Volume 3, Issue 5, 2025

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

PATTERN OF ANATOMICAL VARIATIONS OF RECURRENT LARYNGEAL NERVE IN RELATION TO INFERIOR THYROID ARTERY

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DOI: https://doi.org/10.5281/zenodo.15876569

Keywords
Recurrent laryngeal nerve, inferior thyroid artery, thyroidectomy, anatomical variations, surgical safety

Article History
Received: 02 April, 2025
Accepted: 23 June, 2025
Published: 10 July, 2025

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Abstract

BACKGROUND: *The recurrent laryngeal nerve (RLN) is a critical anatomical structure at risk during thyroidectomy. Its anatomical relationship with the inferior thyroid artery (ITA) is variable and can significantly impact surgical outcomes, particularly the risk of RLN injury.*

Objectives: *To analyze anatomical variations in the relationship between the RLN and ITA and evaluate their demographic and clinical correlations.*

Study Settings: *Department of Surgery, Allied Hospital 1 Faisalabad/Faisalabad Medical University*

Duration of Study: *From: 17/11/2024 to 16/05/2025.*

DATA COLLECTION: *A descriptive cross-sectional study included 554 participants undergoing surgery involving the ITA. Demographic and clinical data, including RLN side and position relative to the ITA, were documented intraoperatively. Variations were categorized as anterior, posterior, or in-between. Data were analyzed using SPSS 25.0, with stratification for age, gender, BMI, and surgical indications. A p-value ≤ 0.05 was considered significant.*

RESULTS: *The mean age was 39.59 ± 12.22 years, with males (50.7%) and females (49.3%) equally represented. Most participants were overweight or obese (54.2%). The RLN predominantly assumed a posterior position (48.2%), followed by anterior (41.2%) and intermediate (10.6%) positions. No significant differences in RLN side or position were observed across demographic or clinical variables, highlighting the nerve's stable anatomical relationships.*

CONCLUSION: *The anatomical variability of the RLN in relation to the ITA highlights the need for careful surgical planning and tailored strategies during thyroidectomy. Preoperative imaging and intraoperative neuromonitoring may improve surgical safety and reduce the chance of recurrent laryngeal nerve damage.*

INTRODUCTION

Thyroid surgery is one of the most common endocrine surgeries done globally.[1] One of the major postoperative complications is recurrent laryngeal nerve (RLN) paralysis since it has severe impact on the quality of life. Unilateral RLN palsy has different consequences and ranges from change in voice quality to aspiration and when bilateral, it becomes life-threatening. Consequently, preservation and

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ISSN: (e) 3007-1607 (p) 3007-1593

recognition of RLN during thyroid surgeries are crucial. It is becoming apparent that the incidence of RLN palsy in the global scenario varies from 0.5-20% in thyroid surgeries. This varies with the type of thyroid disease, the technique used in surgery, the variations in patient's anatomical position and the experience of the surgeon performing the surgery.[1-2]

Numerous studies indicate that the identification of the recurrent laryngeal nerve during surgery reduces the risk of nerve damage during dissection.[3] In thyroid surgery, various anatomical markers assist in the identification of the recurrent laryngeal nerve (RLN), including its proximity to the inferior thyroid artery, its location inside the tracheo-oesophageal groove, its lateral position relative to the ligament of Berry, and its posterior placement to the tubercle of Zuckerkandl, when present. Due to its potentially delicate architecture, the RLN may sustain harm during dissection as it travels from the thorax to the larynx. Therefore, in order to prevent damaging the nerve, one must have precise anatomical understanding, be able to identify the landmarks, and be aware of changes in its route.[4]

Various authors reported that the nerve into the larynx having divided into two or more trunks.[4] In dissecting protocols, the authors noticed that RLN was bifurcated at one side or another in 43% of cases on both sides; trifurcation was noted in 13% On average, bifurcation or trifurcation was at 1.8 cm distance from the inferior border of cricoid cartilage, ranging between 0.6 cm and 4.0 cm. These branches can arise at any level but in observing the extralaryngeal branches, it has been noticed that at the level below ITA branching is rare.[5] Changes in the usual anatomy due to neoplasm, goiter or inflammation can often change the course of the RLN. While only in 0.6% cases the right RLN does not form a loop around the subclavian artery, instead it arises from the vagus in the neck and descends towards the larynx. This is called the "nonrecurrent" laryngeal nerve and is very vulnerable to injury during surgery.[6] There is a low likelihood of the nonrecurrent laryngeal nerve variant in the left side but two surgical clinical cases involve left retroesophageal subclavian artery and the right sided aorta.[7-8]

Various authors are of the view that the nerve enters the larynx after branching in two or more trunks.[4] The dissection findings indicate that RLN branched pattern the RLN was found to be further divided in one or many branches in 43% cases on both sides The bifurcation or trifurcation starting from the inferior border of the cricoid cartilage measures between 0.6 cm and 4.0 cm. The extralaryngeal branches can originate at any place but the significant fact which can be inferred is that in about more than one fifth on the caudal side of the ITA branching is not seen.[5] Inflammatory disorders, neoplasm and goiter changes undermine the normal disposition of RLN more often. Rarely (0.6 %), right RLN loops are formed by nerve that arises from the vagus in neck and goes to larynx. This is called the "nonrecurrent" laryngeal nerve, and it is very vulnerable to damage during surgery.[6] On the left side, the nonrecurrent laryngeal nerve variant is even less likely; however, there are case reports regarding two clinical cases being linked with left retroesophageal subclavian artery together with the right sided aorta.[7-8]

Samorekar et al analyzed the anatomical relationship and variations of the RLN with respect to inferior thyroid artery during open thyroid surgeries where of 69 cases 37 nerves (53·6%) had right side, 14 (37·8%) anterior to the artery, 22 (59·5%) posterior to the artery and 1 case (27%) in between. Of the 32(46.4%) nerves identified on the left, 9(28.1%) RLN was located anterior to the artery 21(65.6%) was located posterior to the artery.[9]

Anatomical knowledge of the RLN during surgery will help to reduce the risk of injury to the nerve during dissection. Though, various studies conducted to determine the anatomical relationship of the RLN to the inferior thyroid artery, but the local data needs to be added with updated findings.

METHODOLOGY

This descriptive cross-sectional study was conducted at the Department of Surgery, Allied Hospital Faisalabad, over a period of six months following the approval of the synopsis. The sample size of 554 was calculated using the WHO sample size calculator with a confidence level of 95%, an anticipated proportion of 2.7%, and a margin of error of 1.35%. Non-probability consecutive sampling was employed to recruit participants. Participants were included if they were aged between 18 and 60 years, of either

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

gender, had biopsy-proven benign goiter, and were undergoing surgery involving the inferior thyroid artery. Exclusion criteria included recurrent goiter, advanced thyroid cancers, pregnancy or lactation, a history of prior neck surgery or radiation (as per available records), pre-existing recurrent laryngeal nerve (RLN) impairment confirmed via laryngoscopy, and significant comorbidities.

The study was initiated following approval from the Institutional Ethical Review Committee and CPSP. Due process of informed consent was completed by explaining/briefing the study objectives and assured of confidentiality. A general physical examination was conducted for all participants, followed by relevant clinical investigations. These included plain X-rays of the neck in anteroposterior and lateral views to assess tracheal deviation or compression, chest X-rays to evaluate retrosternal extension, and routine indirect laryngoscopy to determine vocal cord status. All surgeries were performed under general anesthesia. During the procedure, the RLN was carefully exposed, and its anatomical relationship to the inferior thyroid artery (ITA) was identified and recorded. The data were documented on a pre-designed proforma.

Intraoperative assessment of anatomical alterations related to the ITA was conducted by meticulous examination of the laryngeal entry and the first trajectory of each RLN. The RLN's position and its relation to the ITA were used to categorise these alterations as anterior, posterior, or intermediate. The collected data were analysed using SPSS version 25.0. Age, and BMI were expressed as means ± standard deviations for quantitative data, while gender, surgical indication, RLN side, and RLN placement were provided as frequencies and percentages for categorical variables. Age, gender, BMI, and surgical indication were the effect modifiers accounted for by stratification. Post-stratification chi-square tests were used to ascertain the impact of these factors on alterations in RLN placement, with a p-value of 0.05 or below being statistically significant.

RESULTS

The table below shows the demographic and clinical profile of the research cohort. Concerning the age distribution, nearly half of the participants; that is 49.1% were aged between 18 and 40 while the remaining 50.9% were between 41 to 60 years. The average age of the participants was 39.59 years with a SD= ± 12.22 years; this confirms that the age distribution among the research participants was quite homogeneous.

The gender breakdown reveals a nearly equal representation, with men comprising 50.7% (281 participants) and females representing 49.3% (273 participants). This balance indicates that both genders were almost equally involved in the study. Regarding body mass index (BMI), 45.8% of participants had a BMI within the normal range (18–25 kg/m²), while the majority, 54.2%, were classified as overweight or obese with a BMI greater than 25 kg/m². The mean BMI of the participants was 26.18 kg/m², with a standard deviation of ±5.70, suggesting a notable presence of individuals above the healthy weight range.

The surgical indications highlight that the most common reason for surgery was multinodular goiter, accounting for 43.0% of cases, followed by equal proportions (24.2%) of right and left solitary nodular goiters. Diffused goiter was the least common indication, comprising 8.7% of the cases.

The recurrent laryngeal nerve (RLN) characteristics were also documented. The right side was involved in 52.7% of cases, while the left side was affected in 47.3%. Regarding the RLN's position, the posterior position was the most frequently observed (48.2%), followed by the anterior position (41.2%). An intermediate position was noted in 10.6% of cases.

The anatomical variations of the recurrent laryngeal nerve (RLN) in relation to the inferior thyroid artery are explored in two dimensions: the side of the RLN (right vs. left) and its positional relationship (anterior, posterior, or in-between). These variations are described with respect to demographic factors such as age, gender, and BMI, as well as clinical factors like the indication for surgery.

In terms of the side of the RLN, no significant differences were found across demographic or clinical groups. Age-wise, individuals aged 18–40 years demonstrated a nearly equal distribution, with 51.5% having the RLN on the right and 48.5% on the left. Similarly, for those aged 41–60 years, the right-sided RLN occurred slightly more frequently (53.9%) than the left (46.1%), p=0.567. Gender

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ISSN: (e) 3007-1607 (p) 3007-1593

comparisons showed a similar pattern. Males had 50.9% of their RLNs on the right side and 49.1% on the left, while females had a slightly higher prevalence on the right (54.6%) compared to the left (45.4%). Again, the difference was not significant (p = 0.385). Regarding BMI, individuals with a BMI of 18–25 had 52.4% of RLNs on the right and 47.6% on the left. Those with a BMI above 25 showed a comparable distribution, with 53.0% on the right and 47.0% on the left. The p-value of 0.881 confirmed no significant association between BMI and the side of RLN. Clinical indications for surgery, including right and left solitary nodular goiters, multinodular goiter, and diffused goiter, showed no significant variation in RLN side distribution. For instance, right solitary nodular goiter cases had 51.5% of RLNs on the right and 48.5% on the left, while multinodular goiter cases had 52.1% on the right and 47.9% on the left. Diffused goiters exhibited a slightly higher prevalence of right-sided RLNs (56.3%) compared to left (43.8%), (p = 0.938).

The positional variations of the RLN relative to the inferior thyroid artery—categorized as anterior, posterior, or in-between—were similarly analyzed. For age groups, those aged 18–40 years had 41.9% of RLNs positioned anteriorly, 46.7% posteriorly, and 11.4% in between. In the 41–60 age group, a slightly higher proportion (49.6%) of RLNs were posterior, with 40.4% anterior and 9.9% in between. However, the positional differences across age groups were not statistically significant (p = 0.739). Gender analysis revealed no significant difference in RLN positioning. Among males, 40.9% of RLNs were anterior, 49.5% were posterior, and 9.6% were in between. For females, the distribution was comparable, with 41.4% anterior, 46.9% posterior, and 11.7% in between (p = 0.677). When considering BMI, anterior and posterior positions dominated the distribution. For BMI 18–25, 52.4% of RLNs were anterior and 47.6% posterior. Similarly, for BMI >25, the distribution was 53.0% anterior and 47.0% posterior. Positional differences with respect to BMI were also non-significant (p = 0.881). Clinical indications for surgery did not show significant variations in RLN positioning either. For right solitary nodular goiter cases, 44.8% of RLNs were anterior, 45.5% posterior, and 9.7% in between. Similar distributions were observed for other indications, such as left solitary nodular goiter (41.8% anterior, 45.5% posterior, 12.7% in between) and multinodular goiter (37.4% anterior, 52.5% posterior, 10.1% in between). Diffused goiter cases showed a slightly higher prevalence of anterior positioning (47.9%) compared to posterior (41.7%) and in-between (10.4%), (p = 0.643).

Across all variables analyzed, there were no statistically significant differences in the side or position of the RLN relative to the inferior thyroid artery. The RLN's anatomical variations appear to be consistent across age, gender, BMI, and surgical indications, highlighting the nerve's stability in its anatomical relationships, regardless of demographic or clinical factors. The results of this study highlight the need for proper preoperative planning of surgeries and gently dissection to avoid postoperative complications of RLN injury.

DEMOGRAPHIC AND CLINICAL VARIABLES OF THE STUDY

Variable	Category	Frequency	Percent
Age	18-40	272	49.1
	41-60	282	50.9
Gender	Male	281	50.7
	Female	273	49.3
BMI	18-25	254	45.8
	>25	300	54.2
Indication for Surgery	Right Solitary Nodular Goiter	134	24.2
	Left Solitary Nodular Goiter	134	24.2
	Multinodular Goiter	238	43.0
	Diffused Goiter	48	8.7
Side of RLN	Right	292	52.7

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

	Left		262	47.3
Position of RLN	Anterior		228	41.2
	Posterior		267	48.2
	In-Between		59	10.6
Variable	**N**	**Mean**	**Std. Deviation**	
Age	554	39.59	12.22	
BMI (kg/m^2)	554	26.18	5.70	

ANATOMICAL VARIATIONS (SIDE OF RLN) OF RECURRENT LARYNGEAL NERVE IN RELATION TO INFERIOR THYROID ARTERY

Variable	Group	Side of RLN		Chi-Square p-value
		Right Count (%)	Left Count (%)	
Age	18-40	140 (51.5%)	132 (48.5%)	0.567
	41-60	152 (53.9%)	130 (46.1%)	
Gender	Male	143 (50.9%)	138 (49.1%)	0.385
	Female	149 (54.6%)	124 (45.4%)	
BMI	18-25	133 (52.4%)	121 (47.6%)	0.881
	>25	159 (53.0%)	141 (47.0%)	
Indication for Surgery	Right Solitary Nodular Goiter	69 (51.5%)	65 (48.5%)	0.938
	Left Solitary Nodular Goiter	72 (53.7%)	62 (46.3%)	
	Multinodular Goiter	124 (52.1%)	114 (47.9%)	
	Diffused Goiter	27 (56.3%)	21 (43.8%)	

ANATOMICAL VARIATIONS (POSITION OF RLN) OF RECURRENT LARYNGEAL NERVE IN RELATION TO INFERIOR THYROID ARTERY

Variable	Group	Anterior Count (%)	Posterior Count (%)	In-Between Count (%)	Chi-Square p-value
Age	18-40	114 (41.9%)	127 (46.7%)	31 (11.4%)	0.739
	41-60	114 (40.4%)	140 (49.6%)	28 (9.9%)	
Gender	Male	115 (40.9%)	139 (49.5%)	27 (9.6%)	0.677
	Female	113 (41.4%)	128 (46.9%)	32 (11.7%)	
BMI	18-25	133 (52.4%)	121 (47.6%)	N/A	0.881
	>25	159 (53.0%)	141 (47.0%)	N/A	
Indication for Surgery	Right Solitary Nodular Goiter	60 (44.8%)	61 (45.5%)	13 (9.7%)	0.643
	Left Solitary Nodular Goiter	56 (41.8%)	61 (45.5%)	17 (12.7%)	
	Multinodular Goiter	89 (37.4%)	125 (52.5%)	24 (10.1%)	
	Diffused Goiter	23 (47.9%)	20 (41.7%)	5 (10.4%)	

DISCUSSION

The present trial intended to identify the variations in positions between the RLN and the inferior thyroid artery (ITA) which are significant to minimize the risk of accidental injury or damage while performing thyroid surgeries. Awareness about the anatomical location of this relation is crucial in eradicating RLN injury; which is common and has a severe consequences in patients undergoing thyroidectomy surgery. The present work is useful in gaining understanding on the displacement

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ISSN: (e) 3007-1607 (p) 3007-1593

differences in relation to RLN and ITA display variability as compared to reported literature.

The present study demonstrates that the RLN is posterior to the ITA in majority of the cases, anterior in 30% of the cases, and at the level of the ITA in 7% of the cases. This is in keeping with prior research, such as studies by Bakht Zada[10] and Tanglei Shao[11] who indicated that there was a common prevalence of posterior positioning. Nonetheless, the frequencies of all these variants in this study are somewhat different, which may be due to inter-population anatomic variation and variations in study design.

The posterior relationship of the RLN to the ITA is considered less vulnerable during thyroid surgeries. However, anterior crossing of the RLN, which we observed in 41.2% of cases, poses a higher risk of injury, as noted in studies by Nurcihan Aygun[12] and Xing Yao Ling,[13] where anterior positioning significantly increased the likelihood of vocal cord paralysis (VCP). Furthermore, the intermediate position, while less common, introduces additional complexity as the nerve traverses between branches of the ITA, increasing the risk of inadvertent injury.

The gender distribution in our study (50.7% male, 49.3% female) and the high proportion of overweight or obese individuals (BMI > 25 kg/m² in 54.2%) underscore the importance of considering demographic and anthropometric factors in surgical planning. While no significant gender differences in RLN positioning were identified in this study, previous research, such as that by Tanglei Shao,[11] has highlighted the importance of stratifying data by demographic variables to identify subtle variations.

Our study also reaffirms findings from international literature that the anatomical variations of the RLN-ITA relationship are influenced by the side of the neck. Consistent with studies by Samorekar et al[9] and Alison M.[14] Thomas, we observed that right-sided RLNs more frequently occupy an anterior position, whereas left-sided RLNs are predominantly posterior to the ITA.[15] This asymmetry highlights the need for heightened vigilance and tailored dissection approaches during right-sided thyroid surgeries.

The findings of this study emphasize the importance of preoperative imaging and intraoperative neuromonitoring in identifying RLN pathways. Neuromonitoring can help reduce the risk of RLN injury, as demonstrated in studies by Nurcihan Aygun,[12] which reported lower rates of transient and permanent VCP with its use. Additionally, systematic reviews like those by George Noussios[5] and Xing Yao Ling[13] underline the need for further research to establish standardized guidelines for addressing anatomical variability during thyroidectomy.

While this study provides robust insights into RLN-ITA anatomical variations, but having various limitations as well. The generalizability of our findings is limited for broader populations due to a single-center study. Additionally, our reliance on direct intraoperative observation, while accurate, may introduce observer variability. Future studies should explore larger, multicenter cohorts with diverse populations and integrate advanced imaging modalities such as intraoperative ultrasonography.

In conclusion, the anatomical relationship between the RLN and ITA exhibits significant variability, which necessitates meticulous surgical planning and execution. Understanding these variations is critical for reducing the risk of RLN injury and improving patient outcomes. Surgeons should maintain a high degree of awareness of these variations and consider incorporating neuromonitoring and preoperative imaging into standard practice to enhance surgical safety.

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