ORIGINAL ARTICLE

Investigating inter-thalamic adhesion in cadavers: Anatomical insights and radiological correlations

Suma Dnyanesh[1], Shilpa M. Bhimalli[1], Rajendra Mali[2], Anjali Patil[3], Dnyanesh K[4]*

[1]Department of Anatomy, [2]Department of Radiology, [3]Department of Community Medicine,

[4]Department of Pediatrics, KAHER's J. N. Medical College, Belagavi-590010 (Karnataka), India

Abstract

Background: The significance of Inter Thalamic Adhesion (ITA) has often been minimized due to its inconsistent presence and seemingly negligible functional relevance. Recent technological advancements in neuroimaging, however, have reignited interest in this anatomical feature, suggesting that its potential may be more complex than previously understood. *Aim and Objectives*: To determine the prevalence, morphology, and dimensions of the ITA in brains of people from North Karnataka. *Material and Methods*: A total of 100 brains (including 50 cadaveric specimens and 50 MRI scans) were examined in the midsagittal plane to detect the presence or absence of ITAs, as well as their location on the lateral wall of the third ventricle and their size. *Results:* The ITA was present in 90% of the samples. Out of the total sample, 38 brains were from female individuals, with an ITA absence observed in only 2 cases (5.2%). In the male group, comprising 62 brains, 8 individuals (12.9%) lacked an ITA. Oval shape was the most common (52 cases), followed by elliptical (33 cases) shape. The majority of ITAs (54 cases) were primarily located in the anterosuperior quadrant, often extending into the posterosuperior quadrant. Individuals younger than 50 years old exhibited significantly larger horizontal ($p = 0.001$) and vertical diameter ($p = 0.002$) measurements compared to those aged 50 and above. *Conclusion*: The absence and duplication of the ITA are quite frequent occurrences in brains of North Karnataka people. Evidence from morphometric data supports the concept that ITA's size changes with age. Future research should continue to explore the ITA's functional roles and its implications for neurological health and disease.

Keywords: Brain, Inter-Thalamic Adhesion, Cadaver, Thalamus, Neuroanatomy, Schizophrenia, Third Ventricle

Introduction

Inter Thalamic Adhesions (ITA), represent a slender, variably present structure connecting the two thalami within the third ventricle of the brain. Despite its size, the ITA serves as a connection point between the two thalamic bodies. Understanding its structure and function contributes to a more comprehensive understanding of the brain's intricate neural circuitry [1]. Although it is frequently mentioned in anatomical texts, the ITA's significance has often been minimized due to its inconsistent presence and seemingly negligible functional relevance. Recent technological advancements in neuroimaging, however, have reignited interest in this anatomical feature, suggesting that its potential may be more complex than previously understood. It is postulated to impact the pressure distribution within the third ventricular cavity by affecting flow of Cerebrospinal Fluid (CSF) [2]. Neurosurgeons performing endoscopic ventriculostomy often encounter morphological variations of ITA, particularly in those with neural tube abnormalities, where an enlarged ITA can obstruct the view of the third ventricle floor during the procedure for hydrocephalus. Therefore, a detailed understanding of

this structure is crucial for effective preoperative planning [3].

Accurate knowledge of ITA's anatomy is necessary for knowing the thalamic region's normal and variant anatomy, which is crucial for precise neuroimaging interpretation [4]. The anatomy of the ITA and its radiological correlates have not been thoroughly investigated in Northern part of Karnataka. Such a study is necessary to fill the knowledge gap, particularly since investigations and clinical procedures are known to be impacted by regional variations in anatomical structures. Furthermore, the correlation between radiological imaging and cadaveric discoveries can improve our comprehension of ITA's visibility and clinical significance, including its involvement in conditions like hydrocephalus and neurodegenerative disorders.

Thus the primary goal of this research was to conduct a detailed exploration of the ITA in cadaveric specimens, with an emphasis on anatomical characterization and radiological correlation within a population from North Karnataka. By combining meticulous dissection techniques with modern imaging modalities, this research aimed to elucidate the morphological variations and prevalence of the ITA, potentially aiding in the interpretation of neuroimaging findings and improving our understanding of its clinical significance.

Material and Methods

In this study, we employed a comparative approach, utilizing both cadaveric specimens and MRI images to investigate the ITA. A total of 100 brains were incorporated in this study, consisting of cadaveric specimens and MRI images. The study used a sample size of 50 cadaveric specimens and 50 MRI images to identify anatomical variations and assess their radiological correlations.

This balanced number was used to ensure the reliability of the observations. The sample size was also influenced by the availability of resources like cadaveric specimens, ensuring feasibility while maintaining study objectives.

Cadaveric brains

The inclusion criterion for cadaveric brains was intact brain that displayed no evidence of neuropathological diseases or visible anatomical abnormalities. Those with severe abnormalities and defects, intracranial lesions, or head injuries were excluded from the study. Fifty formalin-fixed adult cadaveric brains (37 male and 13 female) were obtained from the Department of Anatomy, KAHER's J. N. Medical College, Belagavi. They were carefully sliced through the body of the corpus callosum using a brain knife and cavity of third ventricle in the midsagittal plane ensuring minimal disruption to the midline structures. The presence or absence of the ITA was visually assessed. Two imaginary lines were used to split the third ventricle's lateral wall into four quadrants. The X-axis was established as a straight line connecting the highest point of the Anterior Commissure (CA) to the lowest point of the Posterior Commissure (CP). The Y-axis intersected the midpoint of this CA-CP line (Figure 1).The position of the ITA in relation to the lateral wall of the third ventricle was categorized into four quadrants: anterosuperior, anteroinferior, posterosuperior, and posteroinferior. Using digital calipers, their Horizontal Diameters (HD) and Vertical Diameters (VD) were measured (Figure 2). The anteroposterior length of ITA at the level of the posterior point of the interventricular foramen was defined as HD, while VD was defined as the vertical tangential length passing through its center. Brains with visible damage or pathological

abnormalities affecting the midline structures were excluded.

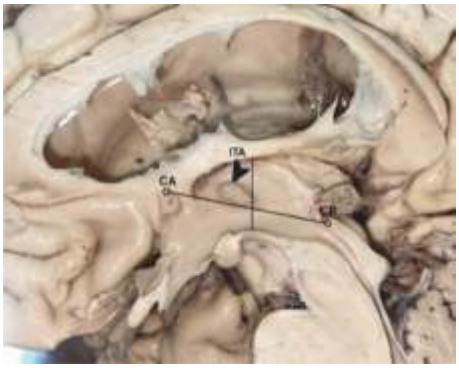


Figure 1: CA-CP line

Figure 2: Measurements with digital callipers

Figure 3: Double ITA in cadaveric specimen

MRI brain protocol

A 3.0 Tesla Siemens MRI machine (Magnetom Spectra) was used to examine the brains (25 male and 25 female) in axial, coronal, and sagittal planes using 4 mm contiguous slices, including sequences in FLAIR, gradient echo T1, spin echo T1, and turbo spin echo T2. The absence or presence of the ITA was determined by visually inspecting the scans for a distinct band of tissue connecting the two thalami (Figure 4**)**. Similar to the cadaveric specimens, the horizontal and vertical diameters of the ITA were measured in those scans where it was identifiable. The location of the ITA was also recorded based on the same quadrant system. A straight line from the superior most point of the CA to the inferior most end of the CP was established as the X-axis. The midpoint of this CA-CP line was intercepted by the Y-axis. This coordinate system divided the lateral wall of the third ventricle into four quadrants (Figure 5). By measuring the anteroposterior length of the ITA at the level of the posterior point of the interventricular foramen of Monro, the HD was determined. The VD was calculated by measuring its vertical tangential length across its center.

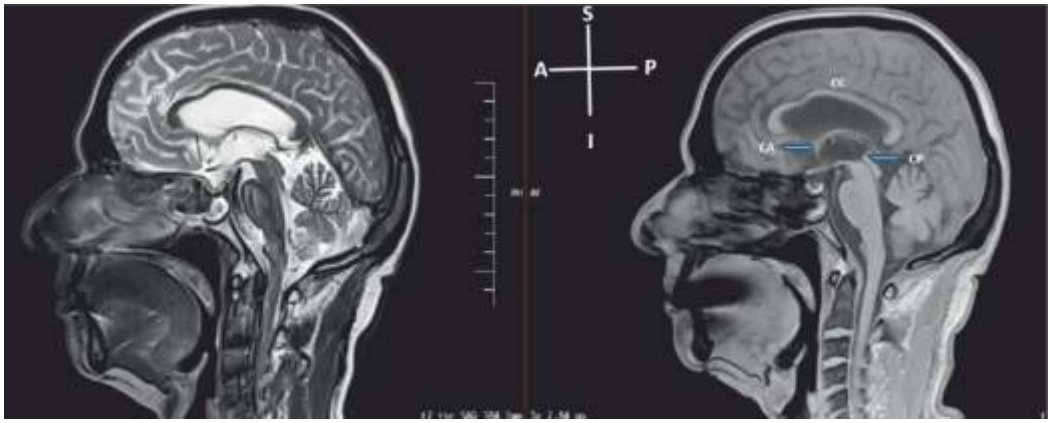


Figure 4: Sagittal T2W & T1W MR images without interthalamic adhesion. CA: Anterior commissure; CP: Posterior commissure; CC: Corpus callosum

Figure 5: Sagittal T1W MR Image shows interthalamic adhesion in anterosuperior (AS) and posterosuperior (PS) quadrants

Results

Prevalence and gender distribution

The presence of ITA was observed in 90% of the samples, indicating a high prevalence within the studied population. Out of the total sample, 38 brains were from female individuals, with an ITA absence observed in only 2 cases (5.2%). In the male group, comprising 62 brains, 8 individuals (12.9%) lacked ITA. Although this difference was not statistically examined, it indicates that females have a relatively higher prevalence of ITA than males.

Morphological variations

The ITA showed significant heterogeneity in its shape. The most common shape observed was round (52 cases), followed by oval (33 cases). Round and pinpoint ITAs were less common, observed in 3 and 2 cases, respectively. It was discovered to be double in 4 instances (Figure 3).

Location

The majority of ITAs (54 cases) were primarily located in the anterosuperior quadrant, often extending into the posterosuperior quadrant. In 32 cases,

the ITA was tightly restricted to the anterosuperior quadrant. Interestingly, one case presented with an ITA spanning all four quadrants of the third ventricle.

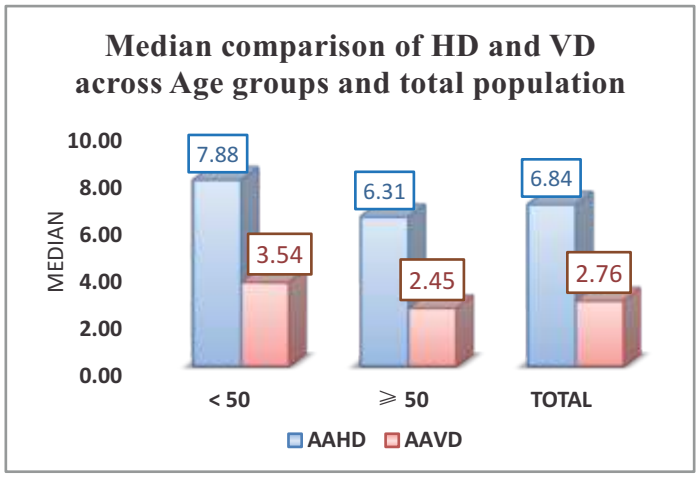
Dimensional analysis and correlations

Analysis of ITA dimensions showed differences that were statistically significant in both HD and VD across different age groups (Figure 6). Individuals younger than 50 years old exhibited significantly larger HD and VD measurements compared to those aged 50 and above ($p = 0.001$ for HD, $p = 0.002$ for VD) (Table1).

Table 1: Correlations between dimensions and age

Age	Mean ± SD	Mean Rank	Z	*p*	n
HD					
< 50	7.57 ± 3.96	59.5	-3.276	0.001 **	46
⩾ 50	5.71 ± 2.62	40.65	--	--	52
Total	6.58 ± 3.43	--	--	--	--
VD					
< 50	4.01 ± 2.92	59.1	-3.145	0.002 **	46
⩾ 50	2.55 ± 1.44	41.01	--	--	52
Total	3.24 ± 2.36	--	--	--	--

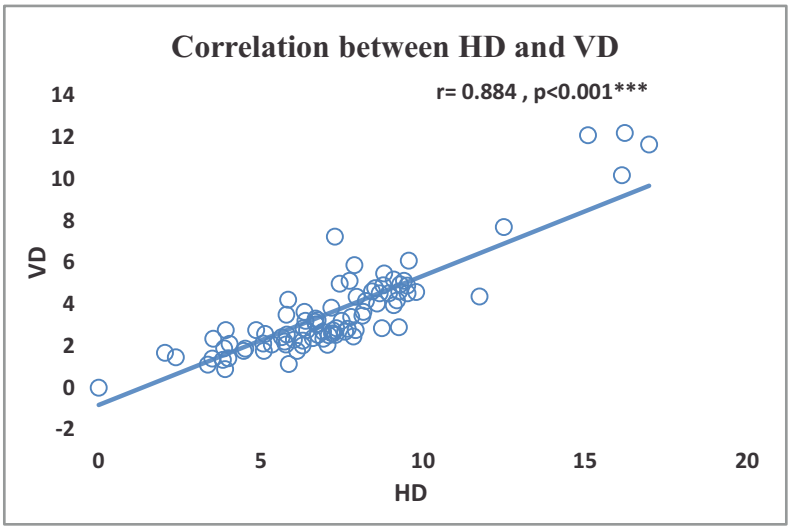
HD – Horizontal diameter; VD – Vertical diameter



HD – Horizontal diameter; VD – Vertical diameter

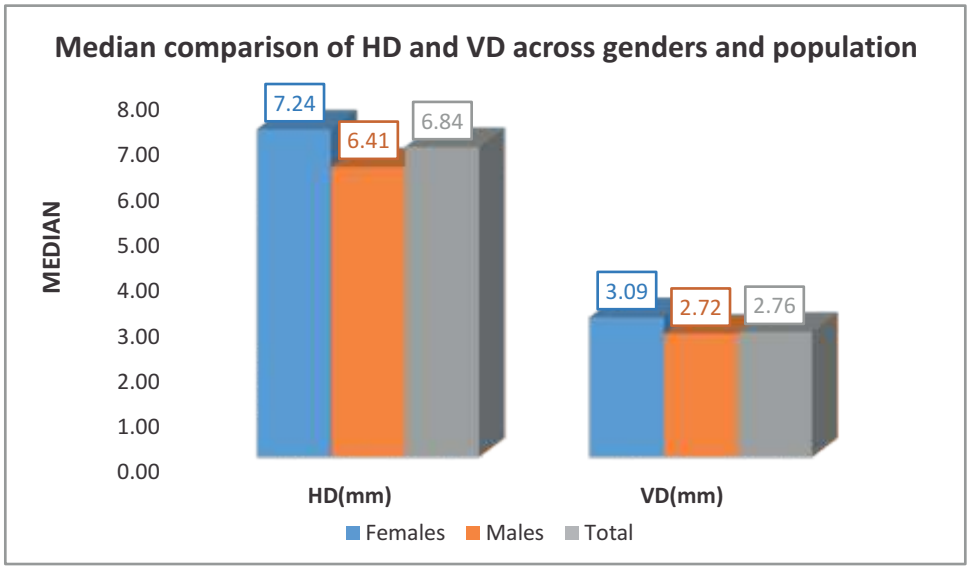
Figure 6: Correlation between dimensions and age

Further analysis using Spearman's correlation coefficient revealed a weak to moderate negative association between age and both HD (r = -0.31, p = 0.002) and VD (r = -0.338, p = 0.001). This suggests a trend of decreasing ITA dimensions with increasing age. There was a significant positive connection found between HD and VD (r = 0.884, $p < 0.001$), indicating that larger horizontal dimensions are generally associated with larger vertical dimensions of the ITA (Figure 7). No significant difference was found in HD and VD values between males and females with $p > 0.05$ (Figure 8).



HD – Horizontal diameter; VD – Vertical diameter

Figure 7: Correlation between HD and VD



HD – Horizontal diameter; VD – Vertical diameter

Figure 8: Comparison of HD and VD across genders

Discussion

ITA represents a midplane anatomical body that serves to connect the thalami, exhibiting notable variations in both morphology and prevalence [1, 5]. Existing literature indicates that, the prevalence rates of ITA falls within the range of 70-87.3% in individuals deemed healthy [6-7]. In a study by Patra *et al*., the ITA was observed in 87% of the 100 brains examined. They discovered that men had it more frequently than women [6]. On the other hand, it was more frequent in females in the current study

Allen and Gorski *et al*., reported that ITA was observed in 78% females and 68% males after studying 100 healthy cadavers [8]. Andrew *et al*., found the prevalence of ITA in healthy population to be 87.3%, with females exhibiting a higher prevalence regardless of the imaging modality utilized [9]. Alireza *et al*., who studied 1410 participants noted that females exhibited 2.75 times greater likelihood of having ITA [10]. Kyung *et al*., studied 146 Korean brains and reported a prevalence of 88.4% [11]. ITA was detected in 90% of participants in the current investigation, with females accounting for 94.8% of cases. The 90% frequency that we found in our study is consistent with other findings that it is a common occurrence in general population (Table 2).

Table 2: Prevalence in different population

Study	Total sample size	Female sample size	Female ITA presence (n)	Male sample size	Male ITA presence (n)	Overall ITA absence (n)	Overall ITA presence (n)
Patra *et al.*	100	30	26 (86.67%)	70	61 (87.14%)	13%	87%
Allen and Gorski	100	50	39 (78%)	50	34 (68%)	27%	73%
Korean Study	146	--	--	--	--	11.6%	88.4%
Fikret *et al.*	161	--	--	--	--	8.6%	91.4%
Current study	100	38	34 (94.8%)	62	54 (87.1%)	10%	90%

ITA – Interthalamic adhesion

Absent ITA was identified in 14 out of 161 patients in a research conducted by Fikret *et al.*, in individuals who underwent MRI evaluation which accounted for 8.6% [12]. In the present study, we found it to be absent in 10% cases. Prior research discusses the relationship between the absence of ITA and mental health issues, particularly schizophrenia spectrum disorders. In residual schizophrenia, a higher prevalence of ITA absence was observed, suggesting a potential association with negative symptoms [13]. A study done by Borghei *et al*., showed, patients admitted to hospitals due to their first episode of schizophrenia displayed a lack of ITA [14]. Haghir *et al*. also tried to establish a connection between ITA absence and schizophrenia but failed to provide definitive findings [13]. Conversely, de Souza Crippa and colleagues found that while the lack of the ITA was similar in both cases and controls, it was slightly more common in male schizophrenia patients [15].

Various morphological types of ITA have been observed in previous studies, such as type 1 (adherent/ adhesion appearance), type 2 (commissure/ bridge appearance), type 3 (no adhesion), and type 4 (double bridge) [16]. In the present study we found type 1 ITA in all the cases.

Pavlovic *et al*. utilised the CA-CP line technique in a study involving 43 Serbian brains to identify ITA. The majority of the brains exhibited ITA presence in the anterosuperior quadrant extending caudally into the posterosuperior quadrant in 16 instances (41.02%). However, merely two cases (5.13%) displayed complete localization within the anterosuperior quadrant. According to them, ITA establishes connections between the thalami in the anterior-superior quadrants of the lateral walls of the third ventricle [16]. Similar findings were also reported by Apurba *et al*. [1]. The same authors conducted another study by the using magnetic resonance images in which ITA was found located commonly in the anterosuperior quadrant with posterosuperior extension (76.74%). Discrepancies in the ITA location between cadaveric brains and MR images may be because of variations in the ITA size [6].

Conversely Kyung *et al*., revealed that it was predominantly situated in the center of the third ventricle positioning in the posterior-superior quadrant in 146 Korean brains [11]. The present study is aligning with previous studies with the majority of ITA (54 cases) primarily situated in the anterosuperior quadrant often extending into the posterosuperior quadrant. In 32 cases, it was strictly confined to the anterosuperior quadrant. We also noted a large ITA which measured 16.98 mm horizontally and occupied all the four quadrants. The observation of a markedly large ITA was documented in a male cadaver, which measured approximately 3 cm in diameter that occupied a substantial portion of the third ventricle, thereby potentially contributing to disruptions in CSF flow [17]. A case of obstructive hydrocephalus was reported by Amisha *et al*., due to an enlarged ITA [18].

Different morphological types of ITA have been reported in previous studies. These studies indicate a general trend in the distribution of ITA shapes, with round and oval being more common, and elliptical and pinpoint being less frequent. The same was reported in the current study. The variations may be influenced by the sample population and the methodologies used in each study.

The appearance of ITA typically emerges around the second trimester of gestation, accompanied by various characteristics of the ventricular system of

the brain. As individuals age, the third ventricular capacity expands, eventually leading to the shrinkage of the ITA [17]. Numerous investigations have elucidated age-related changes in ITA. Its presence is a common occurrence, yet it may be absent in up to 35% of instances. Research indicates a reduction in the size of ITA as individuals age, particularly beyond 70 years, while younger individuals tend to exhibit larger ITAs. Its nonexistence can be identified in early childhood, suggesting a congenital etiology, and with advancing age its prevalence decreases [16]. MRI is a cornerstone of neuroscience research and also a critical diagnostic tool in medicine. It enables the identification of anatomical variations, such as malformations or developmental abnormalities, and is crucial for detecting and monitoring infections that affect the brain [19-20].

Using MRI, Mohammadi *et al*. assessed ITA in people of the South-East of the Caspian Sea border. The study reported that there was no relationship between ITA dimensions and age or gender groups [21]. On the contrary, Ying reported the existence of variations in both the dimensions and presence of ITA in relation to age and gender [22].

In a study done by Alireza *et al*., the occurrence of ITA was evident in 87.3% using MRI on a cohort of 1410 participants stretching from 2 months to 93 years of age. The absence of ITA was particularly noticeable in the early stages of life and declined with advancing age. ITA also called as Massa Intermedia (MI) has been linked to cognitive differences and psychiatric disorder manifestations in individuals lacking MI [10]. Mehmet and colleagues examined alterations associated with age and observed its increased frequency in the paediatric population [5].

Allen and Gorski, in their study, reported that pediatric patients who present with midline abnormalities frequently had ITA defects. Absence, dysmorphism, displacement of ITA were more commonly observed in patients with such abnormalities [8]. While certain studies have lacked documenting a decline in ITA prevalence with increasing age, research conducted by Trzesniak *et al*., has indicated a decrease in ITA prevalence as individuals grow older [23]. Fikret *et al*. observed a thinning and elongation of the ITA with increasing age [12]. Shane and colleagues indicated that ITA experiences progressive atrophy following the third decade of life and has the potential to diminish in elderly subjects, irrespective of their brain volume [24]. Current study revealed that individuals younger than 50 years exhibited significantly large ITA as compared to those above 50.

This raises the question of whether age indeed influences the prevalence of ITA. Clarity on this issue might be possible with a thorough longitudinal study spanning across all age groups. The discrepancies in age and gender-related findings may be linked to atypical processes in neurodevelopmental growth, but are more frequently observed in males [25]. Research conducted by Nishad *et al*. has yielded findings that offer proof of gender disparities in ITA dimensions throughout the entire course of life. These variations have been connected to cognitive processes and the nearby thalamic structure. The dimensions of the ITA, encompassing HD and VD, are found to exhibit differences, notably with females displaying larger average areas compared to males [26]. Fikret *et al*., revealed that the horizontal length was more in males compared to females, while the vertical and anteroposterior lengths were similar across both genders

[12]. Apurba *et al*., carried out two distinct investigations concerning ITA, where they found the HD was greater than the VD in all the cases [1, 6]. Statistical analysis of ITA in current study revealed a strong positive correlation between HD and VD, indicating that larger horizontal dimensions were linked with larger vertical dimensions.

Clarissa *et al*., reported in her study that patients with mesial temporal lobe epilepsy had reduced length of ITA, which may contribute to cognitive impairment [27]. According to a study done by Ann *et al*., lack of ITA was detected in 12.9% of healthy individuals which was linked to decreased volume of gray matter in specific brain areas involved in emotional and cognitive regulation. The study found that brains lacking ITA had reduced gray matter volume in the premotor cortex, inferior frontal gyrus, and anterior temporal cortex [28].

Conclusion

Exploration of ITA in cadaveric specimens, combined with radiological correlations, has yielded important insights into this often-overlooked anatomical structure. Recognizing the ITA's anatomical variations can enhance the precision of neurosurgical procedures involving the thalamus, potentially reducing surgical risks and improving patient outcomes. Furthermore, the ability to identify and assess the ITA through imaging can support the early diagnosis and management of conditions that affect the thalamic region, thereby contributing to better clinical care. Radiological correlation is particularly significant where precise imaging is essential for planning neurosurgical interventions and understanding the structural integrity of the thalamus in various neurological conditions. Our study enriches the existing body of knowledge and lays the groundwork for further investigations into the ITA's functional importance. Future research should continue to explore the ITA's functional roles and its implications for neurological health and disease.

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***Author for Correspondence:**

Dr. Suma Dnyanesh, Department of Anatomy, KAHER's J. N. Medical College, Belagavi- 590010, Karnataka, India

Email: drsuma410@gmail.com Cell: 8147483424

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