The Central Thalamic Nucleus as the Core Hypothesis of the Consciousness Vortex Model

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Abstract

The neural basis of consciousness is a central issue in the field of neuroscience, with the "hard problem" of consciousness revolving around the unclear physical origin of subjective experience. Existing theories (such as IIT, GWT, etc.) are confined to information-logic recursive frameworks, failing to identify core physical structures and often focusing on the cortex, which contradicts clinical evidence that thalamic damage leads to loss of consciousness. To address these limitations, this paper proposes and argues that **the central medial thalamic nucleus (CM) is the core anchor for consciousness generation.** Using the **Consciousness Flow Vortex Model (CFVM)** as an analytical framework, the study systematically elucidates CM's critical role in information convergence, rhythm regulation, and global integration from three dimensions: closed-loop cycles, central focusing, and global synchronization. The analysis demonstrates that CM can serve as the central anchor for consciousness production, effectively explaining the characteristics of awareness, integration, stability, and subjectivity in consciousness. This hypothesis not only constructs a comprehensive theoretical model for consciousness research but also provides a clear structural localization for the neural mechanisms of consciousness, offering new opportunities for breakthroughs in the neuroscience of consciousness.

Keywords: Central medial thalamic nucleus, consciousness anchor, consciousness vortex theory, physical origin of subjective experience, consciousness awakening and awareness, CFVM, conscious awareness

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1. Introduction

The problem of consciousness is the ultimate challenge jointly faced by philosophy, clinical medicine, and neuroscience, with its core bottleneck lying in the "lack of origin": to date, there is no universally accepted, operational definition of the essence of consciousness, nor has the core physical locus supporting the generation of consciousness been identified (Chalmers, 1995) David Chalmers. Compared to cognitive functions such as vision, movement, and memory, which have clear neural foundations, consciousness research has long been in a state of lacking a unified theoretical foundation and explicit structural anchors, leading to a fragmented research impasse and difficulty in forming a falsifiable unified theoretical system (Block, 1995; Tononi et al., 2016).

To break through this dilemma, the academic community has proposed four mainstream

theories of consciousness: the Global Workspace Theory (GWT), Integrated Information Theory (IIT), Dynamic Core Hypothesis, and Higher-Order Thought Theory (HOT). GWT views consciousness as the global broadcasting of information across cortical networks (Baars, 1988); IIT quantifies consciousness through integrated information (Φ value) (Tononi, 2004); the Dynamic Core Hypothesis explains consciousness based on thalamocortical network clusters (Edelman & Tononi, 2000); and HOT interprets conscious representation from the perspective of cognitive monitoring (Rosenthal, 2005). These theories have propelled consciousness research into an empirical stage, yet all possess fundamental limitations.

Current theories remain at the level of phenomenon induction and functional modeling, failing to identify the core structure triggering consciousness (Koch, 2024). GWT cannot explain the origin of cortical broadcast initiation (Baars et al., 2019); IIT lacks fixed brain region specificity, making targeted verification challenging (Oizumi et al., 2014); the dynamic core hypothesis does not differentiate functional differences among thalamic subnuclei (Edelman, 2003); HOT detaches from the physical substrate of consciousness (Block, 2007). Overall research emphasizes the cortex over the thalamus, prioritizes networks over anchor points, leading to a lack of unified frameworks in clinical diagnosis and mechanism studies (Laureys et al., 2004).

Addressing these limitations, this paper proposes the core hypothesis of the consciousness vortex model: the centromedian nucleus (CM) of the thalamus serves as a necessary anchor point for consciousness integration, responsible for information convergence, rhythm synchronization, and state maintenance; the cortex acts as a content processor, governing perceptual encoding and higher-order consciousness decoding. This model complements existing cortical theories, with CM providing core anchoring and dynamic forces, while the cortex offers content dimensions, synergistically forming a complete consciousness system (Schiff & Plum, 2000). This paper integrates anatomical connectivity, electrophysiological data, functional magnetic resonance imaging (Fmri), clinical lesion evidence, and deep brain stimulation (DBS) evidence to multimodally demonstrate CM's role as a consciousness anchor point.

This paper is divided into eight parts: first, the problem is posed in the introduction, followed by an elaboration on the construction of the consciousness vortex model, the anatomical basis of the central thalamic nucleus, multimodal evidence from imaging, electrophysiological, and clinical pathological perspectives. Through discussion, the theoretical innovations are clarified, clinical significance is defined, and finally, the conclusions of the entire paper are summarized.

2.0 The Consciousness Vortex Model—The Core Dynamic Mechanism of Conscious Awareness

2.1 Tracing the Origin of Consciousness—The Background of the Consciousness Vortex Model

The fundamental question in consciousness research has always been to answer how consciousness emerges from neural activity and how subjective awareness arises from objective physical processes. This "origin problem" constitutes the core of consciousness science and remains a bottleneck that existing theories struggle to break through. Whether it is the **Global**

Workspace Theory (GWT)'s characterization of cortical broadcasting functions (Dehaene & Changeux, 2011), Integrated Information Theory (IIT)'s quantification of system integration (Tononi et al., 2016), or the Dynamic Core Hypothesis's emphasis on network synchrony (Edelman & Tononi, 2000), these theories essentially describe the network features or functional manifestations of consciousness after its emergence, rather than tracing the initial mechanisms, core structures, and dynamic processes by which consciousness **transitions from nonexistence to existence, from physical to subjective** .

In other words, existing theories stop at the **phenomenological level** of consciousness and fail to touch upon the **source** of consciousness emergence. Therefore, true breakthroughs in consciousness research must return to the source: elucidating the **initial structure, core dynamics, and closed-loop mechanisms** that support consciousness generation, and constructing a unified theory that fully maps the conditions and internal logic of consciousness production.

This study, based on the core axiom of neuroscience that "structure determines function," proposes the **Consciousness Vortex Model**. This model is not a philosophical metaphor; it represents a specific structure and a physical mechanism of action.

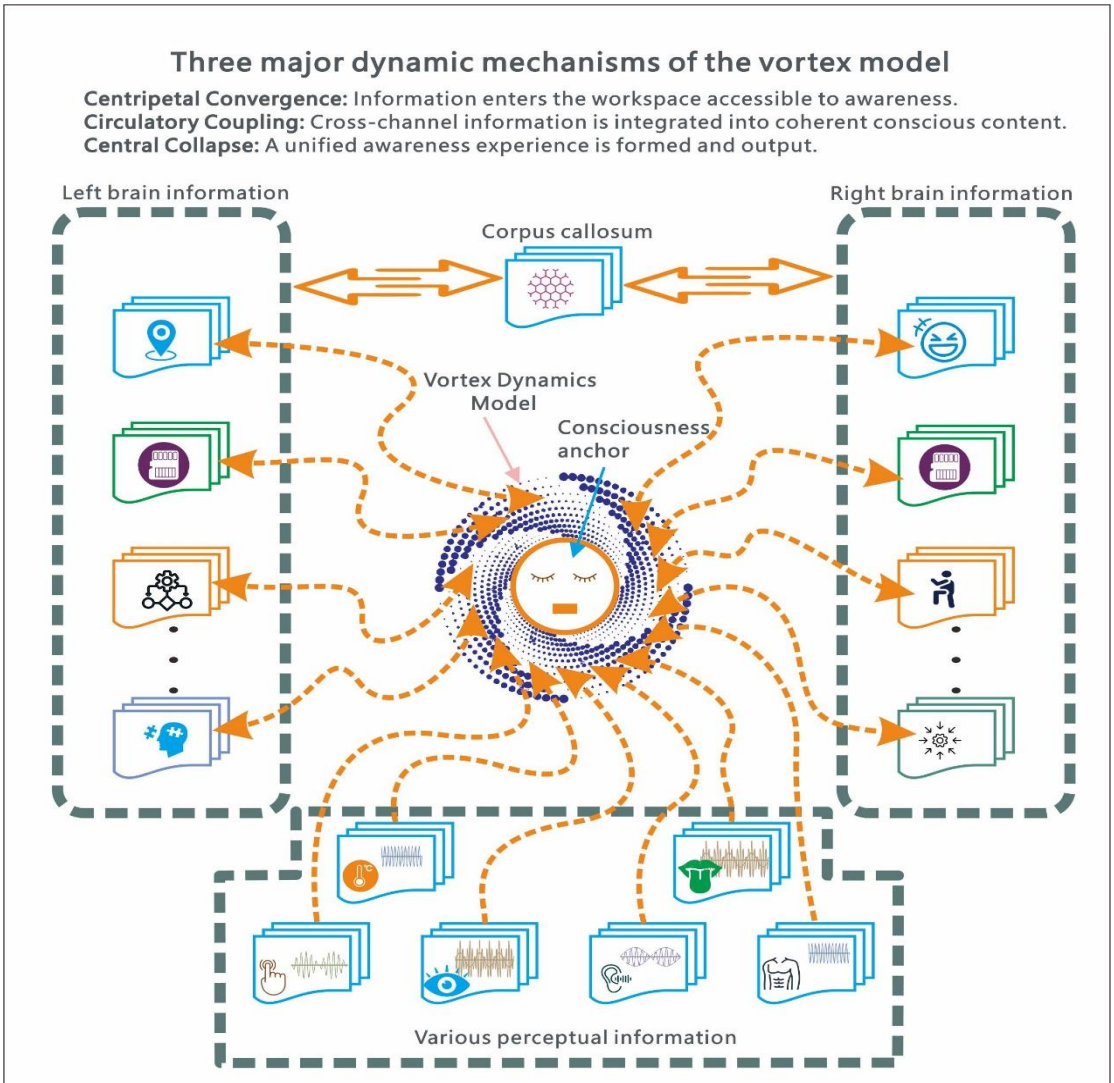

FIGURE 1|Schematic Diagram of Information Integration Mechanism of Consciousness Stream Vortex

2.2 Vortex Dynamics Model — The Neurostructural Basis of Real Existence

Based on the reflection and integration of existing cortical center theories, tracing back to the fundamental mechanisms of consciousness generation naturally leads to the **Vortex Model of Consciousness**. The common limitations of current theories lie in: **emphasizing outcomes over origins, networks over anchor points, and functions over dynamics**. GWT fails to explain the **initiation origin** of global broadcasting; IIT lacks a **specific core structure** to support integrated information; the dynamic core hypothesis does not clearly identify the **organizer** of network synchronization; thalamus-related studies remain scattered across localized functions such as arousal, attention, and modulation (Schiff, 2010), failing to distill a unified mechanism for consciousness generation. This limitation has been corroborated in recent large-scale empirical tests: adversarial collaboration experiments published in Nature (2025) (Cogitate Consortium et al., 2025) show that the core predictions of the two mainstream consciousness theories, GWT and IIT, are unsupported by experimental evidence and cannot explain the key mechanisms of consciousness generation. The Vortex Model of Consciousness builds upon these theories by further tracing back to the source, integrating the necessary conditions, core structures, dynamic processes, and internal logic of consciousness emergence into a **self-consistent, complete, and testable** theoretical framework.

This model is not an abstract metaphor but is grounded in **real neural structures**:

- **Vortex Core (Central Medial Thalamic Nucleus, CM)** : Illustrated centrally is the **core node** of whole-brain information convergence and rhythm synchronization, as well as the **central anchor point** of the consciousness vortex (Van der Werf et al., 2002).
- **Vortex Arms (Thalamo-System Neural Network)** : The radiating projection fibers from CM in the diagram are responsible for **driving cortical processing upward and feeding back information downward** , forming the information projection pathways of the vortex (Schiff, 2022).
- **Interhemispheric Synchronization Structure (Corpus Callosum)** : The commissural fibers connecting the left and right cerebral hemispheres ensure the **synchronized transmission and integration** of information processing across both hemispheres, supporting the **unity** of conscious experience (Bloom & Hynd, 2005).

Together, these three components form the **physical foundation** of consciousness generation, naturally fulfilling the two essential requirements of **central unity and global integration** .

2.3 Vortex Dynamics — Fully Mapping the Three Core Mechanisms of Consciousness Generation

With the structural basis clarified, the consciousness vortex model, through the three dynamic phases of **centripetal convergence, circulatory coupling, and central collapse** , comprehensively maps the entire process from information input to awareness generation:

- **Centripetal Convergence**: Multimodal sensory information from the cortex, thalamus, and periphery converges directionally into CM **(centromedian nucleus)**, entering a workspace accessible to consciousness (Llinás et al., 1998).
- **Circulatory Coupling**: Information forms a**sustained recursive loop** between CM and the cortex, where cross-channel information is integrated into coherent conscious content, establishing a stable vortex ring (recursive closed-loop) dynamic (Destexhe, 2009).
- **Central Collapse**: Under the**rhythmic synchronization** of the intralaminar nuclei,

dispersed neural information ultimately "collapses" into a**unified, coherent subjective awareness experience** and is output (Buzsáki, 2006).

This "structure-dynamics" system simultaneously adheres to three**core logical principles**:

- **Closed Cycle**: Information originates from CM, undergoes cortical processing, and returns to CM, forming a**uninterrupted recursive closed loop**;
- **Recursive Feedback**: Bidirectional thalamocortical projections enable the**continuous integration and iterative optimization** of information;
- **Central Anchoring**: CM locks in the**global rhythmic synchronization** to stabilize the**stability, unity, and subjectivity** of consciousness.

In summary, the consciousness vortex model integrates **structural anchors, logical closure, and dynamic mechanisms** into a unified whole, inherently satisfying the **recursive self-sustaining** requirements for consciousness generation, achieving a leap from "phenomenological description" to "source mechanism explanation."

2.4 Vortex Operational States—Determining Arousal and Awareness

Based on the operational principles of the consciousness vortex model, the relationship between arousal and awareness can be clearly defined: When the consciousness vortex autonomously initiates operation through the endogenous neural rhythms of the central thalamic nucleus, the brain enters a stable state of arousal. This process relies solely on intrinsic dynamics and does not require external information input (Pinault, 2004; Steriade, 2003).

Building upon this foundational arousal, sensory information such as visual, auditory, and somatosensory inputs converges into the vortex system via the vortex arm pathways, participating in the convergence and circulatory coupling of information flow. The initially simple neural arousal state further evolves into conscious content with subjective dimensions, i.e., conscious awareness (Merker, 2007).

In short, autonomous vortex operation generates arousal, while sensory information participation facilitates awareness. These two processes are sequential, mechanistically independent yet interdependent, clearly delineating the essential differences between basic neural arousal and higher-order subjective conscious experiences. This framework also provides a rational dynamical explanation for various states of consciousness disorders.

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3. The Thalamus and Central Nucleus: Anatomical Structures and Mechanisms of Consciousness Integration

3.1 The Core Axiom of Structure Determining Function

Structure determines function is a core axiom in biology and neuroscience (Dobzhansky, 1973). From neuronal morphology to neural circuit topology, the specificity of anatomical structure has always been the physical basis for the realization of system functions (Honey et al., 2010; Sporns, 2011). In the thalamic system, the location, cytoarchitecture, and connectivity patterns of nuclei directly define their roles in the whole-brain information network (Sheridan & Tadi, 2023). The central medial nucleus (CM) of the thalamus, as a key member of the intralaminar nuclear group, possesses unique anatomical positioning, cellular structure, and projection pathways. These features are not randomly arranged but rather represent an "optimal structural

solution" formed through evolution to adapt to multimodal information integration functions (Lilyasa et al., 2019; Van der Werf et al., 2002). From the perspective of structure determining function, CM's central position within the internal medullary lamina of the thalamus naturally makes it a convergence node for the ascending reticular activating system, subcortical pathways, and extensive cortical projections (Saalmann, 2014). The anatomical environment enclosed by the internal medullary lamina endows it with unique neural communication advantages and circuit isolation properties (Jones, 1998). The superposition of these structural characteristics ultimately determines CM's critical function as the core anchor of the consciousness vortex model, enabling cross-regional information synchronization and awareness generation.

From a macroscopic anatomical perspective of the brain, the central medial nucleus (CM) of the thalamus is situated at the center of a typical nested structure: it is enveloped by thalamic regions, while the thalamus itself lies at the core of the telencephalic region. This hierarchical nesting from macro to micro scales endows the CM with a natural anatomical advantage for integrating whole-brain information, providing a structural foundation for its role as the central anchor in the consciousness vortex model.

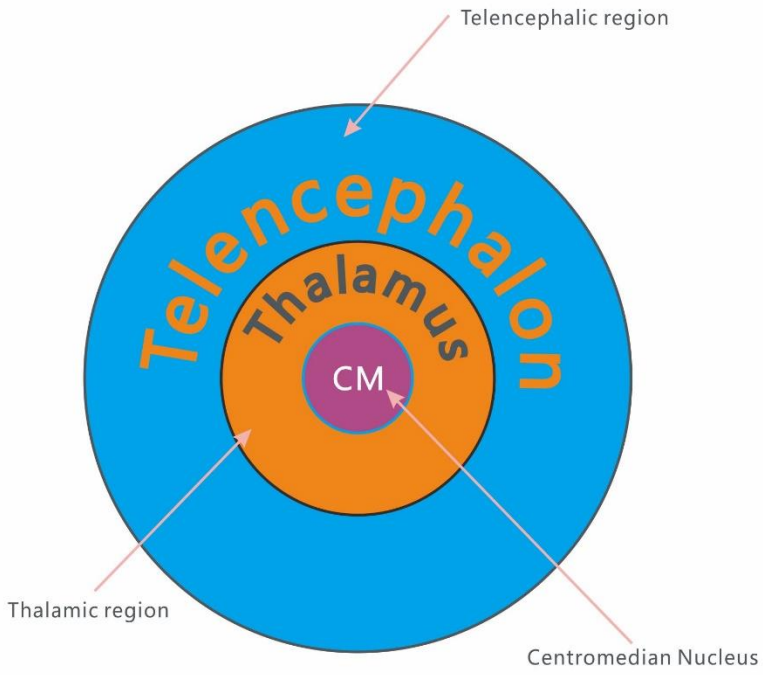

FIGURE 2|The Nested Location of the Centromedian Nucleus (CM) in the Macrostructure of the Brain

From a local thalamic perspective, the central medial nucleus (CM) occupies a highly centralized anatomical and functional network hub, a distribution pattern that directly reflects its structural basis as a global information integration hub (Jones, 1998; Van der Werf et al., 2002).

In terms of physical location, the CM is enveloped by the internal medullary lamina of the thalamus. Through the internal medullary lamina pathway (red dashed line in the figure), it

forms direct, bidirectional communication connections with multiple surrounding thalamic nuclei. These include the anterior nuclear group (AN) involved in emotion and memory regulation, the medial/lateral geniculate bodies (MGN/LGN) processing auditory and visual information, the ventral posteromedial nucleus (VPM) mediating facial and oral sensations, the ventral anterior nucleus (VA) participating in motor control, as well as the midline thalamic nuclei (MTN) and mediodorsal nucleus (M/MD), among others. Simultaneously, the CM establishes secondary connections via other internal thalamic pathways (orange dashed lines) with the ventral lateral nucleus (VL), ventral posterolateral nucleus (VPL), and lateral posterior/dorsal lateral nuclei (LP/LD), forming a radial network centered on the CM that covers multimodal information such as sensation, movement, cognition, and emotion.

This local topological structure centered on the CM endows it with unique functional advantages: it does not merely act as a relay station for single sensory modalities, but can simultaneously receive, integrate, and coordinate information inputs from different thalamic nuclei, achieving synchronization and unification of cross-modal signals (Saalmann, 2014). This is precisely its core structural support as the integration anchor in the consciousness vortex model.

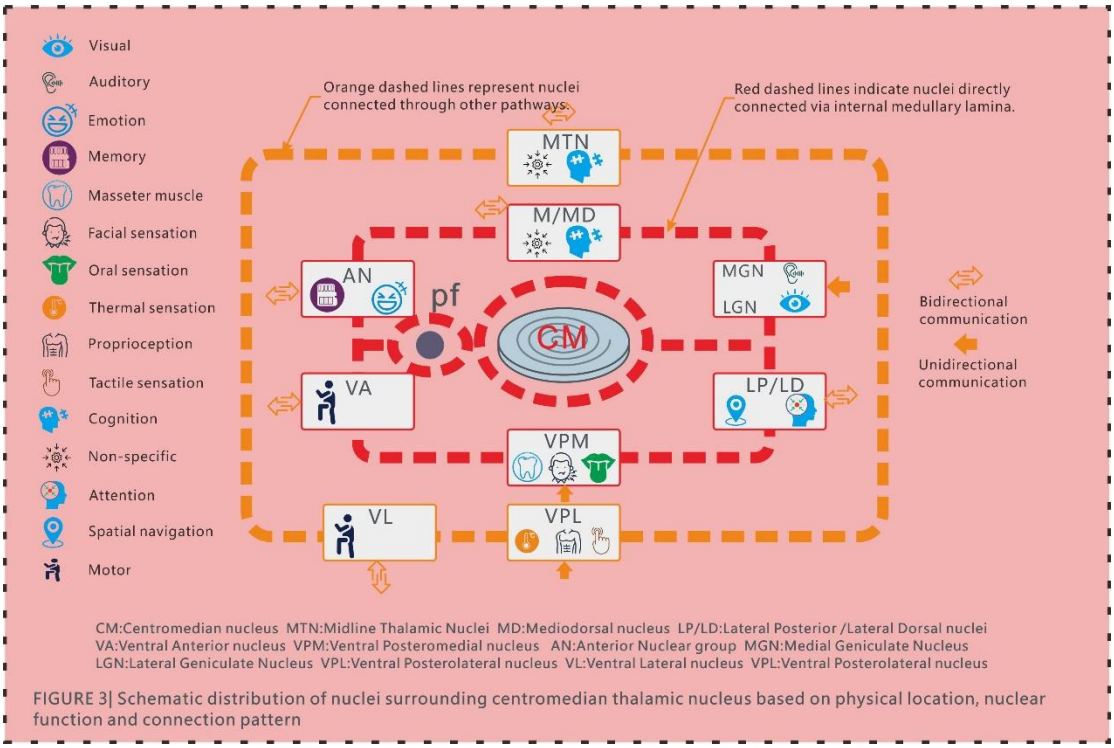

FIGURE 3| Schematic distribution of nuclei surrounding centromedian thalamic nucleus based on physical location, nuclear function and connection pattern

3.2 Central Nucleus (CM) – "Centrality" and "Coreness" Individual Traits

The CM is located within the internal medullary lamina of the thalamus and is the largest and most well-developed nucleus in the posterior intralaminar nuclear group, exhibiting a lenticular shape with all dimensions less than 10 mm and a volume of approximately 310 mm^3. Its neuronal density is as high as about 2200 neurons/mm^3, with a total neuron count of approximately 664,000–682,000 (Jones, 1998 and Morel et al., 1997), making it one of the thalamic nuclei with the highest neuronal density. The CM primarily consists of medium-sized, spiny multipolar neurons and can be divided into a dorsomedial magnocellular region and a ventrolateral parvocellular region. The cellular distribution exhibits a center-focused gradient characteristic, naturally forming a "center-radiation" topological structure.

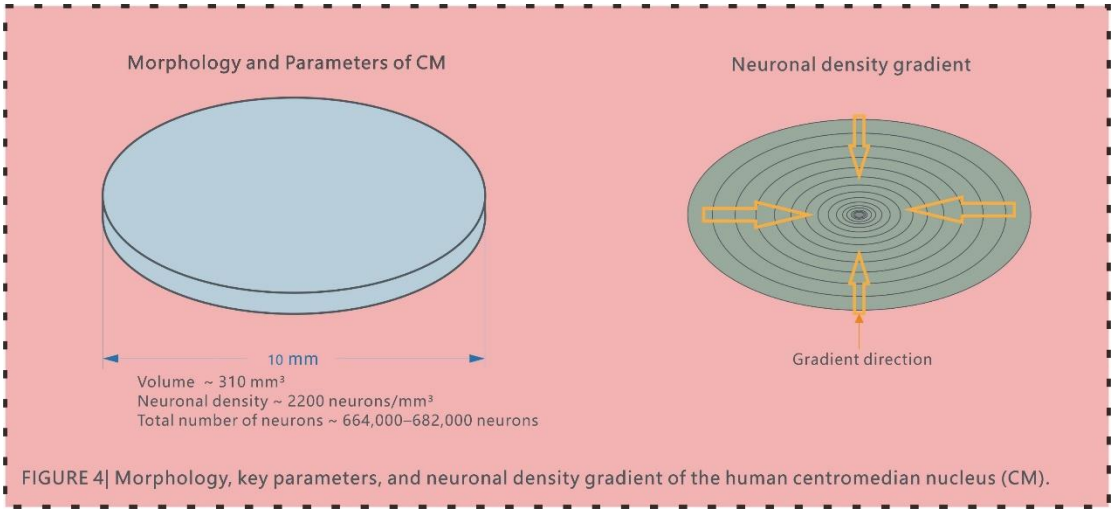

FIGURE 4| Morphology, key parameters, and neuronal density gradient of the human centromedian nucleus (CM).

This study hypothesizes that the centromedian nucleus (CM) of the thalamus may be regarded as a consciousness awakening anchor—a physical entity for the initial formation of consciousness—laying the material foundation and theoretical groundwork for future consciousness research.

From the perspective of an "endogenous image display," the high-density neuronal clusters in the CM form the "pixel array" basis for information processing. Its extensive cortical projections and multimodal information integration capabilities position it as a core node for integrating signals from different sensory channels and constructing a unified subjective image stream. These anatomical structural features provide a robust neurobiological foundation for the continuity, integrity, and unity of conscious experience.

3.3 CM Anatomical Location – The Physical Center of the Thalamus

Whole-Brain Core Convergence Node: It is located in the core area of the thalamic internal medullary lamina, surrounded by all key thalamic nuclei such as the ventral anterior nucleus, ventral posterior nucleus, medial dorsal nucleus, and parafascicular nucleus, making it the only structure within the thalamus that can simultaneously access all nuclei (Jones, 1998);

Centralized Topological Structure: From a whole-brain perspective, the CM is situated at a critical midline deep-brain position, serving as the convergence hub of the brainstem-thalamus-cortex tripartite structure: it receives descending cortical signals above, connects to the ascending reticular activating system of the brainstem below, and links to the limbic system and basal ganglia laterally, acting as a key node for global information flow (Van der Werf et al., 2002). This highly centralized topological connectivity naturally positions it as the convergence and divergence center of whole-brain information flow, providing critical structural foundations for the consciousness vortex model.

Radiating Central Structure: The internal medullary lamina fibers radiate from the CM to surrounding nuclei, forming a topological structure centered on the CM, which aligns closely with the information convergence characteristics of a vortex center (Jones, 1998).

3.4 Complete Encapsulation by the Internal Medullary Lamina – CM as the Whole-Brain Data Convergence Anchor

The most fundamental structural characteristic of the central medial thalamic nucleus (CM) lies in its complete encapsulation and penetration by the dense fibers of the internal medullary

lamina, forming the critical anatomical foundation for global information exchange:

Ultimate Communication Speed: The internal medullary lamina consists of highly myelinated large-diameter axons, enabling neural conduction speeds of 30–50 m/s. Embedded directly within the core of the internal medullary lamina, the CM facilitates direct, millisecond-level information exchange across the entire brain without synaptic relay, providing the structural prerequisite for continuous, delay-free transmission of conscious streams (Jones, 1998).

Global Interaction Efficiency: As the thalamic "information superhighway," the CM establishes bidirectional connections with nearly all thalamic nuclei via internal medullary lamina fibers, enabling instantaneous integration of multimodal neural signals at the CM. This positions the CM as the central hub for intra-thalamic information exchange (Van der Werf et al., 2002).

Synchronization Regulation Basis: The dense fiber environment of the internal medullary lamina provides favorable conditions for the CM to participate in the synchronization regulation of thalamocortical circuits. Through neural oscillations such as theta waves, the CM contributes to the rhythmic coordination of activity across the entire thalamus and cortex, ensuring the dynamic stability of consciousness-related neural processes (Saalmann, 2014).

Long-range projection topological structure: CM neurons are predominantly composed of highly myelinated long projection fibers that extensively project along the internal medullary lamina to the entire cerebral cortex, basal ganglia, brainstem, and limbic system. These fibers can broadcast synchronized signals throughout the brain and enable closed-loop regulation, serving as a key anchor for consciousness-related whole-brain functional integration (Jones, 1998).

Central hub for whole-brain information interaction: The internal medullary lamina contains bidirectional projection fibers connecting thalamic nuclei, the cortex, and the brainstem. CM, situated at the intersection of these high-density pathways, acts as a natural hub for whole-brain information exchange (Jones, 1998; Van der Werf et al., 2002).

Topological centrality: The Y-shaped bifurcation structure of the internal medullary lamina positions CM at the dual anatomical and connectivity center within the three-dimensional thalamic space, providing a structural foundation for centripetal information convergence (Jones, 1998).

3.5 Clustering of major functional nuclei—highlighting the central hub position

The core advantage of the thalamic central medial nucleus (CM) lies in its position at the convergence center of the brain's key functional nuclei, making it the central integration hub for whole-brain consciousness information. These nuclei are listed in order of increasing physical distance:

Parafascicular nucleus (Pf): The parafascicular nucleus is small in volume with densely packed cells, forming a tight nuclear complex with the centromedian nucleus of the thalamus. It is a critical subunit within the thalamic intralaminar nuclei involved in the global regulation of neural rhythms (Jones, 1998). The Pf extensively receives ascending arousal signals from the brainstem, specific sensory inputs from the thalamus, and descending regulatory information from the cortex. It integrates and rhythmically organizes multi-frequency neural oscillations, enabling phase alignment and temporal synchronization of activities across different brain regions (Van der Werf et al., 2002). The output of this nucleus prioritizes interactions within thalamic internal circuits, transmitting calibrated global rhythmic signals to

the CM (centromedian nucleus), which then coordinates whole-brain synchronization via thalamic radiations. Direct projections to the cerebral cortex serve only as a secondary pathway (Jones, 1998). During wakefulness, the Pf maintains stable high activity levels, ensuring sustained global neural synchronization. Under consciousness-suppressed states such as anesthesia or sleep, its neural activity significantly declines, accompanied by the disintegration of whole-brain coherence. During consciousness recovery, the Pf's rhythmic functions can reactivate first, mediating the return of brain networks to synchronized steady states. Thus, the Pf is a pivotal structure in maintaining global neural integration and supporting the unity of consciousness (Van der Werf et al., 2002).

Ventral posteromedial nucleus (VPM): The ventral posteromedial nucleus (VPM) of the thalamus is a specific sensory nucleus, traditionally described as relaying head and facial somatic sensations and gustatory information to the primary somatosensory cortex (Jones, 1998). However, from the perspective of conscious integration, the reciprocal connections between VPM and the centromedian nucleus (CM) of the thalamus hold more critical functional significance. VPM transmits processed head, facial, and visceral sensory information directly to CM via intrathalamic pathways, providing essential modality-specific inputs for CM's multimodal integration (Van der Werf et al., 2002). In contrast, according to the axiom that structure determines function, VPM's projections to the primary somatosensory cortex solely serve precise local sensory representation and play a secondary role in the global synchronization of consciousness. Thus, VPM should functionally be regarded more as an "upstream input node" to CM rather than merely a cortical relay station.

Dorsomedial nucleus / Mediodorsal nucleus (M/MD): The dorsomedial nucleus of the thalamus is a core component of the medial thalamic nuclear group, with extensive bidirectional projections to the prefrontal cortex and limbic system. It participates in higher cognitive functions such as working memory, attentional regulation, decision-making, and emotional regulation (Jones, 1998). The MD and CM have tight intrathalamic functional connectivity, working together to form the thalamic cognitive-arousal integration circuit. This circuit integrates advanced cognitive and emotional regulation information into the global integration network, supporting the dynamic regulation of conscious states and the richness of perceptual content (Saalmann, 2014).

Medial geniculate nucleus (MGN): The medial geniculate nucleus is a specific auditory relay nucleus in the thalamus, classically known for mediating the transmission and detailed processing of auditory information to the primary auditory cortex (Jones, 1998). Research indicates that, in addition to its cortical projection pathways, the MGN can also transmit preliminarily processed auditory information to the CM via intrathalamic pathways, contributing to the global integration of multimodal information (Van der Werf et al., 2002). Its cortical pathways primarily serve local perceptual functions such as auditory detail discrimination and sound localization, while its CM projection pathways are involved in constructing global conscious scenes. Thus, the MGN can be regarded as an upstream auditory input unit to the CM.

Lateral Geniculate Nucleus (LGN): The lateral geniculate nucleus is a classical visual relay nucleus in the thalamus, responsible for transmitting visual information from the retina to the primary visual cortex to complete the initial parsing of visual signals (Jones, 1998). In addition to the traditional cortical pathway, the LGN can transmit preprocessed visual signals

to the CM through intrinsic intra-thalamic fiber connections, providing visual-dimensional information support for global multimodal integration (Van der Werf et al., 2002). Comparative analysis reveals that the LGN–cortical pathway emphasizes the encoding of visual details, while the LGN–CM pathway participates in the unified construction of the global conscious scene, reflecting its upstream input function that serves global awareness.

Anterior Thalamic Nucleus (AN): The anterior thalamic nucleus is a key node in the limbic-thalamic circuit, primarily involved in the relay regulation of episodic memory encoding, spatial navigation, and emotional information (Jones, 1998). The AN receives memory- and emotion-related signals from the hippocampal-mammillary body pathway and transmits this information to the CM via intra-thalamic pathways, providing contextual continuity and emotional-dimensional support for conscious experience (Van der Werf et al., 2002). Its cortical projections to the cingulate gyrus and prefrontal cortex mainly maintain the homeostasis of local memory and emotional circuits, while the AN–CM pathway participates in the integration of global conscious content, serving as a critical upstream source of memory and emotional information for the CM.

The aforementioned core functional nuclei of the thalamus are anatomically adjacent to the CM and functionally transmit specific sensory, cognitive, memory, and emotional information to the CM, forming an intrinsic thalamic integration network centered on the CM. Existing classical thalamic theories emphasize the specific information relay function of each nucleus to the cortex, focusing on localized processing of perception and cognition (Jones, 1998). However, based on the core neuroscientific axiom that structure determines function, combined with the CM's unique central topological position, its clustered connectivity pattern with other brain nuclei, and its extensive upstream and downstream projections, it can be inferred that the central medial thalamic nucleus is not merely a secondary relay structure. Instead, it serves as a core neural substrate for global information integration, rhythm synchronization, and the emergence of awareness, acting as a key hub in the construction of a unified field of consciousness.

3.6 All Features Point to CM as the Anchor of Consciousness Generation

Synthesizing the anatomical and functional analyses of the central medial thalamic nucleus (CM) in this chapter, and proceeding from the neuroscientific axiom that "structure determines function," its multiple structural features collectively indicate the pivotal role of CM as the core anchor for consciousness generation:

Topological Centrality: The CM is located at a critical topological node within the thalamus and the entire brain's information pathways, serving as a natural convergence hub for multimodal sensory, cognitive, and emotional information. This provides a structural foundation for global regulation in consciousness integration (Jones, 1998; Van der Werf et al., 2002).

Complete Encapsulation: The dense fibrous encapsulation of the internal medullary lamina provides the CM with a relatively independent signal loop environment, offering an anatomical basis for its involvement in the rhythmic synchronization and dynamic stability of the thalamocortical loop (Jones, 1998; Saalmann, 2014).

Functional Hub: The clustered distribution of major functional nuclei in the thalamus positions the CM as a core node for global information interaction and synchronous regulation, endowed with the critical capacity to drive coordinated neural activity across the brain (Van der Werf et

al., 2002).

These combined structural and functional characteristics indicate that the CM is one of the few thalamic nuclei that simultaneously integrates information, maintains closed-loop operations, and enables global regulation, serving as a key neural substrate and central anchor for conscious awareness.

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4. Imaging Evidence—Strong Correlation Between Consciousness and the Anchor

Multiple independent high-field (3T/7T) functional magnetic resonance imaging (fMRI) studies consistently demonstrate that the central thalamic nucleus (including the centromedian-parafascicular complex) exhibits highly reproducible imaging features during conscious states, fully aligning with the consciousness hub model. Key evidence includes:

4.1 Magnetic Resonance Imaging During Wakeful Consciousness

In the conscious state, the central thalamic nuclei exhibit a centrally localized, highly activated region with the highest symmetry and intensity within the thalamus.

High-resolution 7T-fMRI studies reveal that during the awake resting state, a localized activation focus with sharp boundaries and significantly higher signal intensity compared to surrounding nuclei appears in the central thalamic region. This focus aligns closely with the centromedian nucleus (CM) and parafascicular nucleus (Pf) complex. The central high-intensity pattern is not an isolated occurrence but a highly stable common feature among healthy subjects, demonstrating nearly perfect bilateral symmetry in the thalamus. This supports its role as a topological hub for global signaling (Cambareri et al., 2025; Zhang et al., 2025; Dehaene et al., 2014).

4.2 Activation Pattern Magnetic Resonance Imaging

In the conscious state, the activation pattern of the centromedian thalamic nucleus (CM) exhibits omnidirectional symmetry, radiating in a circular distribution centered on itself without directional bias. Functional connectivity analysis reveals that the centromedian nucleus does not form dominant connections with unidirectional cortical or subcortical regions. Instead, it projects broadly and radially to the entire cerebral cortex and thalamic subnuclei, forming a densely central, annularly diffused functional connectivity network. This unbiased symmetric pattern aligns with the anatomical structure where internal medullary lamina fibers converge into the CM, providing a functional foundation for the dynamic integration of whole-brain information.

4.3 Magnetic Resonance Imaging in Anesthesia, Sleep, and Disorders of Consciousness

Multiple studies on anesthesia and disorders of consciousness consistently demonstrate that as consciousness levels decline, the BOLD signal in the centromedian thalamic nucleus shows significant attenuation, disrupting the symmetry of its central highlighted regions and collapsing the radial functional connectivity pattern. When subjects awaken from anesthesia or sleep, or when patients with impaired consciousness regain awareness through treatment, the central activation of the CM rapidly recovers, and the annular functional connectivity network

is reconstructed. These dynamic changes are highly synchronized with the "on/off" transitions of conscious states **(Baker et al., 2014; Owen et al., 2025)**.

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5. Electrophysiological Evidence—Consciousness Strongly Correlates with Anchoring Points

Electrophysiological recordings from the centromedian nucleus (CM) of the thalamus provide dynamic and direct validation of its central role as a key anchoring point for consciousness-related neural activity.

5.1 Intrinsic Link Between High-Frequency Oscillations and Vortex Mechanisms

During wakeful consciousness, CM neurons exhibit prominent high-frequency electrical activity in the gamma band (30–100 Hz), and these oscillations synchronously drive coherent activity in bilateral cortical regions (Llinás et al., 1998; Steriade, 2000).
Within the framework of the consciousness vortex model, this phenomenon is not merely rhythmic synchronization but a critical electrophysiological signature of the multimodal information integration process in the CM, corresponding to the complete sequence of "information convergence → resonance modulation → perceptual salience" within the CM. When multimodal information is integrated into a unified conscious content, the global gamma wave synchrony is significantly enhanced.

5.2 Temporal Key Anchoring Points for Consciousness State Transitions

During anesthesia induction, sleep-wake transitions, and in patients with impaired consciousness, changes in the electrical activity of the CM occur earlier than cortical signal alterations: during anesthesia, CM neuronal firing rates are suppressed first, and during awakening, they recover earliest, accompanied by the restart of cortical synchronized activity. This electrophysiological temporal characteristic of "preceding the cortex and preceding consciousness" strongly suggests that the CM is a critical regulatory anchor for the initiation and maintenance of consciousness (Alkire et al., 2008; Baker et al., 2014).

5.3 Dynamic Hub of Cross-Regional Coherence

Intracranial electrophysiological recordings reveal significant functional connectivity between the central medial thalamic nucleus (CM) and key consciousness nodes in the default mode network and frontoparietal control network, such as the prefrontal and parietal cortices. The strength of this connectivity is significantly positively correlated with subjective clarity of consciousness and task awareness levels in subjects (Van der Werf et al., 2002; Dehaene et al., 2014). Further research indicates that CM field potential changes can predict the efficiency of cortical multimodal information integration and the activation state of the global workspace in advance. This corroborates the CM's core role as a dynamic hub for whole-brain information interaction: by maintaining coherent oscillations with cortical consciousness networks, it enables synchronized transmission and integration of cross-regional information, providing the essential neural foundation for coherent and unified conscious experiences.

5.4 The Central Nucleus as the Strongest Core Anchor Point for Whole-Brain Synchrony

Resting-state functional connectivity analysis confirms that the central thalamic nucleus is a

key hub in the whole-brain functional network, exhibiting the highest functional connectivity strength and phase synchrony with all brain regions among thalamic nuclei.

Anesthesia studies further provide causal evidence: inhibition of central nucleus activity directly leads to the collapse of whole-brain cortical synchrony; in animal models under anesthesia, electrical stimulation of the central thalamic nucleus significantly restores cortical cooperative activity. These findings suggest that the central nucleus plays a dominant regulatory role in driving whole-brain neural synchronization and integration, serving as a critical upstream structure for global cooperative activities related to consciousness states (Lupi et al., 2026; Cambareri et al., 2025).

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6. Clinical Pathological Evidence—Consciousness Strongly Correlates with Anchor Points

6.1 Strong Causal Evidence: DBS Stimulation of the CM-Pf Complex Directly Restores Consciousness

Schiff et al. (2007) reported a case of a patient who remained in a minimally conscious state for 6 years after traumatic brain injury. After receiving deep brain stimulation of the bilateral centromedian nucleus (CM-Pf complex), the patient's level of consciousness significantly improved, restoring abilities such as following commands, uttering words, and watching movies (Schiff et al., 2007).

A meta-analysis including 49 patients with chronic disorders of consciousness showed that 7 patients experienced significant recovery of consciousness after DBS treatment, with all effective patients undergoing surgery within 12 months post-injury. Their CRS-R (Coma Recovery Scale-Revised) scores showed significant improvement (Zhang et al., 2025).

These clinical intervention findings directly corroborate the functional role of the CM-Pf complex as a core anchor of the consciousness vortex: applying electrical stimulation to it can actively drive the reboot of whole-brain synchronized activity, providing the necessary neural foundation for the generation of conscious experience.

6.2 Electrophysiological "Fingerprint" Evidence of CM in Patients with Disorders of Consciousness

Compared to patients in a minimally conscious state (MCS), patients in a vegetative state (VS/UWS) exhibit significant differences in CM/Pf nuclear group neurons: reduced number of activated neurons, prolonged burst discharge duration (average >8ms), and decreased discharge intensity. The "neuron index" constructed based on CM neuron activity shows a significant positive correlation with the patient's CRS-R score, enabling precise differentiation of consciousness levels and prediction of rehabilitation outcomes **(Chen et al., 2024)**.

6.3 Temporal Switching Effects of CM Under Anesthesia/Sedation

General anesthetics (e.g., propofol) specifically inhibit the activity of thalamic intralaminar nuclei (including CM), blocking their synchronized input to the cortex, leading to loss of consciousness**(Bastos et al., 2021)**. During patient recovery, high-frequency oscillatory activity in CM precedes cortical activity restoration, serving as a critical temporal anchor for

consciousness "reboot," directly reflecting its hub role as an "anchor"**(Andrada et al., 2012)**.

6.4 Direct Association Between CM Damage and Consciousness Impairment

Occlusion of the Percheron artery supplying the bilateral paramedian thalamic regions (including the CM) leads to bilateral thalamic infarction. Patients exhibit fluctuating levels of consciousness, persistent drowsiness, or even coma, with the severity directly correlated to the extent of CM nucleus damage **(Kang et al., 2023)**. fMRI studies in patients with chronic disorders of consciousness show significantly reduced functional connectivity of the CM nucleus. Moreover, the strength of its connections with the prefrontal and parietal cortices is directly related to the patient's level of consciousness**(Chen et al., 2020)**.

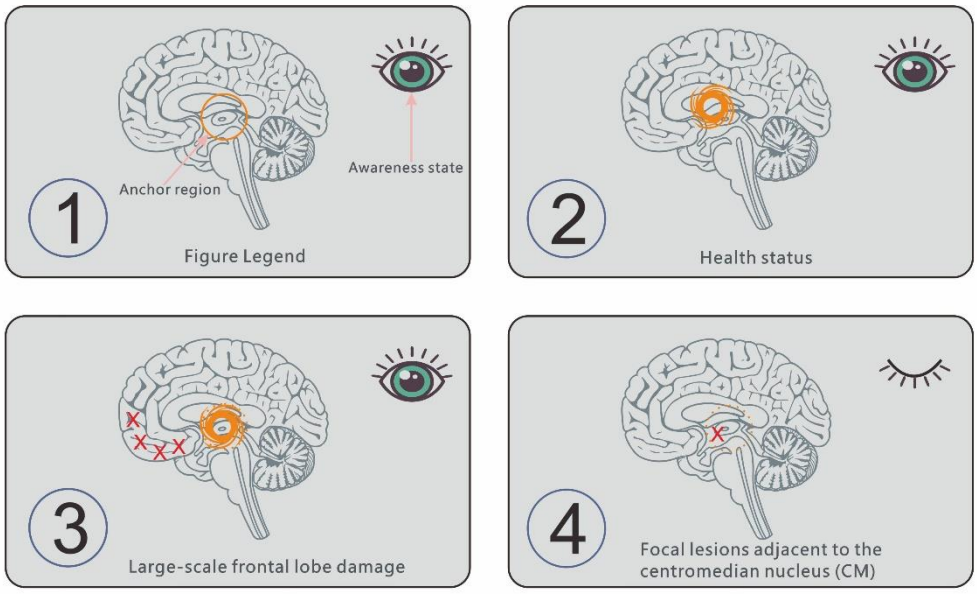

FIGURE 5|Schematic Comparison of the Effects of Large-Scale Cerebral Cortex Damage Versus Focal Lesions Adjacent to the Centromedian Nucleus (CM) on Awareness State

7. Discussion

7.1 The Vortex as a Non-Philosophical Metaphor

The consciousness vortex model proposed in this study is not an abstract philosophical metaphor, nor does it aim to identify a physical "vortex anatomical structure" within the brain. Instead, it is a testable neurodynamic model constructed based on the anatomical topology, neuronal density gradients, and functional connectivity patterns of the centromedian (CM) and parafascicular (Pf) thalamic nuclei (Luppi et al., 2024; Schiff et al., 2007).

It describes the dynamic signal integration logic of the central thalamic nucleus as an anchor point of consciousness: through the centripetal convergence structure, the functional manifestation of central collapse, and the dynamic mechanism of circulatory coupling, achieving centripetal convergence, circulatory coupling, and recursive self-verification, forming a self-consistent and self-sustaining neurodynamic closed loop. All its core elements highly correspond to the real characteristics of CM, possessing clear scientific verifiability, and hold significant reference value for later consciousness neuroscience research in terms of

expression and understanding (Zhang et al., 2025).

7.2 Re-positioning and Division of Functions of Thalamic Nuclei

From the perspective that structure determines function, this study boldly redefines the functions of various thalamic nuclei in the consciousness circuit, which is also a significant highlight of this research (Jones, 2025):

- **Specific input nuclei (LGN, MGN, VPM, VPL, AN, MD)**: These nuclei are not, as traditionally believed, primarily functioning to project directly to the cortex. Instead, they act as pre-input stations for unimodal information, with their main information flow directed internally within the thalamus, preferentially transmitting preliminarily processed sensory, emotional, and memory signals to the intralaminar nuclei (CM-Pf). Projections to the primary cortex only convey spatially localized information, playing a secondary role in the global construction of consciousness (Luppi et al., 2024).
- **Collaborative Nuclei (CL, Pc, Pf):** : The intralaminar thalamic nuclei are a collection of nuclei embedded within the internal medullary lamina. Among them, the centromedian nucleus (CM) serves as the core functional hub of this nuclear group, while the central lateral nucleus (CL), paracentral nucleus (Pc), and parafascicular nucleus (Pf) are functional units that form synergistic circuits with CM. Together, they support the CM-centered process of global information synchronization and integration (Monti et al., 2025).
- **Centromedian Nucleus (CM)** : As the ultimate integration anchor for conscious experience, CM receives multimodal content inputs from other thalamic nuclei, completes the final integration of information, and broadcasts it to the entire cortex via radial projections, constructing a unified and continuous conscious awareness experience (Schiff et al., 2007; Zhang et al., 2025).

7.3 Explicit Rejection of the Traditional Cortical Origin of Consciousness

Based on the axiom "structure determines function," combined with the macroscopic location of the thalamic centromedian nucleus (CM) in the brain, its anatomical positioning within the thalamus, its role as a topological hub for global information convergence, and its unique structure surrounded by the internal medullary lamina and critical nuclei, this study explicitly rejects the traditional view that "the cortex is the core source of consciousness" (Jones, 2025; Coppola, 2025).

The cortex is essentially only responsible for the decoding function during conscious activity execution and lacks the centripetal convergence and closed-loop circulation structure required for the self-organization and self-maintenance of consciousness; while the CM, as the topological center of whole-brain information, is the original anchor point of conscious awareness (Luppi et al., 2024).

This diagram illustrates the theoretical framework of the traditional cortical-centric theory: assuming that the consciousness anchor points are located in the left and right cerebral cortices, with the central medial thalamic nucleus (CM) merely serving as a passive information relay station. However, this model has fundamental flaws: the cortex lacks a topologically centripetal convergence structure, and interhemispheric synchronization is difficult to achieve due to physical distance, ultimately leading to the fragmentation and incoherence of conscious experience. The shortcomings of this hypothetical model precisely highlight the superiority of the consciousness vortex model centered on the CM proposed in this study.

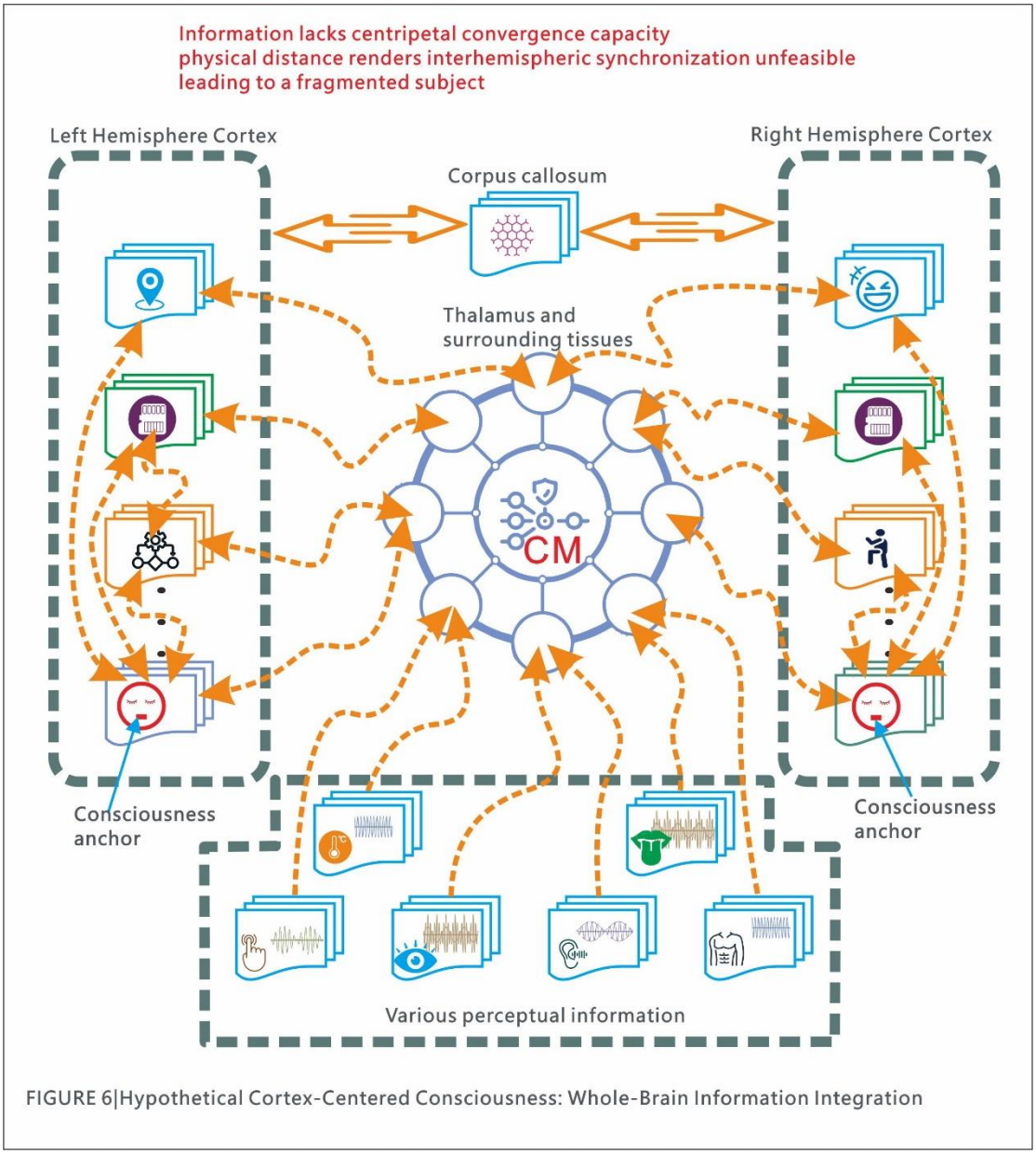

FIGURE 6|Hypothetical Cortex-Centered Consciousness: Whole-Brain Information Integration

In recent years, there has been a significant shift in the paradigm of consciousness neuroscience research. The traditional view that the cerebral cortex dominates consciousness has gradually been questioned. Multiple high-level empirical studies have confirmed that thalamic nuclei, especially the central medial thalamic nucleus (CM), play a decisive regulatory role in consciousness awakening, perceptual gating, and anesthesia-induced loss of consciousness. Subcortical thalamic nuclei have now become the frontier and core direction in current research on consciousness mechanisms (Monti et al., 2025; Schiff et al., 2007).

7.4 Clinical Significance

The consciousness vortex model proposed in this study offers novel explanations for various clinically observed consciousness-related phenomena: anesthetic-induced coma, sleep-wake cycles, disorders of consciousness, fluctuating awareness in vegetative states, and encephalopathic consciousness disturbances may all be directly linked to abnormal CM activity and global neural synchronization imbalances (Zhang et al., 2025; Luppi et al., 2024). These

findings provide potential biomarkers and intervention targets for clinical assessment, treatment, and prognosis determination of consciousness disorders (Monti et al., 2025).

7.5 Research Limitations and Future Directions

This study has the following limitations: Current experimental data lack direct functional connectivity and interaction mechanisms between specific thalamic nuclei and the centromedian nucleus (CM), making it challenging to fully elucidate CM's role as a consciousness anchor in whole-brain integration circuits (Chauvin et al., 2025). Future research could employ high-resolution electrophysiological recordings and targeted modulation techniques to investigate signal transmission patterns and cooperative mechanisms between thalamic nuclei and CM, potentially revealing the core neural substrates of consciousness generation (Luppi et al., 2024; Zhang et al., 2025).

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8. Conclusion

This study proposes a consciousness vortex model (not merely a philosophical metaphor) based on the neurodynamic characteristics of consciousness generation, providing a verifiable explanatory framework for the mechanism of conscious awareness. Guided by the core axiom of "structure determines function," this research integrates anatomical structures, functional connectivity, electrophysiological features, imaging evidence, and clinical pathological manifestations to systematically support the hypothesis that the central medial thalamic nucleus (CM) serves as the core anchor of consciousness.

The consciousness vortex model and the CM consciousness anchor theory point to new research directions for exploring the nature of consciousness; however, a complete elucidation of their underlying core mechanisms still relies on subsequent targeted electrophysiological and clinical intervention studies to further validate and deepen these findings.

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