

Doppler Assessment of Inferior Thyroid Artery and its Correlation with Thyroid Volume in Euthyroid Adults: A cross-sectional Study

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ABSTRACT

Introduction: Doppler ultrasound provides hemodynamic information about thyroid vascularity. Establishing normative values for inferior thyroid artery parameters is essential for differentiating physiological from pathological conditions. This study aimed to determine normative Doppler parameters of the inferior thyroid artery in clinically euthyroid adults in Nepal.

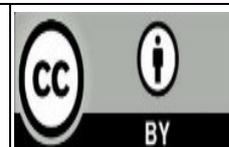
Methods: A cross-sectional study was conducted with 122 clinically euthyroid adults aged 18 years and above at a tertiary care hospital from January 1st to March 31st, 2024. Doppler parameters including Peak Systolic Velocity (PSV), Resistive Index (RI), and Pulsatility Index (PI) were measured using high-resolution ultrasound. Descriptive statistics, independent t-tests, one-way ANOVA, and Pearson correlation analyses were performed using SPSS version 25.0.

Results: The mean PSV was 17.66 cm/s (SD ± 2.82), RI was 0.50 (SD ± 0.06), and PI was 0.72 (SD ± 0.08). Mean thyroid volume was 8.01 mL (SD ± 2.48) for the overall cohort, with males showing 8.20 mL (SD ± 2.95) and females 7.83 mL (SD ± 1.93). No significant gender differences were observed in PSV (p=0.41), RI (p=0.08), PI (p=0.18), or thyroid volume (p=0.52). Weak correlations were found between PSV and age (r=-0.15) and between Peak Systolic Velocity and thyroid volume (r= -0.02).

Conclusions: This study provides baseline normative data for inferior thyroid artery Doppler parameters in euthyroid Nepali adults. The findings demonstrate stable hemodynamics across genders and age groups, serving as reference values for clinical practice.

Keywords: *Artery; Doppler ultrasound; Graves' disease; thyroid; Vascular resistance.*

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INTRODUCTION

The thyroid gland, supplied by the superior and inferior thyroid arteries, [1] is traditionally assessed using biochemical markers and grayscale ultrasonography. [2,3] Doppler ultrasound provides additional hemodynamic information. [4,5] Color and spectral Doppler quantify blood flow and resistance indices, with the inferior thyroid artery preferred for sampling due to its accessibility. [6,7,8,9,10]

In Graves disease, Peak Systolic Velocity (PSV) increases due to hypervascularity ("thyroid inferno"), [6,10] while destructive thyroiditis shows normal or decreased vascularity. [11] Differentiating these conditions is crucial for management. [12] Normal Doppler parameter ranges vary by ethnicity, iodine intake, genetics, environment and oral contraceptive use. [1,13] Zuhur et al. highlighted PSV differences between gestational thyrotoxicosis and Graves disease, though sensitivity remains limited. [2]

In Nepal, local normative data for euthyroid adults are lacking, [14,15] vital to prevent misdiagnosis and guide treatment. [16,17] This study establishes

normative Doppler parameters of the inferior thyroid artery in euthyroid Nepali adults and evaluates associations with age, gender, and thyroid volume.

METHODS

Study Design and Setting

This was an analytical cross-sectional study conducted in the Department of Radiology, Nepalgunj Medical College and Teaching Hospital from January 1st to March 31st, 2024. Ethical approval was obtained from the Institutional Review Committee of Nepalgunj Medical College (NGMC/IRC/20/080-81). All participants provided written informed consent prior to enrollment after detailed explanation of the study objectives and procedures.

Study Population

A total of 122 participants were recruited using purposive sampling technique from patients referred to the radiology department for ultrasound examination of organs other than the neck. The sample size was calculated using the formula for estimating population mean with specified

precision: $n = (Z^2 \times \sigma^2) / d^2$, where Z is the standard normal value (1.96 for 95% confidence interval), σ is the estimated standard deviation of Peak Systolic Velocity (assumed to be 6.5 cm/s based on the study by Salroo et al. [3]), and d is the desired precision (1.2 cm/s). This calculation yielded a minimum sample size of 111 participants. Accounting for potential 10% non-compliance or technical failures, the final sample size was determined to be 122 participants.

Inclusion Criteria: Adults aged 18 years and above who were clinically and laboratory confirmed euthyroid, defined as absence of clinical symptoms of hyperthyroidism or hypothyroidism, with no known history of thyroid disease and having normal thyroid function tests (TSH: 0.4-4.0 mIU/L, FT4: 0.8-1.8 ng/dL, FT3: 2.3-4.2 pg/mL).

Exclusion Criteria: History of thyroid surgery or neck irradiation, known endocrine disorders including diabetes mellitus or adrenal disorders, renal or cardiac abnormalities that could affect systemic hemodynamics, current pregnancy or lactation, use of medications known to affect thyroid function or vascularity such as oral contraceptives, amiodarone or lithium, and any

contraindication to Doppler ultrasound examination.

Ultrasound Protocol

All ultrasound examinations were performed by a single experienced consultant radiologist to ensure consistency in measurements. A high-resolution ultrasound machine (Logiq P6, GE Healthcare, Madison, WI, USA) equipped with a 7-12 MHz linear array transducer with color Doppler function was used for all examinations.

Grayscale Imaging: Participants were positioned supine with the neck in slight hyperextension using a pillow placed beneath the shoulders. The thyroid gland was systematically scanned in both transverse and longitudinal planes. Each thyroid lobe was measured in three dimensions: anteroposterior diameter, transverse diameter, and craniocaudal length. Thyroid volume was calculated for each lobe using the ellipsoid formula: $\text{Volume} = (\text{AP} \times \text{TR} \times \text{CC}) \times \pi/6$, where AP represents anteroposterior diameter, TR represents transverse diameter, and CC represents craniocaudal length. Total thyroid volume was calculated as the sum of both lobes. The isthmus was excluded from volume calculation unless its thickness exceeded 3 mm.

Doppler Assessment: Color Doppler was activated to identify the inferior thyroid artery as it entered the lower pole of the thyroid gland or as it crossed posterior to the common carotid artery. The spectral Doppler sample volume (1-2 mm) was positioned in the center of the vessel lumen. The angle of insonation was maintained below 60 degrees to ensure accurate velocity measurements and minimize angle-related errors (Figure 1). At least three consecutive cardiac cycles with consistent waveforms were obtained for each measurement. All examinations were performed with participants at rest for a 5-minute.

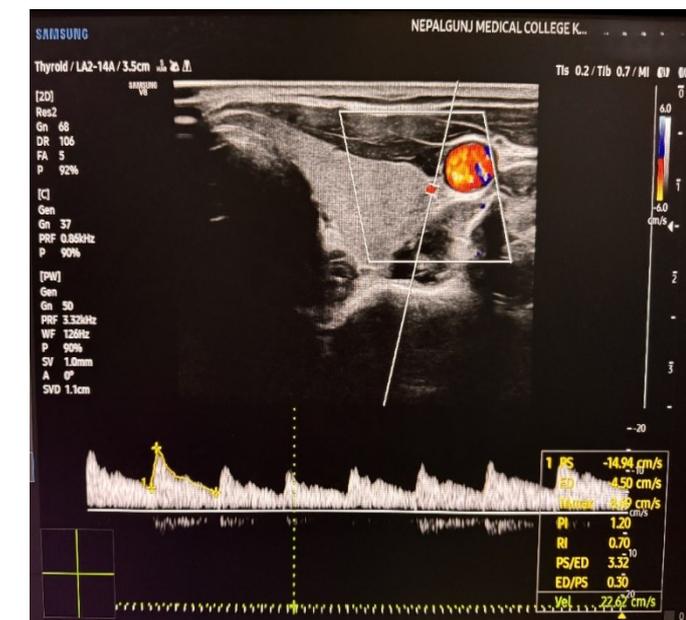
Figure 1. Spectral Doppler ultrasound of the inferior thyroid artery demonstrating a normal arterial waveform

The following spectral Doppler parameters were recorded:

1. Peak Systolic Velocity (PSV): The maximum velocity during the systolic phase of the cardiac cycle, measured in cm/s.
2. End-Diastolic Velocity (EDV): The minimum velocity at end-diastole, measured in cm/s.
3. Resistive Index (RI): Calculated using the formula $RI = (PSV - EDV)/PSV$.
4. Pulsatility Index (PI): Calculated using the formula $PI = (PSV - EDV)/\text{mean flow velocity}$.

Statistical Analysis

Data were analyzed using SPSS version 25.0 (IBM Corp, Armonk, NY, USA). Continuous variables were expressed as mean \pm standard deviation. The Kolmogorov-Smirnov test assessed normality. Independent t-tests compared parameters between genders. One-way ANOVA compared across age groups. Pearson correlation determined relationships between parameters, age, and thyroid



volume. P-values <0.05 were considered statistically significant at 95% confidence level.

RESULTS

Demographic Characteristics

The study population consisted of 122 clinically euthyroid adults (61 males, 61 females) with ages ranging from 18 to 72 years. The mean age was 42.5 ± 14.8 years, with males averaging 43.2 ± 15.1 years and females 41.8 ± 14.5 years.

Inferior Thyroid Artery Doppler Parameters and Thyroid Volume

The descriptive analysis of hemodynamic and morphological parameters is summarized in Table 1. The mean Peak Systolic Velocity across the entire cohort was 17.66 cm/s with a standard deviation of 2.82 cm/s, indicating relatively consistent values across participants. The mean thyroid volume was 8.01 mL, which is consistent with values reported in Asian populations.

Table 1: Normative Doppler Parameters of the Inferior Thyroid Artery (n=122)

Parameters	Mean	SD	Range
Peak Systolic Velocity (cm/s)	17.66	2.82	12.4 – 23.8
Resistive Index	0.50	0.06	0.38 – 0.64

Pulsatility Index	0.72	0.08	0.56 – 0.88
Thyroid Volume (mL)	8.01	2.48	3.50 – 14.20

Comparative Analysis by Gender

Statistical analysis revealed no significant differences between male and female participants in any of the measured inferior thyroid artery parameters (Table 2). This finding suggests that gender is not a primary determinant of thyroid blood flow velocity or vascular resistance in euthyroid individuals in this population.

Table 2: Comparison of Doppler Parameters between Genders(n=122)

Parameter	Male (Mean ± SD)	Female (Mean ± SD)	p-value
Peak Systolic Velocity (cm/s)	17.71 ± 2.83	17.60 ± 2.83	0.41
Resistive Index	0.51 ± 0.07	0.49 ± 0.05	0.08
Pulsatility Index	0.72 ± 0.08	0.73 ± 0.08	0.18
Thyroid Volume (mL)	8.20 ± 2.95	7.83 ± 1.93	0.52

Correlation Analysis

Correlation studies were performed to determine whether age or thyroid gland size influenced inferior thyroid artery hemodynamics. A weak negative correlation (r = -0.15, p=0.10) was found

between PSV and age, suggesting a slight decrease in velocity with advancing age, though this relationship did not reach statistical significance. A negligible correlation ($r = -0.02$, $p=0.84$) was observed between thyroid volume and Peak Systolic Velocity, indicating that gland size doesn't substantially affect blood flow velocity in euthyroid individuals.

A perfect positive correlation ($r = 1.00$, $p<0.001$) was observed between RI and Pulsatility Index, as both indices reflect vascular resistance through related formulas

DISCUSSION

Doppler ultrasound has significantly enhanced diagnostic capabilities in thyroid pathologies. [8,18] Our study established reference values for inferior thyroid artery Doppler parameters in a Nepali euthyroid population, with a mean Peak Systolic Velocity of 17.66 cm/s providing a critical benchmark for local clinicians. Our mean PSV of 17.66 ± 2.82 cm/s is comparable to South Asian studies. Salroo et al. reported 15.65 ± 6.5 cm/s in Kashmir, [3] consistent with our findings.

Geographic proximity and similar genetic and dietary factors may explain these similarities.

Western studies report slightly higher velocities (20-25 cm/s).[19] These variations highlight the importance of region-specific normative data. Differences may reflect variations in iodine nutrition, subclinical autoimmune thyroiditis prevalence, genetic factors, and measurement methodology. [13,14] The significantly lower PSV values observed in euthyroid individuals compared to the thresholds typically used to diagnose Graves disease (often exceeding 40-50 cm/s) reinforces the diagnostic utility of this parameter. [10,20] This clear demarcation between normal and pathological values supports the use of Doppler ultrasound as an adjunctive diagnostic tool in thyroid disease evaluation.

The absence of significant gender-based differences in inferior thyroid artery parameters is consistent with findings by Joish et al.[4] and Chiou et al.[5] While thyroid volume varies with body size, flow velocities and resistance indices remain consistent between genders in euthyroid state. Males showed slightly higher RI (0.51 ± 0.07 vs 0.49 ± 0.05 , $p=0.08$) but this difference was not statistically

significant. These findings suggest separate reference ranges for males and females are unnecessary for euthyroid individuals, though gender differences may emerge in pathological conditions or hormonal transitions. [21]

The weak negative correlation between PSV and age ($r = -0.15$) suggests subtle age-related reduction in thyroid blood flow velocity, aligning with vascular aging effects. [22] This may reflect decreased cardiac output, progressive thyroid fibrosis, reduced metabolic activity, and altered arterial compliance with aging. However, this weak correlation may not translate to clinically significant differences in routine practice, though awareness of this trend may be valuable when interpreting borderline values in elderly patients.

Our mean RI of 0.50 and PI of 0.72 reflect the characteristically low-resistance nature of the highly vascularized thyroid gland. [23] The perfect correlation between RI and PI ($r = 1.00$) is mathematically expected given their related formulas, indicating these indices provide complementary but redundant information regarding distal vascular resistance. In thyroiditis, resistance indices may increase due to vessel

compression and tissue pressure. [2] Establishing 0.50 as mean RI provides baseline reference for evaluating pathological shifts and differentiating thyroiditis from Graves disease. [24] Our mean thyroid volume of 8.01 mL (males: 8.20 mL, females: 7.83 mL) is consistent with Asian studies and reflects normal Nepali thyroid dimensions. [25]

The negligible correlation between thyroid volume and PSV ($r = -0.02$) suggests normal size variations do not affect blood flow velocity in euthyroid individuals. This indicates Doppler parameters primarily reflect functional and pathological states rather than anatomical size, enhancing diagnostic specificity.

Study limitations include sample size that may not capture Nepal's geographic and ethnic diversity, suggesting multicenter studies would be valuable.

Body mass index, blood pressure, and cardiovascular parameters could not be systematically collected. A single operator examination although assigned quality however limited inter-observer variability assessment. Only inferior thyroid artery was assessed; comparative evaluation of both arteries might enhance diagnostic accuracy.

- PI - Pulsatility Index
- PSV - Peak Systolic Velocity
- RI - Resistive Index
- SD - Standard Deviation
- TR – Transverse

CONCLUSIONS

This study successfully established normative values for Peak Systolic Velocity, Resistive Index, and Pulsatility Index of the inferior thyroid artery in clinically euthyroid Nepali adults. The findings demonstrate that inferior thyroid artery hemodynamics are independent of gender and show only minimal age-related variations in euthyroid individuals. The established mean Peak Systolic Velocity of 17.66 cm/s and Resistive Index of 0.50 serve as essential reference points for Nepali radiologists and endocrinologists. By providing locally derived normative data, this research enables more confident interpretation of Doppler studies, potentially reducing unnecessary invasive procedures and improving diagnostic accuracy in thyroid disease management.

LIST OF ABBREVIATIONS

- AP - Anteroposterior
- CC - Craniocaudal
- EDV - End-Diastolic Velocity

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CONFLICTS OF INTEREST

None

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