

# Topographic Evaluation of Acute Isolated Unilateral Thalamic Infarctions on Diffusion-weighted Imaging

 Sebahat Nacar Doğan

University of Health Sciences Turkey, Gaziosmanpaşa Training and Research Hospital, Clinic of Radiology, İstanbul, Turkey

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## ABSTRACT

**Objective:** The thalamus plays a major role in regulating arousal, consciousness, and activity. Distinct vascular distribution of the thalamus causes different syndromic presentations of thalamic nuclei infarctions. During the evaluation of acute thalamic infarction, it is important to determine the thalamic vascular zone that is affected. This study aimed to assess the topography of acute isolated unilateral thalamic infarction on diffusion-weighted imaging, and to investigate the distribution of classic and variant type thalamic infarctions.

**Methods:** The imaging database of the 336 consecutive patients with acute thalamic infarction admitted to the radiology department between January 2015 and February 2020 were retrospectively reviewed. Specifically, patients with acute isolated unilateral thalamic infarction were included. The most affected thalamic territory, variant/classical territory rates, and the comparison of age and gender were evaluated.

**Results:** A total of 141 patients (classic territory group: 104, variant territory group: 37) were reviewed. The ratio of affected classic territory to variant territory was 2.8. Affected classic territories were inferolateral (n=68), anterior (n=25), paramedian (n=11), and posterior (n=0). Affected variant territories were posterolateral (n=18), central (n=13), and anteromedian (n=6). Comparing the patients in both groups, age, sex, and side were similar,  $p=0.435$ ,  $p=0.71$ , and  $p=0.85$ , respectively. Relevant arteries did not have stenosis in 96.2% of patients, and no significant difference was observed between both groups,  $p=0.631$ .

**Conclusion:** In isolated acute unilateral thalamic ischemia, the ratio of the affected variant to the classic territory was approximately 1/3. Therefore, during the radiologic evaluation of acute thalamic ischemia, a variant thalamic territory should be considered in the presence of infarction that does not fit the classic territory, in order to avoid clinical-radiological discrepancies.

**Keywords:** Thalamus, infarction, arteries, magnetic resonance imaging

## INTRODUCTION

Thalamic infarctions constitute approximately 11%-14% of acute ischemic strokes of the posterior circulation, most of which are unilateral (1). Thalamic infarctions are classified traditionally into four groups based on the territories supplied by four main arteries: anterior, paramedian, inferolateral, and posterior. This classification was initially based on neuroanatomic and neuropathologic data. However, this classification is recently

based on imaging techniques, especially diffusion-weighted imaging (DWI), in the acute stage (2).

The thalami are fed by perforating branches of the anterior and posterior circulation (3). The territories of the thalamus can be subdivided traditionally into four groups based on the supplying arteries: anterior, paramedian, inferolateral, and posterior (4-6). The anterior territory is supplied by the tuberothalamic arteries (polar artery), which is the largest branch of the posterior communicating artery (PCoM).

**ORCID IDs of the authors:** S.N.D. 0000-0003-1512-5060.

**Corresponding Author/Sorumlu Yazar:** Sebahat Nacar Doğan,

E-mail: sebahatdogan@yahoo.com

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The paramedian territory is supplied by the paramedian (thalamoperforating) arteries that originates from the P1 segment of the posterior cerebral artery (PCA). The inferolateral territory is fed by inferolateral (thalamogeniculate) arteries that arise as individual vessels from the distal P2 segment of the PCA. The posterior territory is supplied by the posterior choroidal arteries (PChA). The posterior choroid group usually includes one or two medial and one to six lateral PChAs. Medial PChA generally arises from the distal P1 or proximal P2 segments of the PCA. Lateral PChA arises directly from the PCA (distal P2 or proximal P3 segments) or from a branch of the PCA (3-5).

In addition to the classic vascular territories described above, there are also three variant vascular territories: anteromedian, central, and posterolateral. These variant areas can be due to variant vascular distribution or border-zone ischemia (2,4,5). The anteromedian territory is formed by combining the classic anterior and paramedian territories. It involves the posterior part of the anterior territory and the anterior part of the paramedian territory. The central territory involves parts of all the four adjacent classic territories and it is located in the central part of the thalamus. The posterolateral territory is formed by combining classic inferolateral and posterior territories. It involves the posterior part of the inferolateral territory and anterior part of the posterior territory (2,4,5,7).

The clinical spectrum of thalamic infarction can vary depending on the affected territories. Specifically, infarction located on variant territories may confuse the clinical-radiological presentation of a thalamic ischemic stroke. Therefore, it is important to recognize the classic and variant territories of the thalamus. This study aimed to evaluate the topographic patterns of isolated unilateral thalamic infarctions and to investigate the distribution of classic and variant type thalamic infarctions on DWI.

## METHODS

### Ethics, Study Design and Patients

Ethics committee approval was received for this study from the Ethics Committee of Taksim Training and Research Hospital (approval number: 81, date: 19/05/2020).

The imaging database of the 336 consecutive patients with acute thalamic infarction admitted to our radiology department between January 2015 and February 2020 was reviewed retrospectively on a PACS imaging workstation (Infinitt PACS; Infinitt Healthcare, Seoul, Republic of Korea). The primary imaging criteria for inclusion was isolated unithalamic infarction on DWI, whereas bithalamic infarctions, PCA territory infarctions involving the thalamus, accompanying infarcts in other vascular territories, and unithalamic abnormal signal intensity due to causes other than arterial infarctions such as tumor, deep venous thrombosis, and hemorrhage were excluded. After the exclusions, the final cohort consisted

of 141 patients (77 females and 64 males with a mean age of  $66.1 \pm 12.8$ ) of the 336 investigated DWI. Then, the final population was divided into two groups: classic group ( $n=104$ ) and variant group ( $n=37$ ).

### Imaging Protocols

DWIs were obtained using two 1.5 T-magnetic resonance imaging units (GE Signa HDxt and Signa Explorer; GE, Milwaukee, WI, USA). DWIs were acquired in the axial plane with parameters field of view: 25 mm, repetition time: 5000 ms, echo time: 100 ms, acquisition time: 1, number of excitations: 1, and b values of 0 and 1000  $\text{s/mm}^2$ , isotropically weighted. DWI yielded 20 contiguous slices that were 7 mm thick and axial-oblique. Apparent diffusion coefficient (ADC) map was automatically generated from the DWI at  $b=0$  and  $b=1000 \text{ s/mm}^2$ . We checked the ADC maps to ensure that "real" diffusion disturbance occurred. A visual evaluation was performed. Besides, computed tomography angiography (CTA) and magnetic resonance angiography (MRA) were evaluated to investigate the relevant arteries of the thalamus.

### Imaging Analysis

All the DWIs were evaluated by a radiologist with significant experience in neuroradiology (S.N.D. with 11 years in neuroradiology) on a PACS imaging workstation. The radiologist was blinded to the neurologic symptoms during the retrospective imaging review.

All the DWIs were reviewed with regard to the location of the thalamic infarction based on previous templates of classic and variant thalamic territories.

In CTA or MRA examinations, the stenosis of relevant arteries was evaluated.

### Topography of Thalamic Infarctions

Classic thalamic infarctions were assigned four vascular zones based on previously published territory templates (3-5): anterior, paramedian, inferolateral, and dorsal (Figure 1). Isolated posterior territory infarction was not observed in this study. Therefore, to depict the posterior territory, posterior territory infarction accompanying to PCA infarction was used was shown in Figure 1d. Variant thalamic infarctions were assigned into three vascular zones based on previously published territory templates (2,7): anteromedian, central, and posterolateral (Figure 2).

The relevant arteries were basilar artery, PCA, and PcomA.

### Statistical Analysis

IBM SPSS version 22.0 software was used for the data analysis. Normality checks were performed by the Shapiro-Wilk test, and by drawing histograms, Q-Q plots, and box plots. Data were expressed as mean, standard deviation, minimum, maximum, frequency, and percentage. The two categories of non-normally distributed variables were analyzed using the Mann-Whitney U test. T test was used to compare the nominal variables. The significance level was taken as  $p < 0.05$  and bidirectional

## RESULTS

The final cohort consisted of 141 patients (41.9%) with isolated unilateral thalamic infarctions. Thalamic infarctions were located in classic territories in 104 (73.8%) patients and in variant territories in 37 (26.2%) patients. The ratio of affected classic territory to variant territory was 2.8.

In the total cohort, 64 (45.4%) patients were males and 77 (54.6%) were females. The thalamic infarction was located on the right side in 59 patients (41.8%) and on the left side in 82 (58.2%). Comparing the patients in the classic and variant groups, the age, sex, and affected side were similar for both, with  $p=0.435$ ,  $0.761$ , and  $0.852$ , respectively.

The relevant artery was investigated for 80 (56.7%) patients. CTA was performed for 84.8% of patients ( $n=67$ ), and MRA for 15.2% ( $n=12$ ). No stenosis was observed in 77 patients (96.2%). There was more than 50% stenosis in 2 patients (2.5%), and <50% stenosis in one patient (1.3%). No significant difference in relevant artery stenosis was observed between the classic and variant groups,  $p=0.631$ .

Table 1 summarizes the patient demographics.

Regarding the vascular territory of the thalamus, the anterior territory was involved in 25 patients (17.8%), paramedian in

11 (7.8%), inferolateral in 68 (48.2%), posterior in 0 (0.0%), anteromedian in 7 (4.9%), central in 12 (8.5%), and posterolateral in 19 (13.5%) patients. While infarctions were most commonly identified in the inferolateral territory, the posterior territory was not involved in any of the patients.

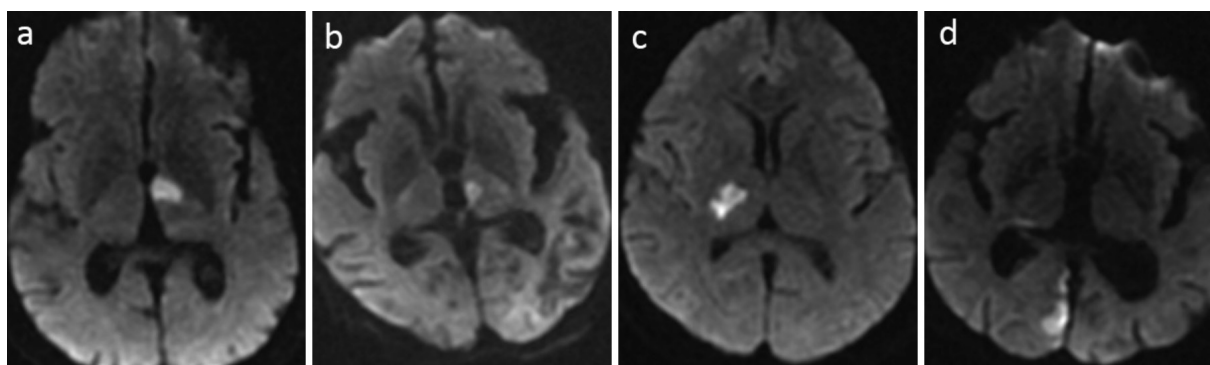
Regarding the classic vascular territory of the thalamus, the anterior territory was involved in 25 patients (24%), paramedian in 11 (10.6%), inferolateral in 68 (65.4%), and posterior in 0 (0.0%). Inferolateral territory was the most frequently affected classic territory. However, the isolated posterior territory infarction was not observed in any patient.

Regarding the variant vascular territory of the thalamus, the anteromedian territory was involved in 6 patients (16.2%), central in 13 (35.1%), and posterolateral in 18 (48.7%). The posterolateral territory was the most frequently affected variant territory.

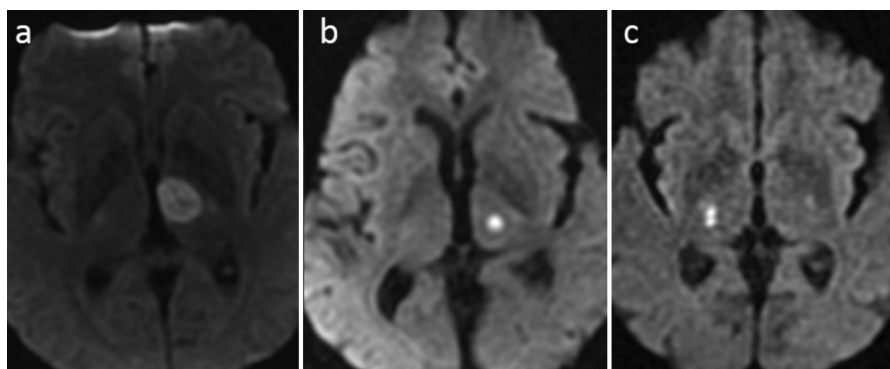
Table 2 shows the distribution of the thalamic infarctions with vascular zones.

## DISCUSSION

In the present study, the topographic pattern of isolated unilateral thalamic infarctions on DWIs was evaluated based on the relevant vascular zones. Several interesting findings were obtained. First, isolated unilateral thalamic infarctions constituted 41.6% of all



**Figure 1.** The classic territories of the thalamus on the DWI: anterior (a), paramedian (b), inferolateral (c), and posterior (d). The posterior territory infarction (d) was depicted from the PCA territory infarction because an isolated posterior territory infarction was not detected  
DWI: Diffusion weighted imaging, PCA: posterior cerebral artery



**Figure 2.** The variant territories of the thalamus on the DWI: anteromedian (a), central (b), and posterolateral (c)  
DWI: Diffusion weighted imaging

thalamic infarctions. Second, the ratio of the involved variant territory to the classic territory was approximately 1/3. Third, while the inferolateral territory was the most frequently affected in all the isolated unilateral thalamic infarctions, the isolated posterior territory infarct was not observed. Fourth, regarding the most frequently affected territory in classic and variant groups, whereas the inferolateral territory was the most frequently affected territory in the classic group, the posterolateral territory was in the variant group. Fifth, the relevant artery did not have any stenosis in 96.2% of patients. Comparing patients in the classic group and variant group, the results of relevant artery stenosis were similar for both.

In the literature, previous studies focused on the clinical-radiologic relationship of acute unilateral thalamic infarction without considering the isolated or a part of the PCA infarction. Meanwhile, this study consisted of only isolated unilateral thalamic infarctions and included a large number of patients. The present study also focused on the type of thalamic infarctions based on the affected vascular territory: classic and variant.

The ratio of isolated unilateral thalamic infarction in all the thalamic infarctions was similar with that of previous studies (8). Considering the affected vascular territory of the thalamic infarction, the variant group constituted approximately 1/3 of the isolated acute unilateral thalamic infarction, consistent with the literature (2).

Regarding the topography of the involved classic territory in previous studies, the inferolateral territory was the most frequently affected in all the studies, whereas the rates of the other territories varied between studies (8-12). Particularly, previous studies have reported various rates of isolated paramedian territory infarction and isolated posterior territory infarction. However, Wang et al. (8) did not report any isolated paramedian territory infarction, and Pezzini et al. (10) did not reveal any isolated posterior territory infarction. In present study, the inferolateral territory was affected the

most, consistent with previous studies (8-12). Besides, while the isolated paramedian territory was observed, the isolated posterior territory infarction was not detected. Although this result was consistent with the findings of Pezzini et al. (10), it was contrary to those of Wang et al. (8). The isolated posterior territory infarctions are the least common infarction of the thalamus. The posterior territory of the thalamus has rich anastomosis; therefore, infarction that locates only the posterior territory could be very rare. Posterior territory infarctions are usually a part of the PCA territory infarction (13-16). In addition, there may be some difficulties especially in differentiating between the classic posterior territory and variant posterolateral territory. The previous studies also did not separately describe the variant territories.

There are few reports that investigated the variant territories of the thalamus (2,7). Kumral et al. (7) evaluated the acute multiple variant type thalamic infarction and they reported that the most commonly affected variant territory was posterolateral in unilateral thalamic infarction. Carrera et al. (2) investigated the isolated variant thalamic infarction. They reported the distribution of affected variant territories such as the anteromedian (n=9), posterolateral (n=8), and central (n=4). In present study, the most frequently affected variant territory was posterolateral, consistent with results of Kumral et al. (7). However, the least frequently affected variant territory was anteromedian, contrary to the findings of Carrera et al. (2). The frequency of the affected variant territory in the present study was different from previous studies. The discrepancy regarding the frequency of the affected variant territory among different studies may be as a result of the small sample size. Therefore, variant thalamic infarction needs to be evaluated in large series.

In addition, in this present study that evaluated relevant arteries were by CTA or MRA, large artery disease was not observed in both the classic and variant group. Therefore, this result can support the fact that variant territory can be as a result of variant vascular distribution rather than border-zone ischemia. Both Kumral et al. (7) and Carrera et al. (2) also reported that the most frequent cause of stroke was cardioembolism, and not large artery disease.

**Table 1. Summary of patient demographics in the total cohort**

	Classic group (n=104)	Variant group (n=37)	Total cohort (n=141)
<b>Gender (n, %)</b>			
Male	48 (46.2%)	16 (43.2%)	64 (45.4%)
Female	56 (53.8%)	21 (56.8%)	77 (54.6%)
Age (mean/range)	66.6 (24-96)	64.6 (33-89)	66.1 (24-96)
<b>Affected side (n, %)</b>			
Right side	44 (42.3%)	15 (40.5%)	59 (41.8%)
Left side	60 (57.7%)	22 (59.5%)	82 (58.2%)
<b>Stenosis of relevant arteries (n, %)</b>			
≥50% stenosis	58 (55.8%)	22 (59.5%)	80 (56.7%)
<50% stenosis	2 (3.4%)	0 (0.0%)	2 (2.5%)
No stenosis	1 (1.7%)	0 (0.0%)	1 (1.3%)
No stenosis	55 (94.9%)	22 (100%)	77 (96.2%)

**Table 2. The distribution of the thalamic infarctions according to vascular zones**

	Total cohort (n=141)
Classic thalamic territory (n, %)	104 (73.8%)
Anterior	25 (24%)
Paramedian	11 (10.6%)
Inferolateral	68 (65.4%)
Posterior	0 (0.0%)
Variant thalamic territory (n, %)	37 (26.2%)
Anteromedian	6 (16.2%)
Central	13 (35.1%)
Inferolateral	18 (48.7%)

## Study Limitations

Several limitations to this study need to be acknowledged. First, the study was retrospective and is subject to all the limitations of this study design. Second, it was a single-center study. Third, only a small number of infarctions were present for certain vascular territories. Forth, the CTA or MRA examination could not be performed in all the patients.

## CONCLUSION

The affected territory in acute isolated thalamic infarction can be in the variant group in approximately 1/3 of patients. Regarding the classic and variant groups, the most frequently affected territories were inferolateral and posterolateral, respectively. Therefore, in daily practice, during the evaluation of acute thalamic infarction on DWI, the infarction area needs to be sought for more carefully, whether it fits the classic territory or not. This is because an accurate topographic evaluation is important to avoid clinical-radiological discrepancies.

**Ethics Committee Approval:** Ethics committee approval was received for this study from the Ethics Committee of Taksim Training and Research Hospital (approval number: 81, date: 19/05/2020).

**Informed Consent:** Informed consent was waived.

**Peer-review:** Externally peer-reviewed.

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