Magnetic Resonance Imaging Methods for Identifying and Delineating the LGN

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Introduction:

The Lateral Geniculate Nucleus (LGN) is a nucleus in the thalamus's posterior part, which links the retinas to the primary visual cortices. The LGN's structure is organized into six coaxially located layers. The four dorsal layers of the LGN are the Parvocellular (P) layers that get input from the midget retinal ganglion cells. The two most ventral layers are Magnocellular (M) and originate from the parasol retinal ganglion cells. The cells in the P and M layers differ in their physical structure (e.g., myelination) and the stimuli that activate them. It has been shown that the LGN undergoes functional and structural changes in the presence of optic neuropathies. However, the LGN's small size has made its identification and delineation challenging and of limited diagnostic use. Here we review MRI methods for LGN localization.

Methods:

A systematic review of publications was done by searching articles containing both keywords of Lateral Geniculate Nucleus(/Body) and MRI. We classified the articles according to the method used to structural, diffusion, and functional MRI-based methods.

Results:

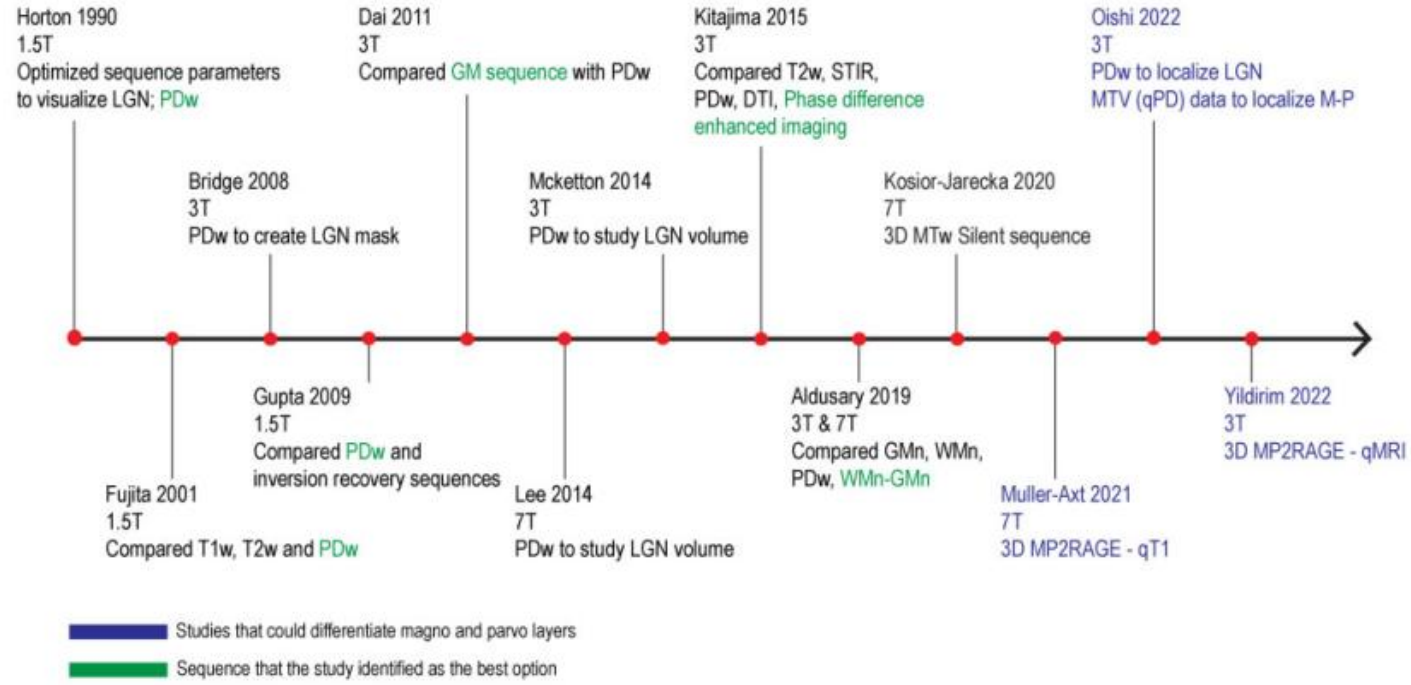
Different structural imaging contrasts, such as proton density-weighted imaging, phase difference enhanced imaging, and white-matter null minus gray-matter null imaging have been suggested as candidates for LGN visualization[1,2]. In recent years, quantitative imaging has also shown promise in LGN P-M layer segregation. Nevertheless, factors such as time constraints or the use of already acquired datasets result in reliance on T1w data where the LGN boundaries are not visible. In these scenarios, probabilistic atlas mapping using Bayesian inference, region growing, and edge enhancement techniques can be useful. However, poor T1 contrast in the posterior thalamus can still lead to LGN misclassification[3-5]. Considering the small target size and between-subject variability, using population atlas-registration methods is not recommended (Figure 1).

In diffusion imaging, the LGN can be delineated by building probabilistic tractography between thalamus voxels and the visual cortex or by classifying local diffusion properties within the thalamus mask[6,7]. The probabilistic tractography approach led to inaccurate results due to dependencies on target definition. In addition, the visual cortex has some confounding connections with other thalamic nuclei, including the inferior Pulvinar; hence, clustering does not identify all voxels of the LGN as belonging to a single cluster. The classification approach requires the determination of the number of clusters; additionally, large voxel sizes have hindered success finding small nuclei.

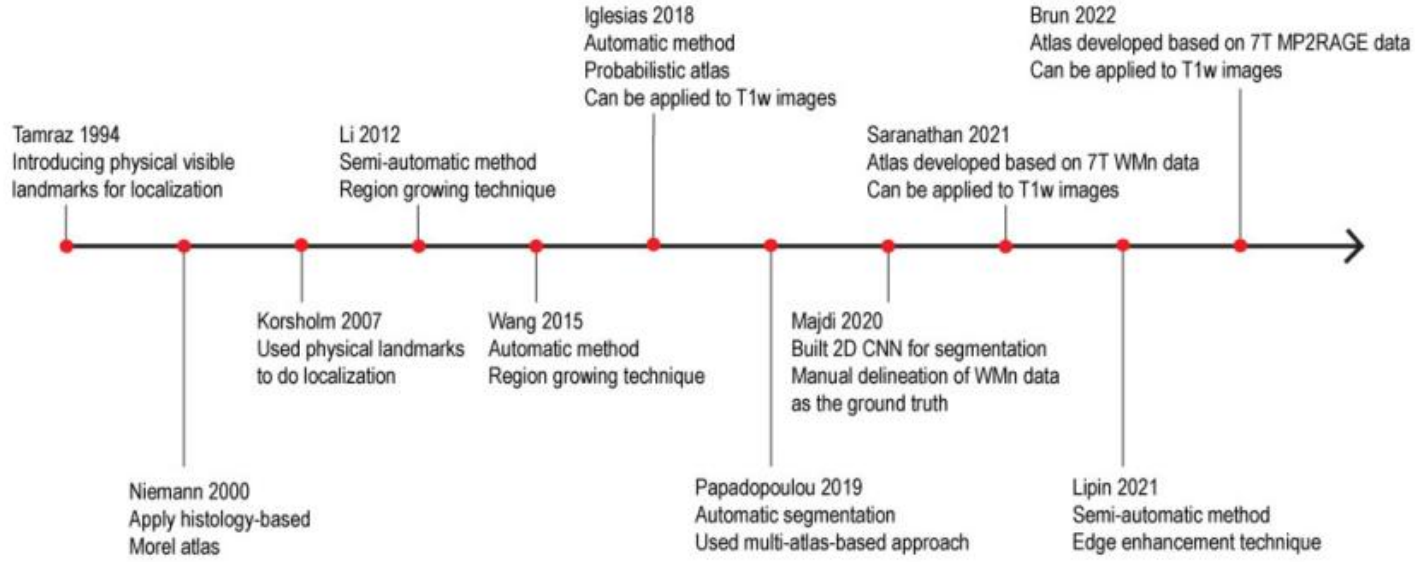
The third group of studies uses functional MRI approaches to delineate the LGN and its layers. Recent functional connectivity studies segmented the thalamus based on the time-course similarity to that of a predefined cortical area or by clustering thalamic voxels based on response similarity[8-9]. Again, as the inferior Pulvinar responds to visual stimuli, differentiating the LGN is challenging. Another group of studies used task fMRI in which visual stimuli with specific characteristics are applied that can identify M and P layers of the LGN. Recently, it has been reported that a combination of cutting-edge pulse sequences, 7T imaging, and visual stimuli with specific characteristics makes it possible to image the eye-specific LGN layers[10].

Figure 1

a - Studies that compared specific sequences to detect LGN volume changes between patients and controls, or to compare LGN visualization using different seqeunces



b - Studies that advanced LGN localization using only T1w data



Conclusions:

Structural imaging is the best choice between the above-mentioned modalities, as one can use quantitative 7T imaging to identify the M-P layers without prior information. Diffusion imaging is unsuitable for LGN detection due to the large voxel size and the need for preliminary information. Functional MRI makes it possible to differentiate

the M and P layers and eye-specific layers. However, it requires some boundary definition using structural imaging for better accuracy (Figure 2). We suggest that combing information from all modalities can increase the identification and delineation accuracy.

Figure 2

Comparisons of MR imaging method used for LGN identification and delineation

MR imaging method		Advantages	Disadvantages
Structural	Data acquisition using suggested sequences	Possibility of identification of the magno and parvo layers even at 3T Feasibility of using high-resolution data	Time & resource demanding Need to do manual delineation
	Work with T1w data	Feasibility of optimization of parameters	
	Probabilistic atlas mapping using Bayesian inference	Implemented in Freesurfer Use already visible contrasts of data	Low contrast in posterior thalamus makes it prone to errors
	Atlas-based registration	Ease of use	High between-subject variability Does not work for patients with LGN alterations Does not work for subjects from different age groups
	Edge enhancement		Not validated against solid ground truth Heavy computation load
	Region growing		Need to define radius of growing
Diffusion	Corticothalamic connection	Data-driven approach More sensitive to major pathways	Tractography is computationally expensive Need to define cortical target regions Need to define thalamus boundary
	Segmentation based on local diffussion properties	Data-driven approach Usually faster than connectivity-based methods Less sensitive to user-defined parameters compared to segmentation-based methods	In most classification algorithms a number of clusters should be set arbitrarily Large voxels in diffusion imaging make segmentation inaccurate for small nuclei Need to define distance/similarity measure
Fucntional	Using resting state data	Data-driven approach	Large inter-subject and between-subject variability To get solid results for an individual a large amount of data acquisition is needed Segmentation relies on the thalamus border defination Partial effect and large voxels The similarity of the response of LGN and Pulvinar makes segregation challenging
	Corticothalamic functional connectivity		
	Clustering of voxels within the thalamus based on response similarity		
	Using visual stimulation (Task fMRI)	Possibility of identification of eye-specific clusters in 7T Possibility of identification of magno and parvo layers even at 3T	The reported LGN volumes are sometimes twice the expected values from histology Partial effect and large voxel size

Modeling and Analysis Methods:

Classification and Predictive Modeling
Connectivity (eg. functional, effective, structural)
Segmentation and Parcellation [1]
Task-Independent and Resting-State Analysis

Neuroanatomy, Physiology, Metabolism and Neurotransmission:

Subcortical Structures [2]

Keywords:

MRI
Thalamus
Vision
Other - Lateral Geniculate Nucleus (LGN)

[1|2]Indicates the priority used for review

Abstract Information

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No

Please indicate below if your study was a "resting state" or "task-activation" study.

Other

Healthy subjects only or patients (note that patient studies may also involve healthy subjects):

Patients

Was any human subjects research approved by the relevant Institutional Review Board or ethics panel? NOTE: Any human subjects studies without IRB approval will be automatically rejected.

Not applicable

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Not applicable

Please indicate which methods were used in your research:

Other, Please specify - Systematic review

Provide references using author date format

[1] Kitajima, M., Hirai, T., Yoneda, T., Iryo, Y., Azuma, M., Tateishi, M., ... & Yamashita, Y. (2015). Visualization of the medial and lateral geniculate nucleus on phase difference enhanced imaging. American Journal of Neuroradiology, 36(9), 1669-1674.
[2] Aldusary, N., Michels, L., Traber, G. L., Hartog-Keisker, B., Wyss, M., Baeshen, A., ... & Piccirelli, M. (2019). Lateral geniculate nucleus volumetry at 3T and 7T: Four different optimized magnetic-resonance-imaging sequences evaluated against a 7T reference acquisition. Neuroimage, 186, 399-409.

[3] Iglesias, J. E., Insausti, R., Lerma-Usabiaga, G., Bocchetta, M., Van Leemput, K., Greve, D. N., ... & Alzheimer's Disease Neuroimaging Initiative. (2018). A probabilistic atlas of the human thalamic nuclei combining ex vivo MRI and histology. Neuroimage, 183, 314-326.
[4] Wang, J., Miao, W., Li, J., Li, M., Zhen, Z., Sabel, B., ... & He, H. (2015). Automatic segmentation of the lateral geniculate nucleus: Application to control and glaucoma patients. Journal of neuroscience methods, 255, 104-114
[5] Lipin, M., Bennett, J., Ying, G. S., Yu, Y., & Ashtari, M. (2021). Improving the Quantification of the Lateral Geniculate Nucleus (LGN) in MRI Using a Novel 3D-Edge Enhancement Technique. Frontiers in Computational Neuroscience, 110.
[6] Renauld, E., Descoteaux, M., Bernier, M., Garyfallidis, E., & Whittingstall, K. (2016). Semi-automatic segmentation of optic radiations and LGN, and their relationship to EEG alpha waves. PloS one, 11(7), e0156436.
[7] Battistella, G., Najdenovska, E., Maeder, P., Ghazaleh, N., Daducci, A., Thiran, J. P., ... & Fornari, E. (2017). Robust thalamic nuclei segmentation method based on local diffusion magnetic resonance properties. Brain Structure and Function, 222(5), 2203-2216.
[8] O'Muircheartaigh, J., Keller, S. S., Barker, G. J., & Richardson, M. P. (2015). White matter connectivity of the thalamus delineates the functional architecture of competing thalamocortical systems. Cerebral Cortex, 25(11), 4477-4489.
[9] van Oort, E. S., Mennes, M., Schröder, T. N., Kumar, V. J., Jimenez, N. I. Z., Grodd, W., ... & Beckmann, C. F. (2018). Functional parcellation using time courses of instantaneous connectivity. Neuroimage, 170, 31-40.
[10] Qian, Y., Zou, J., Zhang, Z., An, J., Zuo, Z., Zhuo, Y., ... & Zhang, P. (2020). Robust functional mapping of layer-selective responses in human lateral geniculate nucleus with high-resolution 7T fMRI. Proceedings of the Royal Society B,

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