/s, $p < 0.01$), PI (0.57 ± 0.03 vs 0.92 ± 0.04 , $p = 0.01$) The average RI value was higher in patients with hyperthyroidism than in those with euthyroidism, but the differences were not significant RI (0.57 ± 0.03 vs 0.63 ± 0.03 , $p = 0.34$). The average PSV, PI and RI values of bilateral STAs were higher in patients with hypothyroidism than in those with euthyroidism but they were not very significant: PSV (21.12 ± 1.82 vs 24.17 ± 2.49 cm/s, $p = 0.72$), PI (0.76 ± 0.03 vs 0.81 ± 0.03 , $p = 0.07$) and RI (0.57 ± 0.03 vs 0.61 ± 0.03 , $p = 0.82$).

Summary and Conclusion: In conclusion, CDU (PSV, PI, RI) parameters do not differ significantly between the right and left lobes of the thyroid gland. PSV is useful for evaluating thyroid functional status to differentiate hyperthyroidism from euthyroidism but RI showed considerable overlap in values between euthyroid and hyperthyroid patients. CDU parameters (PSV, PI, RI) did not show any significant difference between euthyroid and hypothyroid patients. Since there is no significant difference in CDU parameters between the right and left STAs, we propose that parameters of one side can be used to evaluate the clinical condition of patients with thyroid disorders.

Keywords: high-resolution ultrasonography (USG), abnormal thyroid, doppler

Introduction

High resolution ultrasonography (USG) is the most sensitive imaging modality available for examination of the thyroid gland and associated abnormalities [1]. Ultrasound scanning is non-invasive, widely available, less expensive, and does not use any ionizing radiation [1]. The major limitation of ultrasound in thyroid imaging is that it cannot determine thyroid function, i.e., whether the thyroid gland is underactive, overactive or normal in function; for which a blood test or radioactive isotope uptake test is generally required [1]. In early stages of diseases, thyroid glandular

parenchyma are often found normal [2]. Pathological studies have found altered glandular vascularity in various diseases [3]. In pathological conditions such as Graves' disease, thyroid enlargement and hyperfunction are accompanied by a markedly increased blood flow [3]. The thyroid arteries can be visualized on color doppler examination, while the flow parameters from these vessels can be measured by spectral doppler examination¹. As mentioned in the 2011 ATA (American Thyroid Association) guideline, the Color Doppler Flow Sonography (CDFs) of thyroid, as an indicator of thyroid blood flow status, has some practical

values in the differentiation of thyrotoxicosis [4]. However, due to lack of well-designed and evidence-based diagnostic trials, official recommendation is not made [4]. In normal thyroid arteries, a low resistance flow with high peak systolic velocity (PSV) is detected on spectral doppler analysis [1]. Doppler studies on thyrotoxicosis have found high systolic velocities in supplying arteries [5-7]. From the perspective of blood vessel detection, it is rather difficult to accurately position while measuring the velocity of inferior thyroid artery [4]. Also, the variation of vessel lumen sizes and artery spreading directions may interfere with the blood flow velocity detection. The inferior thyroid artery is commonly used in clinical practice⁴. However, since it is deeply located, accurate positioning is difficult.

By contrast, Superior Thyroid Artery (STA) is superficial, and can be easily positioned from its intersecting point with thyroid lobes [4]. In addition, the anatomic variation of STA rarely occurs. Measurement of superior thyroid artery flow is superior for obtaining stable flow velocity data from almost all subjects [8]. So, this study intends to find doppler indices of superior thyroid arteries (STAs) and compare it between euthyroid and abnormal thyroid functional state subjects.

Materials and Methods

- This hospital based prospective observational study was conducted by including 50 patients of different age groups and from both sexes.
- Study was conducted in the Department of Radiodiagnosis, Muzaffarnagar Medical College, Muzaffarnagar, U.P.
- Duration of the study was for eighteen months (April 2019 to Sep 2020).
- After explaining the entire radiological procedure to the patient, informed consent was obtained.
- A detailed clinical history was recorded.
- B scan of thyroid gland was performed using ultrasonography machine - Alpinion Ecube8 with 7-12 MHz linear probe.
- Subsequently, superior thyroid artery was identified and doppler scan was performed

Inclusion Criteria

1. Patients with clinical signs and symptoms of abnormal thyroid function.
2. Patients with normal / abnormal serum T3, T4 and TSH levels.

Exclusion Criteria

1. Patients not willing for the study.
2. Patients with history of thyroidectomy.
3. Patients with history of radioactive iodine therapy.
4. Pregnant women.

Observations and Results

Table 1: Distribution of subjects on the basis of sex

Sex	No. of subjects	Percentage
Males	12	24.00%
Females	38	76.00%
Total	50	100.00%

In our study, subjects were inequally distributed among

males (24%) and females (76%) with higher preponderance in females. (Table 1)

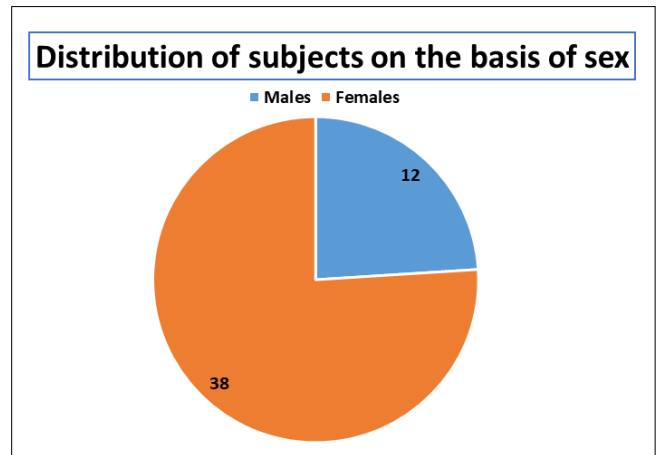


Fig 1: Distribution of subjects on the basis of sex

Table 2: Distribution of subjects on the basis of age

Age group (years)	No. of subjects	Percentage
1-10 years	0	0.00%
11-20 years	5	10.00%
21-30 years	22	44.00%
31-40 years	13	26.00%
41-50 years	6	12.00%
51-60 years	4	8.00%
Total	50	100.00%

Table shows that most of the cases were in the age group of 21-30 years (44%), 2nd largest were in the group of 31-40 years (26%) and smaller numbers were in the age group of 11-20 years (10%), 41-50 years (12%) and 51-60 years (8%). None of the cases were in the age group of 1-10 years or above 60 years. (Table 2)

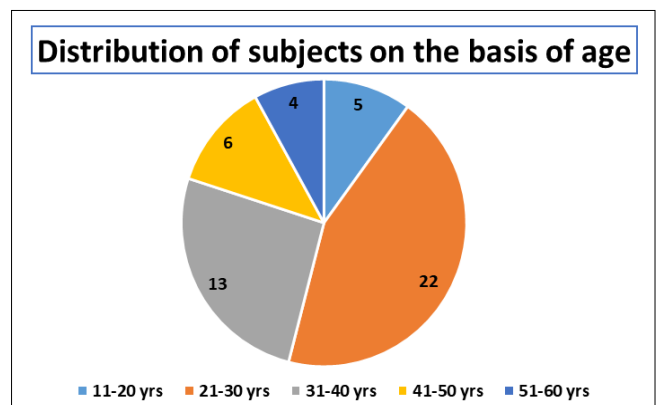


Fig 2: Distribution of subjects on the basis of age

Table 3: Distribution of subjects on the basis of disease etiology

Disease etiology	No. of subjects	Percentage
Hyperthyroid	27	54.00%
Hypothyroid	08	16.00%
Normal	15	30.00%
Total	50	100.00%

Out of the 50 cases studied, 27 subjects had hyperthyroidism (54%), 8 subjects had hypothyroidism (16%) and 15 subjects were normal (30%). (Table 3)

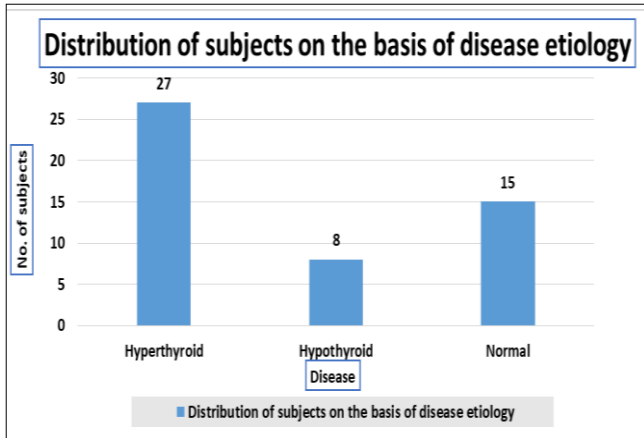


Fig 3: Distribution of subjects on the basis of disease etiology

Table 4: Distribution of the subjects on the basis of sex according to disease

Disease	Male (n=12)		Female (n=38)		Total	Male: Female ratio
	No.	%	No.	%		
Hyperthyroid	5	10	22	44	27	5:22
Hypothyroid	1	2	7	14	8	1:7
Normal	6	12	9	18	15	2:3

Out of 50 subjects studied, 5 males (10%) and 22 females (44%) were hyperthyroid; 1 male (2%) and 7 females (14%) were hypothyroid; 6 males (12%) and 9 females (18%) were euthyroid. (Table 4)

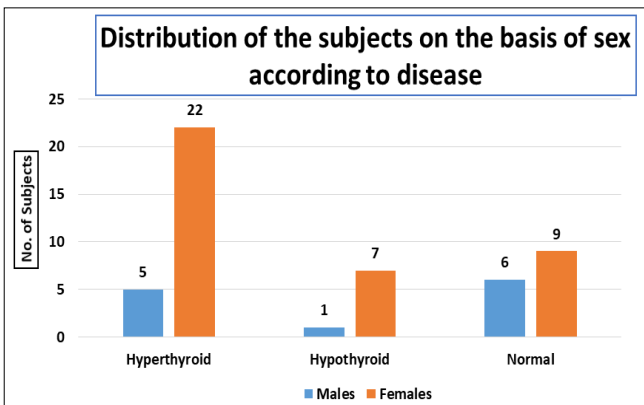


Fig 4: Distribution of the subjects on the basis of sex according to disease

Table 5: Comparison of CDU parameters between right and left superior thyroid arteries in a total of 50 patients

Total samples (n=50)				
Parameter	Side	Mean ± SD	t	P value
PSV (cm/s)	Right	49.76 ± 23.95	-1.88	0.06
	Left	51.22 ± 25.99		
PI	Right	0.86 ± 0.08	-0.13	0.89
	Left	0.86 ± 0.08		
RI	Right	0.60 ± 0.03	-1.66	0.10
	Left	0.61 ± 0.04		

SD: standard deviation; PI: pulsatility index; RI: resistive index; PSV: peak systolic velocity

In a total of 50 patients, 15 were euthyroid patients, 27 were hyperthyroid patients and 8 were hypothyroid patients. CDU images in patients with hyperthyroidism essentially revealed

More vascularity in the thyroid parenchyma and had higher parameter values than CDU images of patients with euthyroidism and hypothyroidism. There were no significant differences in the descriptive statistics of parameters (mean ± SD) between the right and left STAs : PSV (49.76 ± 23.95 vs 51.22 ± 25.99 cm/s, p = 0.06), PI (0.86 ± 0.08 vs 0.86 ± 0.08, p = 0.89) and RI (0.60 ± 0.03 vs 0.61 ± 0.04, p = 0.10). (Table 5)

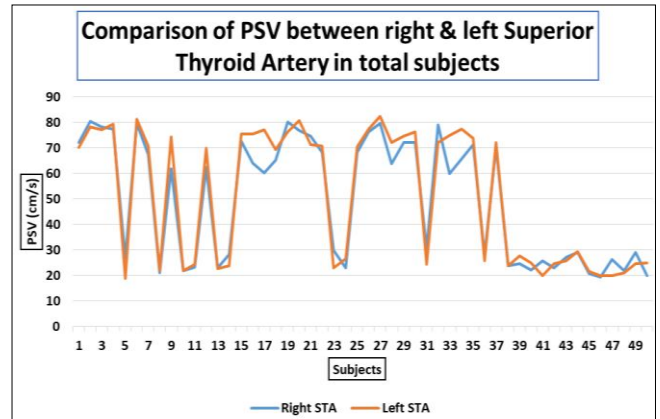


Fig 5: Comparison of PSV between right and left superior thyroid arteries in a total of 50 patients

Table 6: Comparison of CDU parameters between the right and left superior thyroid artery in euthyroid patients

Euthyroid samples (n=15)				
Parameter	Side	Mean ± SD	t	P value
PSV (cm/s)	Right	21.08 ± 1.87	1.63	0.12
	Left	21.32 ± 1.75		
PI	Right	0.76 ± 0.03	1.20	0.25
	Left	0.75 ± 0.02		
RI	Right	0.57 ± 0.02	-1.86	0.06
	Left	0.58 ± 0.34		

SD: standard deviation; PI: pulsatility index; RI: resistive index; PSV: peak systolic velocity

There were a total of 15 euthyroid patients in this study. The female to male ratio was 3:2. There were no significant differences in the descriptive statistics of parameters (mean ± SD) between the right and left STAs: PSV (21.08 ± 1.87 vs 21.32 ± 1.75 cm/s, p = 0.12), PI (0.76 ± 0.03 vs 0.75 ± 0.02, p = 0.25) and RI (0.57 ± 0.02 vs 0.58 ± 0.34, p = 0.06). (Table 6)

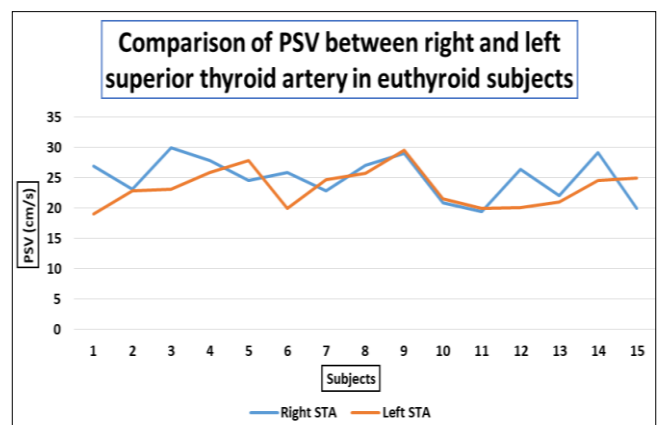


Fig 6: Comparison of PSV between the right and left superior thyroid arteries in euthyroid patients

Table 7: Comparison of Doppler parameters between right and left superior thyroid arteries in hyperthyroid patients

Hyperthyroid samples (n=27)				
Parameter	Site	Mean ± SD	T	P value
PSV (cm/s)	Right	73.21 ± 4.89	-3.28	0.29
	Left	72.75 ± 3.93		
PI	Right	0.89 ± 0.04	0.06	0.94
	Left	0.94 ± 0.03		
RI	Right	0.63 ± 0.03	-1.58	0.15
	Left	0.62 ± 0.04		

A total of 27 patients (22 females and 5 males) had hyperthyroidism. The descriptive statistics of CDU parameters did not differ significantly between the right and left STAs: PSV (73.21 ± 4.89 vs 72.75 ± 3.93 cm/s, p = 0.29), PI (0.89 ± 0.04 vs 0.94 ± 0.03, p = 0.94) and RI (0.63 ± 0.03 vs 0.62 ± 0.04, p = 0.15). (Table 7)

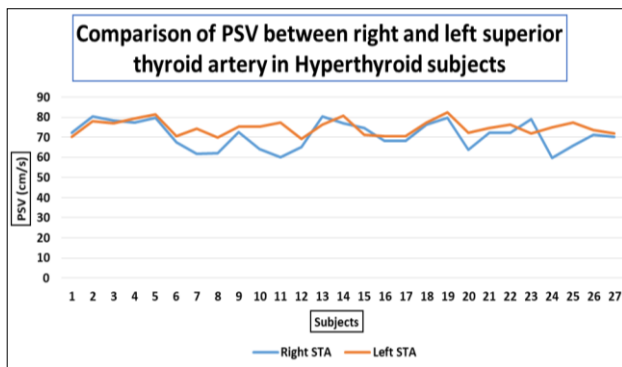


Fig 7: Comparison of PSV between right and left superior thyroid arteries in hyperthyroid patients

Table 8: Comparison of doppler parameters between right and left superior thyroid arteries in hypothyroid patients

Hypothyroid samples (n=8)				
Parameter	Site	Mean ± SD	t	P value
PSV (cm/s)	Right	24.22 ± 3.32	0.22	0.83
	Left	23.96 ± 1.57		
PI	Right	0.81 ± 0.03	1.63	0.12
	Left	0.81 ± 0.04		
RI	Right	0.60 ± 0.04	-1.58	0.15
	Left	0.63 ± 0.03		

A total of 8 patients (7 females and 1 males) had hypothyroidism. The descriptive statistics of CDU parameters did not differ significantly between the right and left STAs: PSV (24.22 ± 3.32 vs 23.96 ± 1.57 cm/s, p = 0.83), PI (0.81 ± 0.03 vs 0.81 ± 0.04, p = 0.12) and RI (0.60 ± 0.04 vs 0.63 ± 0.03, p = 0.15). (Table 8).

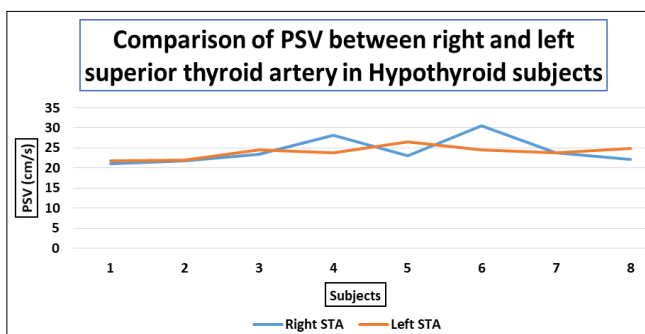


Fig 8: Comparison of PSV between right and left superior thyroid arteries in hypothyroid patients

Table 9: Comparison of the average CDU parameters of the right and left STAs between patients with euthyroidism and those with hyperthyroidism

Parameter	Euthyroid (Mean ± SD)	Hyperthyroid (Mean ± SD)	P value
PSV (cm/s)	21.12 ± 1.82	73.14 ± 4.33	< 0.01
PI	0.76 ± 0.03	0.92 ± 0.04	0.01
RI	0.57 ± 0.03	0.63 ± 0.03	0.34

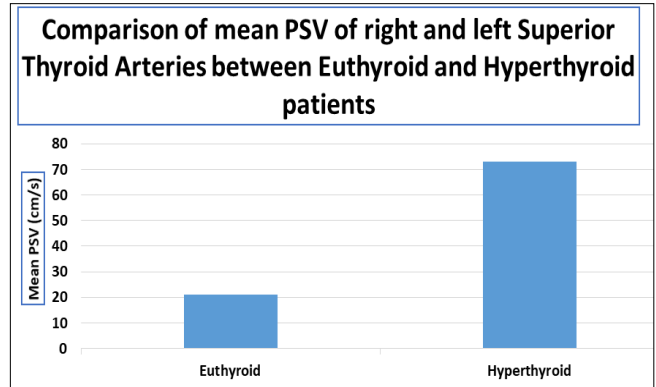


Fig 9: Comparison of mean PSV of the right and left STAs between patients with euthyroidism and those with hyperthyroidism

The average PSV and PI values of bilateral STAs were significantly higher in patients with hyperthyroidism than in those with euthyroidism: PSV (21.12 ± 1.82 vs 73.14 ± 4.33 cm/s, p = < 0.01), PI (0.57 ± 0.03 vs 0.92 ± 0.04, p = 0.01). The average RI value was higher in patients with hyperthyroidism than in those with euthyroidism, but the differences were not significant RI (0.57 ± 0.03 vs 0.63 ± 0.03, p = 0.34). (Table 9)

Table 10: Comparison of the average CDU parameters of the right and left STAs between patients with euthyroidism and those with hypothyroidism

Parameter	Euthyroid (Mean ± SD)	Hypothyroid (Mean ± SD)	P value
PSV (cm/s)	21.12 ± 1.82	24.17 ± 2.49	0.72
PI	0.76 ± 0.03	0.81 ± 0.03	0.07
RI	0.57 ± 0.03	0.61 ± 0.03	0.82

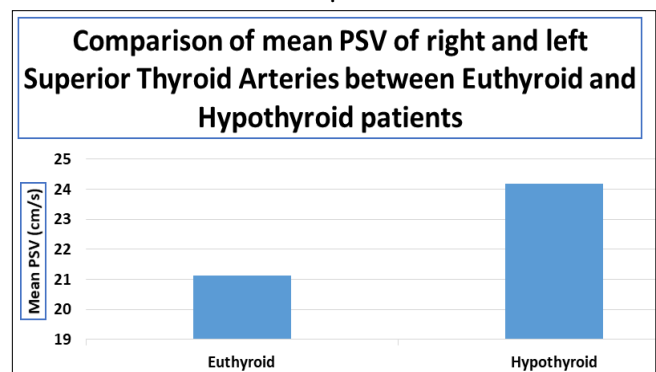


Fig 10: Comparison of mean PSV of the right and left STAs between patients with euthyroidism and those with hypothyroidism

The average PSV, PI and RI values of bilateral STAs were higher in patients with hypothyroidism than in those with euthyroidism but they were not very significant : PSV (21.12 ± 1.82 vs 24.17 ± 2.49 cm/s, p = 0.72), PI (0.76 ± 0.03 vs 0.81 ± 0.03, p = 0.07) and RI (0.57 ± 0.03 vs 0.61 ± 0.03, p = 0.82).

0.03 vs 0.81 ± 0.03 , $p = 0.07$) and RI (0.57 ± 0.03 vs 0.61 ± 0.03 , $p = 0.82$). (Table 10)

Discussion

Two STAs and two ITAs supply the thyroid gland. In a normal thyroid gland, right lobe is larger and more vascularized than the left lobe⁹. However, Tegler *et al*^[10] revealed through an electromagnetic flowmetry study that there was no significant difference in blood flow between the right and left thyroid arteries. Hodgson *et al*^[11] reported similar findings in CDU spectral studies. In 1999, Varsamidis K, Varsamidou E, Mavropoulos G in their study found the mean PSV of STA in control subjects to be 26.2 cm/s. In 2007, Macedo TA, Chammas MC, Jorge PT, De Souza LP, Farage L, Pegoraro BL included 165 euthyroid individuals of Brazil and found mean PSV of STA to be 25.84 cm/s and PI and RI to be 1.03 and 0.62, respectively^[12]. Our results revealed findings for PSV, PI, RI of STA in euthyroid to be 21.12 cm/s, 0.76, 0.57 respectively. Krejza *et al*^[13] reported that the PI of STA was 0.85 ± 0.23 in healthy women. In our experience, we found that it is difficult to obtain optimal CDU spectral parameters in normal thyroid or simple goiter because the STA is very thin. Wang and Chang^[14] found that patients with hyperthyroidism and poorly controlled Graves' disease have higher PI values (PI = 1.36 and 1.24, respectively), whereas patients who were withdrawn from therapy and those with euthyroidism have lower PI values (PI = 0.78 and 0.76, respectively). In our STA study, the value of PI in the euthyroid group (averaged PI of bilateral STA = 0.76 ± 0.03) was lower than that in the hyperthyroid group (0.92 ± 0.04). According to Chou *et al*^[15], there were no significant differences between right and left ITAs or between normal females and males in RI and PSV estimations. Caruso *et al*^[16] reported that the PSV values did not differ significantly between the right and left ITAs in patients with Graves' disease, or in patients with Hashimoto's thyroiditis. Noise interference is more of a problem when calculating PI than when calculating RI; therefore, RI is a more reliable measurement than PI^[14]. RI values of STA in healthy women were 0.55 ± 0.08 in Krejza *et al* study^[13], whereas those of ITA in healthy women were 0.6 ± 0.06 in Chou *et al*'s study^[15]. In 2015, Kim Tea Kayoo *et al.* did a study to validate the superior thyroidal artery mean peak systolic velocity as an alternative to other diagnostic parameters in the differentiation of the causes of thyrotoxicosis in Korean patients. The results found that mean PSV of STA was significantly higher in the untreated GD group than in the DT group. Our study also revealed that mean PSV of hyperthyroid patients was significantly higher when compared to hypothyroid patients. Wang and Chang^[14] reported that RI values could be used to determine the therapeutic method for Graves' disease using a 7.5-MHz transducer. Higher RI levels were found in hyperthyroid patients (0.74 to 0.79) but lower levels were seen in euthyroid patients (0.56 to 0.57). They concluded that patients with RI values above 0.7 should undergo ablative therapy. However, Castagnone *et al*^[17] reported that there was no significant difference in RI values between hyperthyroid patients (0.54 ± 0.03 to 0.63 ± 0.06) and euthyroid patients (0.55 ± 0.02 to 0.61 ± 0.03) when ITA was measured with a 5.0 MHz transducer. In our study, we measured STA with a 7-12 MHz transducer. We found that the mean \pm SD of RI in euthyroid patients (0.57 ± 0.03) was

slightly lower than that in hyperthyroid patients (0.63 ± 0.03), but the difference was not significant ($p = 0.34$). In our study, the average PSV value of normal STA ranged from 18.98 to 29.87 cm/s; however, different mean PSV values have been found in various studies on STA like (17.55 cm/s)^[18] and (25.84 cm/sec)^[12]. Different ultrasonography settings and different frequencies of transducers may contribute to these different results. In comparison between euthyroid and hypothyroid patients, our study did not reveal any significant differences in the doppler parameters like PSV, PI and RI.

Conclusion

In conclusion,

- CDU (PSV, PI, RI) parameters do not differ significantly between the right and left lobes of the thyroid gland.
- PSV is useful for evaluating thyroid functional status to differentiate hyperthyroidism from euthyroidism but RI showed considerable overlap in values between euthyroid and hyperthyroid patients.
- CDU parameters (PSV, PI, RI) did not show any significant difference between euthyroid and hypothyroid patients.
- Since there is no significant difference in CDU parameters between the right and left STAs, we propose that parameters of one side can be used to evaluate the clinical condition of patients with thyroid disorders.
- Further large-scale studies are needed to confirm our findings.

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